

MODULAR ELECTRONICS LEARNING (MODEL) PROJECT



CAREER GUIDE

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LAST UPDATE = 4 MARCH 2025

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Chapter 1

Introduction

Here are some good questions to ask of yourself while reading the various chapters of this module, to test for comprehension:

Chapter – What is Electronics?

- What are some of the common titles by which electronics technician jobs are advertised?
- What does the *OPM* manage within the United States?
- What does the *BLS* manage within the United States?
- What are some of the different jobs and industry sectors within the broad field of electronics work?
- What is some of the specialized equipment commonly used within electronics work?

Chapter – What Makes You Marketable?

- What is *human capital*, and how may you build yours up?
- What are some of the specific traits or aspects of human capital for technical careers?
- Why do employers scrutinize the attendance records of students they consider for employment?
- What are some “red flag” behaviors sometimes exhibited by students?
- What are some of the knowledge areas and skills employers generally find in short supply?
- What are some of the limitations of training offered by employers to their employees?

Chapter – Locating Employment

- What are some non-traditional means of locating employment?

- What kind of agency exists to help you locate a job?
- In what ways are Chambers of Commerce helpful in locating employment?
- What distinguishes a *jobshadow* from an *internship*?
- What is the purpose and value of an *informational interview*?
- What are some of the questions you might ask an employer during an informational interview?

Chapter – Résumés and Cover Letters

- What is the purpose of a résumé?
- What is the purpose of a cover letter?
- How much time should you budget for writing your résumé?
- What are some of the essential contents of a well-written résumé?
- What are some things to avoid in your résumé?
- What are some of the essential contents of a well-written cover letter?
- What are some things to avoid in your cover letter?
- Why should your résumé and cover letter be tailored to the particular job you're applying for?
- What are some ways to convey positive habits and attributes without making claims about yourself?
- What do errors such as mis-spellings and poor grammar communicate to any employer reading résumés and cover letters?
- How might non-technical work experience be valuable when applying for technical jobs?
- What are some criteria for choosing good personal or professional references?

Chapter – Interviews and the Screening Process

- What sorts of things should an employer *never* ask you during an interview?
- What does it mean to say that any information exchanged within an interview is *confidential*?
- What sort of information are employers seeking with a *background check*?
- What are some specific security-related credentials or clearances required for certain jobs?
- Why is drug screening commonplace for technical jobs?
- In what ways are *honesty* and *disclosure* not the same thing?

- How may you apply the STAR method in answering interview questions?
- What distinguishes a behavioral question from a technical or skills-related question?

Chapter – Growing Your Career

- What is *career security*, and how does it compare to *job security*?
- What is the general advice given to recent graduates when seeking their first job?
- Why should you generally choose your next job with the goal of remaining there longer than your last job?
- What are some of the ways to continually educate yourself throughout your career?
- What are some of the written resources ideal for self-education in this career field?
- What is *knowledge-hoarding*, and how is it detrimental to careers?

Chapter – Managing Finances

- What is a 401k or 403b savings plan?
- What does it mean for an investment to be tax-deferred?
- Why is it psychologically advantageous to start investing as early as possible in your career?
- What does it mean to *roll over* an investment?
- In what ways might a Financial Manager be helpful to you?
- How does *debt* impede financial stability?

Chapter – Cautionary Tales

- Under what circumstances might it be wise to disobey a supervisor on the job?
- How might prescription drugs cause problems for employment?
- How long does a typical interview last?

Chapter 2

Disclaimers and caveats

Hi – my name is Tony, and I have worked in and around the field of industrial electronics and automation for over 30 years, 11 years as a technician within three different industries and the remainder as a full-time college instructor of the same subjects.

During my decades working in and teaching this career, I have seen many things and have learned many important lessons. Some of those lessons came as a result of direct experience, some from observing the experiences of others. My goal in writing this guide is to share some of this practical experience with you in the hope that you will find within this career all the challenges and rewards it has to offer.

No amount of experience makes anyone an expert on *everything*, and so you should know some of the limitations and biases of my advice. To understand these limitations and biases, it is necessary to know a bit more about my own experiences in this career.

This guide is written from the perspective of someone who has only been employed as a *technician*, not as a scientist or an engineer. It also comes from the perspective of someone who received most of their education outside of classrooms: my first foray into the world of technology and engineering was growing up on a small farm where my millwright father taught me the basics of construction, welding, electricity, and machine maintenance. This was a place where he and I built experimental wind turbines and solar water heaters, and built our own metal lathe from scrap parts. It was also a place where both my parents strongly supported self-education, purchasing for me electronic kits from Radio Shack and later a personal computer (before the IBM PC or Apple MacIntosh even existed). Our home library was well-stocked with an encyclopedia set, an array of technical books spanning aircraft piloting to electrical engineering, and overseen by parents who respected the power of the written word. My books, computer, and shop were halls of learning far more engaging than most of my public school classes, although I was fortunate enough to have many good teachers who did what they could within their limited schedules and budgets to fuel the fire of a young boy's curiosity about all things scientific. These experiences taught me in a very personal way the value of hard work and self-study, the importance of doggedly pursuing *understanding* in a world that can be crushingly indifferent to individual wants and needs.

As much as my childhood taught me the value of personal effort, it also taught me the value of community support. Outside of my immediate family there were multiple teachers in the public school system who helped kindle my curiosity and love of learning, and they did so well beyond the

requirements of their teaching contracts. From my fourth and fifth grade teachers who started up an Electronics Club at my elementary school in the late 1970's, to my freshman Biology teacher in high school who set up a "special topics" class just so I could have a chance to learn about and repair some of the high school's scientific test equipment, to my junior and senior Physics instructor who gave practical context to the abstract calculus concepts I encountered in Math class, to the Automotive and Metal shop instructors who supported my special projects at every turn, these educators¹ showed me what can happen when people identify a need and help their fellow people meet that need. These weren't just teachers doing their jobs – they were *educators* committed to fostering their students' growth.

An unusual community-based educational opportunity came to my attention in 1996 when I first encountered the Linux computer operating system – software designed to emulate the functions of commercial Unix operating systems – created by an online community of volunteer programmers and Unix enthusiasts, provided entirely free of cost to whomever wished to download and use it. This was the first time I had witnessed the spirit of community learning and amateur design culminate in such a powerful and useful *product*. The GNU General Public License gave all users of Linux software legal permission to view the "source code" and learn from the developers' work, while also ensuring all future versions would remain just as free and "open" as the version received. Linux not only provided me with an opportunity to expand my knowledge of computers, but it also struck me as a community-based model applicable to much more than computer software.

When I entered the technical career field in 1987, it was in the form of a maintenance position at a small machine shop in Yakima, Washington. This was a part-time job for me (25 to 30 hours per week) concurrent with my studies at a private technical school where I was enrolled full-time in their Instrumentation and Industrial Electronics program. Here at this shop I had opportunity to learn about machine tools (lathes, mills, grinders, welding machines, electrical discharge machining) as well as the digital control of those machines. My immediate supervisors² were wonderful people, challenging me with technical tasks appropriate to my knowledge and skill levels, and giving me invaluable work experience which paved the way for future employment. They also provided a forum for me to share what I knew about electricity and electronics with fellow co-workers, setting up an informal classroom to use once a week. It was my first real experience teaching, and it was beneficial to me as well because it helped sharpen my own understanding of what (I thought) I knew while expanding the knowledge base of co-workers who were completing an ambitious project (interfacing a modern Japanese CNC control computer (Fanuc model 11M) to a legacy American milling machine (Cincinnati-Milacron HC-15).

My next career steps took me to an oil refinery, and then to an aluminum smelter. Working in "big industry" was an altogether different experience than the small machine shop. There was still plenty to learn and to do, but notably minimized was the open forum of shared knowledge – instead, I more often encountered people reluctant to share what they knew because they believed "knowledge hoarding" was necessary for their own job security. A noteworthy exception to this sad rule was the Meter & Instrument shop at the aluminum smelter where I found an unusually supportive and tight-knit group of technicians who looked out for each other. There was also a small group of process control computer programmers who freely shared information with me at the smelter, but an alarming number of the other technical tradespeople and engineers were not

¹Listed in order: Don Dineen (4th grade), Bill Charleston (5th grade), Frank Hebert (9th grade Biology), Dick Shelley (11th and 12th grade Physics), Wes Kentch (Automotive Shop), and Bill Roberts (Metal shop).

²Thanks to Mark Cleary (Foreman) and Dale VanTrease (Supervisor), who were wonderful mentors and friends.

interested in helping anyone else learn anything about their job. Time and time again I saw the “knowledge hoarders” foiled while the supportive community of my fellow technicians served to help all of us.

When I made the career switch from hands-on technical work to full-time teaching in 1998, I found the same sharp distinction among my fellow teachers: some were helpful and open to sharing with me anything they knew about their subjects or about teaching in general, while others were “knowledge hoarders” of the first degree. The college environment proved to be no different from industry when it came to the merits of supportive community: those who were willing to share what they knew with others found that same sentiment reciprocated to their own benefit, while the knowledge-hoarders stagnated to their own peril. If there is a time and a place for knowledge-hoarding on the job, I sure haven’t seen it.

Taking this moral lesson to heart, I soon found opportunity at the college to apply the open-source spirit of Linux to a different type of product development: the writing of technical textbooks. For the remainder of my teaching career I have continued writing open-source books primarily for the benefit of my students, and secondarily for the benefit of anyone outside of my classroom walls who desired to learn about these topics. The world is full of people both young and old desiring to learn what I wanted to learn as a child, and if I could place these free resources in their hands I figured it would help make the world a better place. Multiple co-workers at the college initially warned me against making my writings free and available for public download, their reasons ranging from weakening my own job security to losing potential income. Almost two decades later I’m happy to report numerous job offers extended to me as a result of freely publishing these textbooks.

The years spent teaching at the college level has been nothing short of eye-opening. At this point I have literally taught several hundred students, and given the structure of technical courses at the college where I teach this means spending approximately one full academic year with each and every one of my graduating students. What I’ve seen in terms of attitudes, aptitudes, career success, and career failure has been most instructive and serves to inform most of the opinions you will read in this guide. The single most important lesson I have learned in my teaching career is that *attitude is everything*. This applies to instructors and school administrators every bit as much as it applies to students. People who pursue learning with determination and integrity achieve wondrous results. People who regard school as just another obstacle to overcome will be lucky to meet their goals.

Chapter 3

What is Electronics?

A better question might be, “What *isn't* Electronics?” Few industries, consumer goods, public utilities, energy production and distribution networks, communication systems, transportation technologies, military defense systems, etc. could even exist if it were not for electronic circuits. Electricity, of course, is fundamentally the transfer of energy by means of electric charge carriers (tiny charged particles of matter, such as “free” electrons in a metal wire). *Electronics* expands upon the concept of electricity by utilizing components capable of allowing one electrical signal to control another. The person with a sound understanding of electrical and/or electronic concepts and practices will find their knowledge and skills widely applicable.

If this sounds interesting to you, then *read on*. The following sections in this chapter will list common job titles for people with these skills and give more detailed information on what the career of an electronics technician entails.

3.1 Typical electronics job titles

Job titles utilizing these knowledge and skills go by a variety of names, some of them listed here (in no particular order):

- **Electromechanical Technician/Specialist**
- **Electronics Technician/Specialist**
- **Electronics Engineering Technician**
- **Electronics Field Service Technician**
- **Electronics Mechanic**
- **Engineering Technician/Specialist**
- **Engineering Test Technician/Specialist**
- **Power Technician**

- **Hardware Technician/Specialist**
- **Development Technician/Specialist**
- **Solid State Technician/Specialist**
- **Test Technician/Specialist**
- **Calibration Technician**
- **Communications Technician**
- **Telecommunications Technician**
- **Biomedical Technician**
- **Automation Technician/Specialist**
- **Controls Technician/Specialist**
- **RF Technician/Specialist**
- **Signals Technician**
- **Instrument Technician**
- **Broadcast Technician**
- **Avionics Technician**
- **Slot Machine Technician**
- **Building Automation System (BAS) Technician**
- **Systems Engineering Technician**
- **PLC Programmer**
- **SMT Technician**
- **Modbus Technician**

Unlike some other skilled trades such as *electricians*, *welders*, and *plumbers*, the scope of work covered by electronic technicians defies standardization. Many of these titles assume a base knowledge of fundamental electronic principles *plus* specialized training (e.g. Avionics Technicians who maintain specialized electronic equipment for aircraft, Instrument Technicians who maintain industrial measurement and control systems). Often the only way to tell for sure than an advertised “technician” position is an appropriate fit for your electrical/electronics skill-set is to read the job description very closely to see how many of the expected knowledge and skill areas match your own.

However, this lack of standardization actually makes it easier for a generalist to find gainful employment than one might think. Few schools exist to serve every specialized job category, and so often the expectation for an entry-level electronics technician is simply to possess that base-layer of knowledge and skill, with the specialized knowledge and skills learned on the job.

In fact, a person well-educated in any technical field will find it relatively easy to migrate to “other” technical careers. As an instructor of electronics and related subjects I have witnessed a dozens of graduates go on to fulfilling careers where only a fraction of their education directly applied. What makes this possible is if the education is *rigorous* and centered on *first principles*. By “rigorous” I mean an education where students are daily and individually challenged to reason their way through new concepts and problems, rather than memorizing facts and procedures. By “first principles” I mean concepts of mathematics, science, and logic universal in their application. Paradoxically, the key to success in technical education is learning how to interpret new information and solve new problems, rather than mastering specific technologies¹.

¹This fact, in my humble opinion, is why so many technical training programs fail on their promise to prepare students for technical careers. Far too many technical schools do little more than train students to follow procedures and memorize terms, tacitly assuming their students are incapable of achieving more than this. I hold this to be prejudicial and insulting, deciding in advance that students simply cannot attain a better station in life than merely following the instructions of others. My own bias on this matter is to assume anyone can do anything, and that the real impediments are *time* and *opportunity* and *poor attitude*. Take any motivated person – regardless of their intelligence or background – and they can learn to do anything they want given the requisite time and resources. My job as an educator is to banish preconceived beliefs of inadequacy and give students as much time and opportunity as they need to succeed.

Over a period of decades I have had the pleasure of witnessing many students of electronics and industrial automation go on to such careers with job titles such as:

- **Industrial Electrician**
- **Computer Network Technician**
- **Biomedical Technician**
- **HVAC/R Technician** (heating, ventilation, air conditioning, and refrigeration)
- **Combustion Turbine Maintenance Technician**
- **Protective Relay Technician**
- **SCADA System Design Technician**
- **Scientific Support Technician**

Every one of these job titles require competence in specific concepts and technologies (and in some cases formal licenses!) these students never acquired in school, yet they were able to obtain entry-level employment in these fields because what they did learn was sufficient to start. The rest they figured out on the job.

In my opinion the subject of electronics is particularly well-suited to giving people the broad base of foundational knowledge required for success in all these careers, because the study of electric and electronic circuits rests on a broad span of scientific and mathematical and logical “first principles”. It is no accident that many technical job descriptions list a background in electronics as sufficient preparation, even for jobs that are not strictly electrical or electronic in scope. The concepts of *voltage* and *current*, for example, are founded on the first principles of *energy* and *atomic structure*. Elementary *algebra* – an incredibly useful tool for all technical and scientific work – is absolutely essential for the analysis of circuits, even very simple circuits having only a few components. Differential and integral *calculus* represents another set of mathematical “first principles” made accessible by electric circuits, especially regarding the electrical concepts of *capacitance* and *inductance*. *Waves* and *vibrations* and their mathematical basis (*trigonometry*) are elemental to electronic signals, communication systems, and modern electric power grids, with elementary waves typically encountered within the first few months of study for new students of electricity and electronics; yet the exact same “first principles” find application in fields as diverse as mechanical vibration, acoustics, optics, fluid systems, chemistry, and control systems. Logical “first principles” such as *syllogisms*, *reductio ad absurdum*, *inference*, *elimination*, and *Occam’s Razor* are pillars of effective circuit troubleshooting and other types of problem-solving. *Aristotelian logic* and *Boolean logic* forms the basis of even the simplest digital electronic circuits. On top of all this is the advantage of economy: concepts that might require hundreds or even thousands of dollars’ worth of mechanical or chemical apparatus to explore need only a handful of electronic components costing a few dollars. In other words, the study of electricity and electronics is a relatively cheap and easy way to learn a lot of science, math, and logical reasoning.

3.2 OPM definition

The US Office of Personnel Management (OPM) manages the civilian-sector workforce for the American federal government, which of course includes a range of electronics technician careers. The following text (shown in blue font) is sampled verbatim² from their “Classifications and Qualifications” website for the “Electronics Technical Series 0856” occupational definition, and is fairly comprehensive in describing what a large percentage of electronics technicians do.

Series Definition:

This series covers technical positions supervising, leading, or performing work involving applying:

- knowledge of the techniques and theories characteristic of electronics, such as a knowledge of basic electricity and electronic theory, algebra, and elementary physics;
- knowledge of electronic equipment design, development, evaluation, testing, installation, and maintenance; and
- knowledge of the capabilities, limitations, operations, design, characteristics, and functional use of a variety of types and models of electronic equipment and systems related to, but less than, a full professional knowledge of electronic engineering.

Electronics technicians may have gained experience assisting in work situations including:

Maintenance - Developing maintenance standards and procedures for use by others. Analyzing repair practices and developing procedural instructions for use by others on methods and steps to repair equipment.

Installation - Planning and directing the installation of complex systems and associated facilities, particularly where there are site selection and construction problems, dealings with contractors and public utilities, and the possible need to modify equipment for novel site characteristics.

Fabrication - Designing and analyzing circuits, determining design feasibility, evaluating equipment performance under varying environmental conditions, and collecting performance data. Designing or modifying designs to achieve performance and cost objectives. Evaluating the adequacy of equipment for such purposes as repair, calibration, and testing.

Testing and Evaluation/Research and Development - Developing or evaluating new or modified electronic systems. Completing testing, evaluating data, and determining acceptability of equipment modifications, validity, test procedures and data, or legality of operation. Technicians support professional engineers in performing experiments, research, and developmental activities requiring an in-depth knowledge of technical engineering methods, applications, practices, and principles to work on concepts, prototypes, and experimental projects that are without precedent and support state-of-the-art research.

²Sampled on 20 December 2019 from <https://www.opm.gov>. This sampling is partial, omitting text not germane to the description of duties or responsibilities.

Sustainment - Developing, performing, evaluating, or modifying calibration and test equipment, systems, and procedures. Reporting, analyzing, and archiving test data. Performing complex calculations and manipulations of test data to improve performance of systems, instrumentation, measurement standards, techniques, and procedures.

Troubleshooting - Analyzing and diagnosing faults in the operational configuration of electronic systems and equipment. Interpreting circuit wiring, logic cable diagrams, drawings, specifications, and schematics of complete systems and equipment to understand the function and interconnections of the various assemblies and troubleshoot the system.

Trade, Craft, or Labor Work Involves:

- repairing systems and equipment to include detecting and diagnosing malfunctions, tearing down equipment, repairing or replacing parts or components, or aligning, calibrating and testing the modified or repaired equipment;
- performing preventive and corrective maintenance to keep equipment and systems in reliable condition;
- installing equipment in accordance with plans, specifications, and detailed instructions, or reinstalling repaired or modified systems;
- fabricating electronic equipment in accordance with plans, specifications, and instructions including constructing, assembling, arranging, mounting, or wiring electronic parts and components; and
- making measurements to diagnose malfunctions to ensure equipment operates within prescribed standards.

Technical Work Involves:

- developing and designing test and repair equipment, analyzing repair practices, or developing procedural instructions on methods and steps of equipment repairs;
- developing maintenance standards and procedures, testing and evaluating new or modified systems, or analyzing the compatibility of interlocking components and systems;
- planning and directing the installation of complex systems and associated facilities, particularly where there are problems of site selection and construction;
- designing and analyzing circuits, determining feasibility of these designs, evaluating equipment performance under varying environmental conditions, collecting data, or designing or modifying designs to achieve performance and cost objectives; and
- developing or evaluating new or modified systems or monitoring frequency emissions by licensed stations.

Note how the OPM description divides work descriptions into the two categories of “Trade, Craft, or Labor Work” and “Technical Work”. The former category describes prescribed tasks while the latter describes tasks requiring more self-direction and judgment. Both facets of technician work are rewarding in their own ways: prescriptive work is pleasing for those who appreciate neat and thorough completion of discrete tasks, while the latter exercises creativity and agency.

3.3 BLS definition

The US Bureau of Labor Statistics gathers information on civilian employment across America, and publishes its own definitions for different careers. The following text (shown in blue font) is sampled verbatim³ from their “Occupational Outlook Handbook” entry for “Electrical and Electronics Engineering Technicians”.

What Electrical and Electronics Engineering Technicians Do

Electrical and electronics engineering technicians help electrical and electronics engineers design and develop computers, communications equipment, medical monitoring devices, navigational equipment, and other electrical and electronic equipment. They often work in product evaluation and testing, and use measuring and diagnostic devices to adjust, test, and repair equipment. They are also involved in the manufacture and deployment of equipment for automation.

Electrical engineering technicians typically do the following:

- Put together electrical and electronic systems and prototypes
- Build, calibrate, and repair electrical instruments or testing equipment
- Visit construction sites to observe conditions affecting design
- Identify solutions to technical design problems that arise during the construction of electrical systems
- Inspect designs for quality control, report findings, and make recommendations
- Draw diagrams and write specifications to clarify design details of experimental electronics units

Electrical engineering technicians install and maintain electrical control systems and equipment, and modify electrical prototypes, parts, and assemblies to correct problems. When testing systems, they set up equipment and evaluate the performance of developmental parts, assemblies, or systems under simulated conditions. They then analyze test information to resolve design-related problems.

³Sampled on 20 December 2019 from <https://www.bls.gov> with only cosmetic omissions.

Electronics engineering technicians typically do the following:

- Design basic circuitry and draft sketches to clarify details of design documentation, under engineers' direction
- Build prototypes from rough sketches or plans
- Assemble, test, and maintain circuitry or electronic components according to engineering instructions, technical manuals, and knowledge of electronics
- Adjust and replace defective circuitry and electronic components
- Make parts, such as coils and terminal boards, by using bench lathes, drills, or other machine tools

Electronics engineering technicians identify and resolve equipment malfunctions and then work with manufacturers to get replacement parts. They also calibrate and perform preventive maintenance on equipment and systems.

These technicians often need to read blueprints, schematic drawings, and engineering instructions for assembling electronic units. They also write reports and record data on testing techniques, laboratory equipment, and specifications.

Any robust, college-level two-year educational program in Electronics Technology should prepare graduates for work either as Electrical Engineering Technicians or Electronics Engineering Technicians.

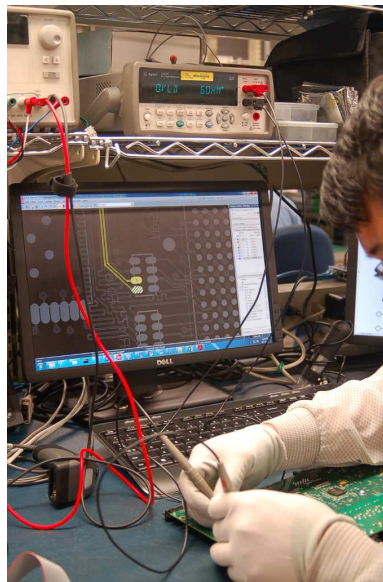
3.4 Jobs and industry sectors

This section will focus on specific technician jobs and industry sectors in which those jobs are found.

3.4.1 Electronics manufacturing/R&D

The manufacture of electronic products is perhaps the most obvious industry sector for electronics technicians. These products must be designed, prototyped, tested, refined, and diagnosed by teams of skilled engineers and technicians working together in teams.

Here, an electronics technician troubleshoots a printed circuit board (PCB) found defective via the quality-control process at a manufacturing facility. He is using an *ohmmeter* to measure the amount of electrical resistance along “traces” (strips of copper metal laid on the board to conduct electrical signals) in order to locate a short-circuit that was causing the board’s microprocessor to read corrupted data from a memory chip:

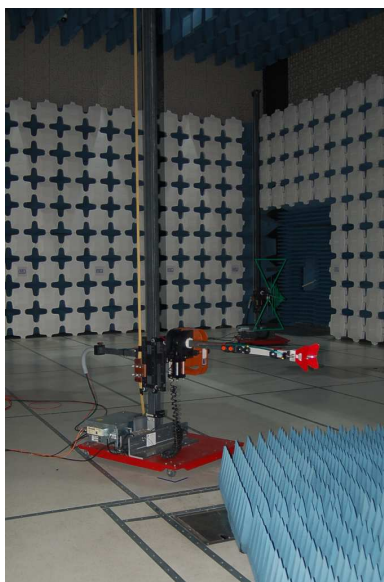


Technicians also work alongside engineers to develop new products, usually in a division named “R&D” (research and development). Here the work largely consists of fabricating “prototype” circuits and running comprehensive tests to ensure the products function properly.

Electronics testing is quite complex and falls into several categories, including:

- **Functional testing** – tests intended to validate that a product performs its function(s) as designed
- **Compliance testing** – tests intended to validate that a product complies with external regulations such as radio-frequency emissions and safety standards, also known as **Type testing**
- **Engineering scans** – tests spanning both functional and compliance validation
- **Parts qualification** – tests intended to validate components are within specification prior to assembly into the final product(s)

An example of compliance testing is seen in the following photograph of an *RF measurement chamber*, a large room shielded from external radio-frequency radiation, designed to serve as an electromagnetically “quiet” testing environment. All electrical and electronic circuits emit radio waves to some degree⁴, and FCC regulations (in the United States) place limits on how much radio-frequency (RF) energy may be emitted by certain products. An electronic product to be tested is placed near the center of this chamber, with directional receiving antennas (shown in the photograph) pointed at the product to precisely measure its emission signature:



RF emissions testing ensures that an electronic product will not interfere with other electronic devices in close proximity.

A similar form of compliance testing is *conducted emissions*, where the amount of electrical “noise” produced by an electronic product is measured on the power conductors feeding it energy to operate. The purpose of this is to ensure an electronic product will not interfere with other electronic devices drawing energy from the same power lines.

Another form of testing is *environmental testing*, where the electronic product is subjected to adverse conditions to ensure it still functions properly. Such adverse conditions include high vibration, high humidity, extreme fluctuations in temperature, and exposure to external sources of RF (radio-frequency) energy.

An entry-level electronics technician would begin their career following test procedures written by engineers and other technicians, but as they advance in knowledge and skill and experience they assume more responsibility for the design of the tests themselves.

⁴In a room as electromagnetically “quiet” as this one, it is striking to discover just how many objects emit RF energy. The simple act of walking across the room generates some RF emissions, as clothing friction generates static-electric potentials that discharge and emit electromagnetic waves with each discharge event. One demonstration shown to me in this room was shaking a plastic bag containing metal coins, and how that simple act generated a surprising amount of detectable RF emissions!

An important aspect of troubleshooting in *any* job and in *any* industry is the primacy of *root-cause analysis*. It is relatively simple to identify the immediate cause of a system failure, but often quite complicated to identify the “root” cause(s) leading to those immediate causes. For example, if a product keeps failing because one of its components fails, the immediate cause of the product fault is the component failure, but what keeps making that component fail? Perhaps the supplier of that component has not properly ensured it meets specification; perhaps it is the wrong component for our circuit design; perhaps the placement of that component exposes it to excessive heat or vibration; perhaps the product design is flawed in a way that over-stresses that component. Diagnosing faults to root cause is sophisticated work, and it is what makes an electronics technician in any diagnostic role highly valuable.

Learning to efficiently and accurately pinpoint root causes of failure is a skill born of thorough study and much practice. A technician must master both the theoretical “first principles” of electricity and electronics as well as become familiar with a range of test equipment and diagnostic technique. This is arguably the most important competency to gain in a technician’s education, and the demonstrated attainment of it serves as an excellent “capstone” assessment. To be a good troubleshooter means you are strong in all the technical areas that matter most, and it is the most highly-prized technical skill for any job in any industry.

3.4.2 Semiconductor manufacturing

Semiconductors are a class of material comprising the heart of all modern electronic technologies and devices. Unlike conductors which always permit the flow of electricity, and insulators which always prohibit the flow of electricity, semiconductors exhibit the unique property of being able to switch between conductive and insulating states. This means semiconductor-based devices are able to *control* the flow of electricity through them.

The dominant base material for modern semiconductors is *silicon*, one of the more abundant elements in the Earth's crust. However, in order to be useful as an electronic semiconductor, silicon must be refined to a state of exceptional purity – far beyond that found in nature. Once silicon has been thus refined and drawn into solid ingots, the ingots are then sliced into thin *wafers*. After this step, the wafers are sent to factories to be processed into usable electronic devices such as transistors, diodes, solar cells, and integrated circuits.

Manufacturing facilities process silicon in dedicated environments called *clean rooms*⁵ where the air is super-filtered to eliminate particles of dust and pollen which would ruin the silicon wafers. The machines performing the fabrication are highly specialized, essentially robotics on a microscopic scale.

The following photograph⁶ shows a typical clean room work environment, where workers must wear white suits to prevent hairs and skin particles from entering the clean room space which would damage the microscopic integrated circuit structures:



Technical knowledge of electronics is helpful for fab room workers, but the most important application of electronics knowledge and skill is in the maintenance of the fab and testing machines themselves.

⁵The common industry term for this type of facility is a *fab*, which is short for *fabrication*. It's essentially an ultra-clean assembly line where silicon wafers are formed into circuit components by a process called *lithography*.

⁶This particular photograph comes courtesy of Steve Jurvetson, and is licensed under the Creative Commons Attribution-Only license version 2.0.

3.4.3 General manufacturing

Manufacturing industries utilize vast arrays of electronic sensors, communication systems, robotics, and other forms of automation.

Shown here is a photograph of one of my former students, David Williams, while working at Tesla Motors in California. In this photo he is standing near a Fanuc robot that he programmed to insert bearings into drive motors for one of Tesla's models of electric car:



Another type of manufacturing environment involves automated conveyors and automated assembly processes performing work that many years ago would have been done by human assemblers working on an “assembly line”. For example, we see in this photograph a set of roller conveyors designed to transport bottles of beer from filling machines to packaging machines where the bottles are placed inside of cardboard boxes for bulk transport:



These automated assembly lines and the various robotic stations they contain use a multitude of proximity sensors, light-beam switches, and other sensors to detect the positions of items as they move along. Variable-speed motors, solenoid valves, pneumatic actuators, and other devices serve to provide motive force to keep everything moving.

It is difficult to encapsulate the range of electronics technician work within general manufacturing industries because the industries themselves are so varied. The programming and maintenance of robots is of course one obvious application of electronics technical work, but other job duties exist as well, a few of them listed here:

- Installing, maintaining, troubleshooting, and upgrading wired data communications networks for plant-floor computer systems and robots
- Installing, maintaining, troubleshooting, and upgrading radio communications systems for manufacturing systems and personnel communication
- Maintaining the electrical power systems energizing all the manufacturing processes
- Programming the automated control systems monitoring and regulating the manufacturing processes
- Calibrating, maintaining, and troubleshooting sensors used to measure parameters in the manufacturing processes
- Maintaining and troubleshooting packaging and labeling equipment used to bundle the products for shipment, and for helping to control inventory

A very common type of control computer used in the manufacturing industries is the *Programmable Logic Controller*, or *PLC*. These control computers are quite a bit simpler to program than the microprocessor and microcontroller systems most electronics technicians learn about in school, designed to be programmed by electricians and other tradespeople less familiar with the fine details of digital logic systems. Any competent electronics technician will find PLCs relatively easy to learn.

3.4.4 CNC manufacturing

Machines designed to cut metal and other materials into specified shapes are called *machine tools*, and they are indispensable to a wide range of manufacturing processes. Lathes and mills are traditional examples of machine tools, a *lathe* being where the machined part is rotated while the cutting tool is stationary, and a *mill* being where the machined part is stationary and the cutting tool rotates. Other types of machine tools exist as well, including precision grinders, electrical-discharge machining (EDM) tools, etc.

A machine tool manipulated by direct control of a human operator is called a *manual* machine tool. While these still find use in modern industry, by far the most prevalent type of machine tool you will find is computer-controlled, often called *CNC* (for “closed numerical control”). Here, a human operator writes a program using a specialized text-based coding language to instruct the machine tool how to go about carving the part into the desired shape. Below is a photograph of a CNC metal lathe:



Inside the compartment where the machining takes place, the shiny object on the left (called a *chuck*) securely grips the part being turned, while tools held in the rotatable “*turret*” may be brought into contact with the rotating part to shape it.

And here is a photograph of a vertical-axis CNC mill, where the chuck (located above, pointed downward) rotates a cutting tool against a metal part clamped into a vise on the movable table below:



Both machines are equipped with *automatic tool-changing* capability, which means the CNC program entered into each tool is also able to instruct the machine to swap one cutting tool for another without human operator intervention. We can see a close-up of a tool “turret” here from the CNC mill:



CNC machine tools are essentially specialized robots, manipulating the rotational speeds and positions of metal components in order to achieve the desired result. Each degree of motional freedom enjoyed by the tool is called an “axis”, and each axis of the tool requires precision electronic sensing to detect its position as well as precise actuation usually provided by a *servo motor*. Additionally, *limit switches* detect positioning at the extreme ends of each axis’s range, serving as a means to stop motion before the axis over-travels and potentially causes damage, as well as for finding the “home” position of each axis upon start-up so that the control computer “knows” where each axis is positioned. CNC machine tools also have computer-controlled coolant and/or lubricant pumps

to flood the part with appropriate liquid(s) to enable smooth, accurate, and reliable machining. As such, every CNC machine tool represents an extensive amount of electronic circuitry requiring maintenance, upgrading, and occasional troubleshooting.

3.4.5 Telecommunications

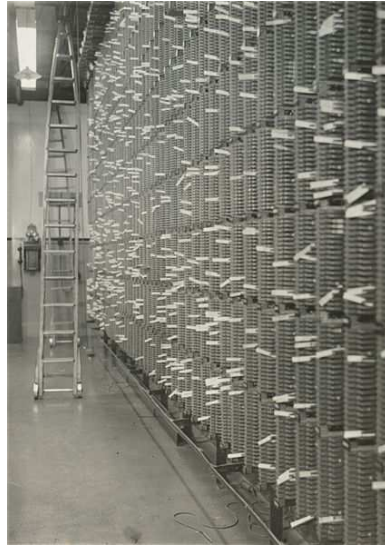
Modern telecommunication systems (e.g. telephone, television, Wi-Fi, internet) are so prevalent as to hardly require explanation. Even many developing nations have access to cellular telephone technology (in some cases going from nothing at all to cell phones, bypassing the wired-telephone technologies of other countries). Electronics technicians are needed to install, upgrade, maintain, and troubleshoot all these systems which have become so vital to modern life.

Radio features prominently in telecommunications work, an example of this being the next two photographs showing antenna arrays overlooking a city:



The tower on the left holds cellular telephone antennas (lower) and FM broadcast antennas (upper). The tower on the right holds covered microwave “dish” antennas for high-speed data communication.

Wired telecommunications networks such as traditional telephone, cable television, and internet service also require electronics technicians for the maintenance of an extensive infrastructure: The photograph shown below is an example of a main distribution frame (MDF) for a telephone network in New Zealand used to marshal wires for a large collection of cables, giving some sense of the complexity of these networks:



Buildings housing these network connections and equipment are known as *central offices* (CO), and from their exterior views are usually unassuming in appearance:



Positions and responsibilities associated with the telecommunications industry include:

- **DC Power Technicians** – modern radio transceiver units such as Remote Radio Heads (RRHs) are powered by DC electricity, and for large installations require sophisticated networks of power supplies, batteries for backup power in case of grid outages, overcurrent protection devices, and overvoltage protection devices to maintain a reliable source of energy to function. These power systems are complex enough to require the services of “DC Power Technicians” to install and maintain. Typical duties for a DC Power Technician include terminating wires, ensuring proper grounding of power systems, routine battery servicing, troubleshooting circuit faults, adding loads to power systems (often while “hot” – still powering existing equipment), writing “Method of Procedure” (MOP) documents, and installing steel racks to hold batteries and other equipment.
- **Central Office (CO) Technicians** – a “central office” is a structure housing telecommunications equipment, from the days of switched telephone networks, usually located near population centers. These buildings contain the electronic equipment processing electronic signals for a variety of communication networks (e.g. telephone, cable television, internet, etc.), and technicians responsible for the maintenance of these central offices must work on all aspects of them. This includes testing and service of the signal-processing equipment, the power supply systems, installation and repair of all manner of cabling and fiber-optic lines, and of course diagnosis of faults.
- **Tower Technicians** – as the name implies, this position is associated with installation and maintenance work at elevated heights on antenna tower structures. This includes cabling termination, electronic equipment testing and repair, electrical grounding, and work on the tower structure itself.
- **Customer Premise Equipment (CPE) Technicians** – telecommunications electronics and cabling located at the customer site is the responsibility of a Field Service or CPE Technician. In addition to solving technical problems, these technicians must interface regularly with human customers, and so good customer-support skills and a cheerful disposition are required in addition to the required technical skills.

3.4.6 Aerospace and avionics

The term “aerospace” could be defined as having to do with *anything that flies*. This includes aircraft (both manned and unmanned), rockets, space probes, satellites, balloons, and missiles. Like all highly technological endeavors, aerospace extensively utilizes electrical and electronic systems for safe and efficient operation.

An example of electronics technician work on space-borne systems is this photograph⁷ showing workers installing electronics on the Juno space probe:



An exciting prospect for electronics work in the aerospace sector is the formation of private spacecraft manufacturers such as SpaceX and Blue Origin. The photograph below shows the first launch of SpaceX’s Falcon Heavy rocket⁸:



⁷Public-domain image courtesy of NASA’s Jet Propulsion Laboratory

⁸This public-domain image provided courtesy of Stuart Rankin.

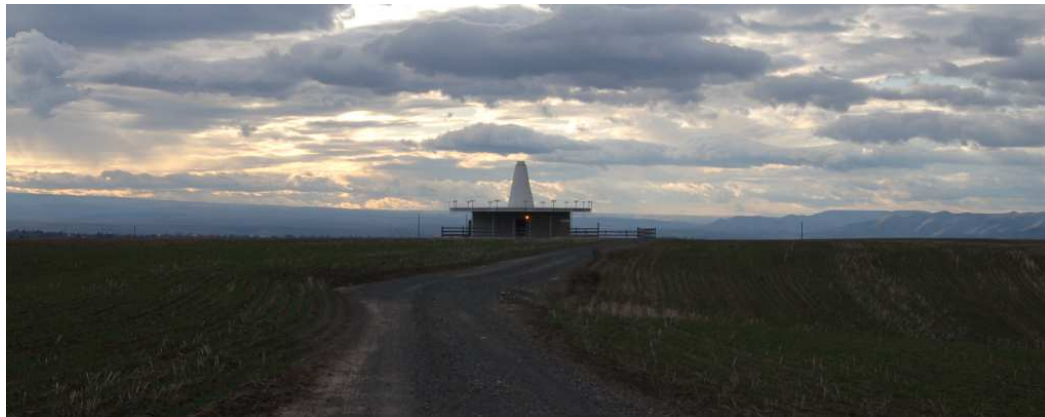
A bit closer to Earth is electronics work associated with regular aircraft. This field has its own title – *avionics* – a contraction of *aviation electronics*, associated with flight control, instrumentation, navigation, and communication systems. A view inside the cockpit of a large aircraft⁹ shows just how complex the pilot instrumentation is, both legacy analog (left) and modern digital “glass” (right):



Commercial aviation (e.g. passenger airlines, cargo planes) electronics work occurs at the manufacturing level as well as at the operations level. General aviation (individually-owned aircraft) also has need of avionics technicians, and in many cases the electronics work associated with general aviation is every bit as complicated as with commercial or even military. The reason for this non-intuitive assessment is that private aircraft, unlike airliners and military planes, are more likely to have avionics packages consisting of a patchwork of manufacturers and technological eras. An apt comparison to the automotive world would be a municipal bus versus a family car: the bus is likely to be outfitted with electronics purchased as part of a comprehensive maintenance plan, whereas the family car’s accessory electronics has been purchased one bit at a time as the family can afford. Thus, the general aviation technician may have to solve problems unheard of in a more expensive aircraft.

⁹In this case, a military C-5 cargo plane manufactured by Lockheed.

Even closer to Earth are ground-based aviation-related electronic systems such as the Very High Frequency Omnidirectional Range (VOR) transmitting station shown in the photograph below:



These radio transmitting stations broadcast signals that aircraft use for navigation, much like using a magnetic compass except that the aircraft navigation equipment consists of specialized radio receivers rather than magnetized needles pointing toward Earth’s magnetic north pole. VOR stations were first commissioned in 1949, at at one time numbered in the thousands worldwide. Now their numbers are greatly diminished to the point where a minimal network remains in operation, as VOR navigation has been largely supplanted by satellite-based (GPS) navigation systems. The “Minimum Operational Network” of VOR stations exists as a backup in case satellite navigation fails¹⁰. The particular station shown in the above photograph is located near a commercial airport where such backup navigation is fairly important, and is part of the “Minimum Operational Network” remaining in service.

However, VOR stations are not the only terrestrial electronic systems important to modern aerospace avionics. Land-based radars and voice communication systems used at rocket launch sites and airports represent another set of electronic systems essential for the safe operation of these vehicles.

¹⁰For the same reason, some recommend reviving the obsolete *Loran* radio-based navigation system once widely used for ship navigation!

3.4.7 Automotive R&D

Research and development of automobiles is an ongoing endeavor, with automobile manufacturers constantly seeking to build vehicles that are more fuel-efficient, less polluting, safer, and more capable. Electronics technicians play a prominent role in R&D laboratories, selecting and installing appropriate sensors to detect the vehicle's performance, writing code for data acquisition systems and interfaces for the vehicle's on-board computers, etc. Here is a photograph¹¹ of a vehicle being tested for engine emissions in such a laboratory:



Electric and hybrid vehicles are, of course, another area of automotive research and development, this next photograph showing a Tesla being tested (also at Argonne National Laboratory):



¹¹Public domain, courtesy of Argonne National Laboratory.

3.4.8 Electrical power

The electric power industry is both vast and highly technological. Sub-categories of this field include:

- **Generation** – where the electrical power is made, by converting some other form of energy into electricity
- **Transmission** – power lines operating at hundreds of thousands of Volts, transmitting electricity efficiently over long distances
- **Distribution** – power lines operating at lower voltages (tens of thousands of Volts), distributing electricity from substations to neighborhoods and industrial zones
- **End-use** – large consumers of electric power often operate their own scaled-down versions of distribution systems within their property, and use sophisticated electronic controls to regulate the use of that energy

Many sources of electric power exist, some of them renewable and others non-renewable. One example of a renewable energy source is *wind*, the following photograph showing replacement of a gearbox on a large wind turbine, this photograph taken by one of my former students now working in the industry:



Substations are facilities routing electricity to different locations as well as change levels of voltage and current. A photograph of one such facility is shown here:



Both precise measurement and fast control are required for safe and efficient operation of an electric power grid. The terms used to describe these functions within a power grid differ somewhat from the terms used in other industries. Instead of calling it all *electronics*, you will more likely hear terms such as *metering* (systems used to quantify the amount of electricity), *protection* (systems used to automatically shut off the electricity in the event of component failure), and *SCADA* (“Supervisory Control And Data Acquisition”) systems used to provide remote measurement and control over long distances. However, the fundamental principles are common to other forms of industrial electronics.

Another career path within the electric power distribution industry is the maintenance of high-voltage power lines. The following photograph shows another former student of mine working atop a high-voltage transmission line tower in Montana for the Bonneville Power Administration (BPA). While in the apprenticeship program at BPA he told me the education he received in electric power systems and electronics made the theory very easy to understand and was a definite advantage in his chosen career:



An important fact to consider when contemplating a career in the electric power industry is its relative immunity from economic cycles and outsourcing. Unlike manufacturing-based industries which may shutter under hard economic times or relocate to other countries with cheaper labor and lax environmental standards, power grids represent billions of dollars in irreplaceable capital investment. Wages and safety standards tend to be very high¹² as well.

¹²As an example of high wages, one large electrical utility I know of pays all overtime work at 200% the standard

3.4.9 Pipelines

Pipelines carrying liquids and gases over long distances operate with similar safety and operational concerns as electric power lines: pipeline operators are concerned with the measurement of product through the lines (for revenue purposes) as well as safety (in the event of a pipeline burst). For this reason pipelines are always equipped with monitoring and control systems interconnected by a variety of electronic communication networks (e.g. satellite radio, microwave, fiber optics, leased telephone lines, cellular radio). As in the electric power industry, these far-flung monitoring and control systems are called *SCADA* and operate under very similar principles.

Stations installed periodically along a pipeline's length are often found in remote locations, and so the *SCADA* equipment in these locations must not only utilize radio for communication (because no wired networks exist there) but must also have their source of electricity for continuous operation. Electrical power may come from solar (photovoltaic) panels, wind turbines, thermionic generators¹³, or some combination of these. The photograph below shows a remote natural gas pressure-monitoring station, the electronic sensor and datalogging hardware powered by solar panels:



A rechargeable battery provides power to the electronics at night when there is no sunlight, and is recharged by solar energy during the day. This way, the gas pipeline's pressure may be continuously monitored with no ordinary electric power service.

hourly wage (i.e. *double time*). This utility literally refers to this rate of pay as *high time*, referencing its origins as an enhanced pay grade for any work done by lineworkers above a certain elevation from ground level (now graciously extended to all skilled craftspeople's overtime). Surveying the wages of protective relay technicians within another public utility revealed annual compensation near the \$200,000 level (in the year 2016).

¹³A "thermionic generator" is a device burning some fuel – e.g. natural gas from a natural gas pipeline – and using the heat of that combustion to produce electricity.

3.4.10 Heavy industries

Industrial operations that are large in scale and often involve the processing of potentially hazardous substances are generally referred to as “heavy” industries. These include chemical processing, oil production and refining, natural gas production, metal smelting and recycling, etc. Such operations make extensive use of electronics, and usually have their own internal power grids (complete with substations) to handle all the electrical power needed to run the operation. A typical example of such an industrial site is shown below, this particular facility being an oil refinery:



3.4.11 Municipal water treatment

It would be difficult to identify an industry less glamorous than municipal water treatment, but this sector is nevertheless extremely important to civilized living and a very stable source of employment for many electronics technicians. Like electric power grids and pipelines, municipal water treatment systems utilize a vast network of pipes, storage tanks, pumps, sumps, and/or reservoirs to provide clean drinking and fire water to residences as well as remove and treat wastewater for sanitation, and this network of water-handling hardware must be monitored and controlled from afar. Therefore, water treatment systems use their own *SCADA* systems to take measurements, display information to human operators, archive long-term data records, and transmit control commands to water-processing equipment. These *SCADA* systems, like pipelines, use a variety of communication media to relay signals across large cities: fiber optics, internet, cellular radio, microwave, leased telephone lines, etc.

An example of a *SCADA* node located at a municipal wastewater “lift station” appears in the left-hand photograph, a directional radio antenna clearly visible at its corner. In the right-hand photograph we see a set of rapid-sand filters used to purify drinking water for a small city, complete with ultrasonic water-level sensors mounted above each filter bay electronically sensing the height of water above each sand bed (to signal to the control computer when each sand bed requires backflushing to rid it of accumulated sediment):



Water and wastewater treatment, of course, is absolutely essential for urban living, which means each and every city in the industrialized world has some form of this. Unlike other industries which cycle with the general state of the economy, jobs in these essential services are fairly recession-proof.

A graphic display drawn by one of my graduates working for a municipal water utility appears in this next image:

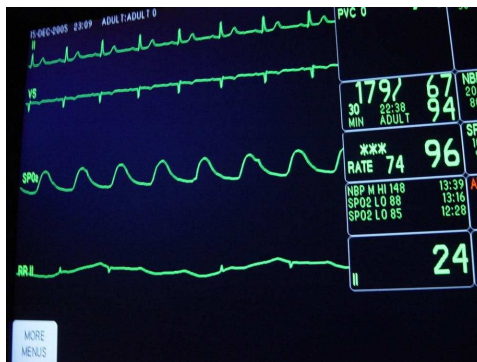


This computer image shows just some of the data typically conveyed by a SCADA system: water pressures, flow rates, and totalized flow quantities. What it does *not* show is all the electronic infrastructure necessary to collect, convey, compute, and display this data: sensors, cables, analog-digital converters, radio transceivers, antennas, personal computers, network servers, and of source computer software.

Like the electric power industry, municipal water treatment is relatively immune from economic cycles and outsourcing. The job is stable, wages are high, and benefits are excellent.

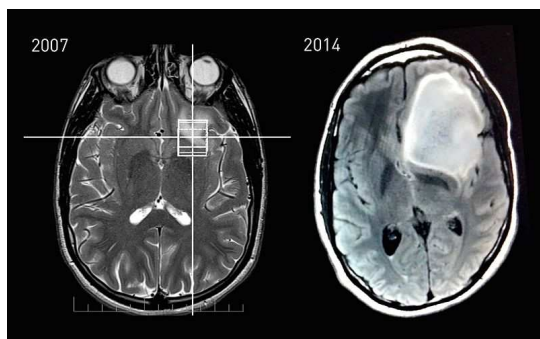
3.4.12 Medical

Electronic sensing and recording systems have long been an essential tool for medical care, and will continue to be so in the future. Many processes inside the body are electrical in nature (e.g. heart rhythm, nerve cell firings, muscle activation) and therefore are readily measured in the form of miniscule voltages and currents which may be amplified, digitized, displayed, recorded, and otherwise processed like any other electronic signal¹⁴:



Many other diagnostic measurements are not electrical in *nature* but nonetheless are measurable using electrical techniques. Scanning technologies such as CAT, PET, and MRI are all good examples of medical imaging which would be impossible if not for complex electronic signal processing and computing. These devices and systems require periodic calibration and maintenance, like any other machine, and technicians trained in their specifics are hired to do this work.

An example of an MRI (Magnetic Resonance Imager) machine's diagnostic capability is seen in the left-hand pair of images from the same patient over a 7 year timespan, showing the presence of a tumor called an astrocytoma in the later image. The right-hand photograph shows the exterior of such a machine, where the patient lies within the center aperture of the machine surrounded by powerful electromagnets generating the intense magnetic field necessary to produce such images:



Much of medical electronics service is done on a contract basis rather than each hospital or imaging center maintaining its own in-house technicians. Also, the certifications required for working

¹⁴Public-domain photograph courtesy of the Johns Hopkins News-Letter, 22 December 2019.

on this equipment are specialized and often manufacturer-dependent. It is quite common for this work to be done by the manufacturer of the imaging equipment¹⁵ by their own technicians trained to service that specific equipment (e.g. an MRI imaging machine manufactured by Siemens being serviced exclusively by Siemens-employed field technicians). However, in general the principles applied in medical electronics are remarkably similar to those used in other electronics fields, and so any competent electronics technician should find it relatively easy to adapt to this field.

3.4.13 Building automation, alarm, and access

An ever-growing career sector is the automation and security of buildings. From fire alarm systems to elevator controls to surveillance and security access systems, modern buildings are becoming ever more complex. Even basic functions such as heating and cooling for new buildings are now fully microprocessor-controlled and digitally networked.

Electronics technicians looking to this career sector may find work both on the construction side as well as the building maintenance side. In both cases it is more likely to find jobs working for contractors than it is to be hired as permanent staff at a site, unless than site is extremely large, complex, and/or has special needs (e.g. high-security installations).

An interesting development in recent years is the addition of local electric power generation to large buildings. Whether it take the form of solar (photovoltaic) panel arrays to turn sunlight into electricity, or combined heating-and-power (CHP) systems extracting more usable energy from natural gas fuel than traditional boiler systems, the electric power networks of modern buildings are becoming more complex over time. Financial incentives exist for homeowners and commercial building owners alike to become net producers of electric power, as this unburdens centralized power generating stations and transmission systems. All these localized power-generation systems require technical support for installation, upgrading, maintenance, and troubleshooting, with people skilled in electronics well-poised for such work.

A number of my electronics and industrial automation graduates¹⁶ have gone into the HVAC (Heating, Ventilation, and Air Conditioning) field on the basis of their knowledge and skills in electric power (especially variable-frequency motor drives, VFDs) and digital networking. Radio-communication technology such as ZigBee is now becoming more popular for climate control systems, and new variables such as carbon dioxide concentration now serve as inputs to these systems along with ambient temperature. Employers tell me it is easier for them to take a person well-versed in electrical power and electronics and train them to be knowledgeable on heating and cooling hardware than it is to take someone who knows heaters and air conditioning really well and teach them electrical power and electronics.

¹⁵Modern medical imaging equipment such as MRI (Magnetic Resonance Imaging) tends to be *extremely* expensive, and so it makes sense to trust the ongoing maintenance of such equipment to factory field technicians, so that any malfunctions may be covered by the manufacturer's warranty.

¹⁶One of them in particular spoke with me after choosing this career instead of industrial work, saying it was really important to him to be able to make customers happy every day on the job (something one does not often experience in heavy industry).

The photograph on the left-hand side shows a control panel for a Direct Digital Control (DDC) system used in a large building. There will be many such panels in a large building, each containing similar box-shaped controller modules connected to temperature sensors, heater and chiller units, etc. The photo on the right shows a typical “thermostat” interface which shows the system is monitoring and controlling more than just room temperature:



Note how the thermostat interface registers carbon dioxide (CO_2) concentration in addition to real-time and target room temperatures, and air circulation status. A standard feature now for building HVAC systems is continuous carbon dioxide monitoring, used to circulate fresh air only into rooms that need it, based on the amount of CO_2 present in the air from occupants' exhalations. The DDC controller modules monitor these sensed variables and decide when and how to activate heating systems, cooling systems, air circulation fans, heat exchangers, etc. in order to maintain healthy air conditions in the building at all times while dissipating as little energy as possible. DDC systems are *networked*, which means the individual control modules communicate information with one another via electronic signals sent through wire cabling connecting the modules together. Specialized network protocols such as BACnet exist for this purpose.

These building controls must be programmed for each building they're installed in, wired together to make a functioning network, and of course tested and maintained. Physical sensors and valve actuators similarly must be configured, wired, tested, and maintained. DDC controllers communicating on a network must each be programmed with a unique identifying “address” to distinguish it from all the other devices connected to that same network. Alterations made to network cables, or damage inflicted on those cables, can interfere with the digital signals in non-obvious ways requiring troubleshooting by skilled technicians.

Below we see photographs of interface panels for a building fire alarm system, the unit on the right commonly referred to as a Fire Alarm Control Unit (FACU):



Like HVAC systems, modern fire alarm systems use digital network communications to link multiple devices (e.g. pull-switches, sirens, beacons), each device having its own address number to distinguish it from others on the same network.

The fact that sophisticated HVAC systems and fire alarm systems are *required* in modern buildings means the demand for electronics technicians to install and maintain these will persist as long as those buildings stand.

3.4.14 Military support

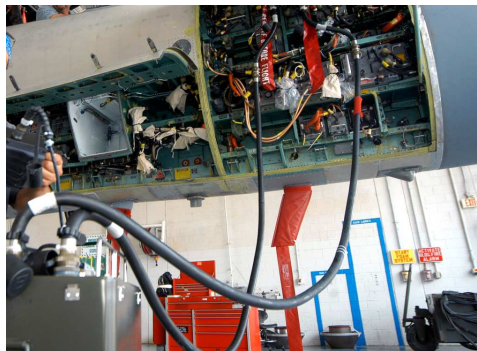
The various branches of the United States military all train and employ their own electronics technicians, but an option open to civilians (and especially to qualified veterans) is *contractor*-based support of military operations. This is a cost-saving alternative to maintaining their own self-sufficient staff of technicians, useful for weathering the politically-driven cycles of military funding ebbs and flows.

Military operations rely very heavily on electronic systems of all types: radio and optical communications, control systems, precision measurement, portable electric power systems, electric propulsion systems for vehicles, weapons guidance systems, remote piloting systems (i.e. drones), and facility security systems to name a few. The technological advancement of these systems ranges from state-of-the-art to surprisingly aged¹⁷.

A prominently visible example of military electronics is *radar* systems, such as this particular antenna array belonging to an American warship¹⁸:



Military bases for various aircraft and sea vessels are popular centers for civilian contractor support, allowing properly-cleared civilians to service these systems without being in militarily-active zones. The next photograph shows flight control system tests underway for an F-15 interceptor jet at an American military airbase¹⁹:



¹⁷One tactical advantage of many analog and early-digital electronic systems is that they are immune to cyberattack, an important advantage for military infrastructure in an age where battlefronts are virtual as well as physical.

¹⁸On board the Nimitz-class aircraft carrier USS Harry S. Truman, photo taken by Mass Communication Specialist 3rd Class Justin R. Pacheco.

¹⁹Photo taken by Sue Sapp.

An absolute requirement for this line of work is a suitable security clearance, which is one reason it is a good career path for military veterans who have already possessed the necessary clearance(s).

3.4.15 Law enforcement

Closely related to military equipment support is maintenance of the electronic systems used by law enforcement. In many cases the technologies used are similar to, if not identical²⁰ to, those used in the military.



Police and sheriff departments located in high-population areas often employ their own electronics technician staff to maintain radio communication systems, cameras, etc. Smaller agencies might contract this work out in lieu of hiring their own technicians.

Federal agencies such as Border Patrol, the FBI, the CIA, and others also need qualified electronics technicians to ensure all their monitoring, communication, data, and other systems function safely and reliably.

²⁰I once had the opportunity to do electronics work on behalf of a Sheriff's office, repairing a night-vision camera system mounted to a military-surplus armored assault vehicle (A "Caiman" mine-resistant ambush-protected "MRAP" tactical transport vehicle, the same as shown in the photograph.). Thanks to Congressional acts redirecting surplus military inventory to municipal law enforcement agencies (e.g. the 1033 Program), many of these agencies must now service these military systems to maintain them in good working order.

3.4.16 Public roads and railway systems

Electronic systems used to direct automobile traffic, monitor driving conditions along highways, and control railroad crossings require the same sort of technical support for installation, upgrading, troubleshooting as other complex systems. State departments of transportation hire electronics technicians for this work, as do railroad companies and cities.

The image on the left is a standard traffic light familiar to anyone reading this document²¹, and the image on the right shows a legacy railroad semaphore²²:



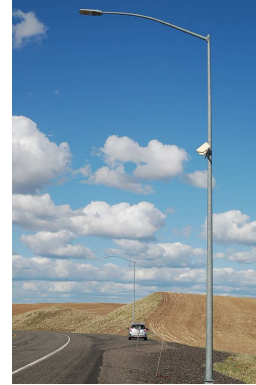
Specialized certifications are often required for these positions, such as those certifications offered by the International Municipal Signal Association (IMSA).

An interesting area of development for municipal traffic signaling system is communication between a city's traffic control system and *autonomous vehicles*. A self-driving automobile has the ability to connect to a traffic control network via radio communication, and is not limited to optical signals as are human drivers.

²¹Public-domain image courtesy of Martin Vorel.

²²Public-domain image courtesy of Linnaea Mallette.

Another application of electronic systems to public roadways is road condition monitoring. Many state highway departments maintain networks of atmospheric and road condition sensors such as these shown below, in order to provide drivers with real-time driving safety information. The structure on the left holds sensors for such ambient variables as wind speed, wind direction, and temperature; on the right we see two cameras focused on the road itself for monitoring surface conditions (e.g. ice, water):



3.4.17 Municipal transportation systems

In addition to electronics work for signaling systems used along public roads and rail lines, specialized transportation systems such as subways and *municipal light rail* also have their own unique technical staffing needs. City-level rail-based transportation systems are powered by electricity and therefore have their own electrical power distribution systems for conveying electrical energy to the traction motors. These specialized rail-based systems also have their own communication and signaling networks, and modern systems are highly automated as well.



3.4.18 Marine transportation

Boats and ships have extensive electrical and electronic systems necessary for their safe and efficient operation. From diesel-electric propulsion systems to radar and other radio-based navigation electronics, the marine industry offers a wide range of employment opportunities for technicians.



The following photograph shows a control panel located within the engine room of a diesel-powered ferry vessel:



Electronic systems typically found aboard large vessels include radar, satellite communication, autopilot systems, closed-circuit television (CCTV), computer networks (e.g. Wi-Fi, Ethernet), medium- and high-frequency radio transceivers, GPS, AIS (Automatic Identification System with radio transponders relaying ship information to other ships), power system monitoring, and depth finders (sonar). For very large vessels there may be electric propulsion systems as well, with a power electronics controlling the electric motor(s) and similar systems regulating the power output of the engine-driven generator(s).

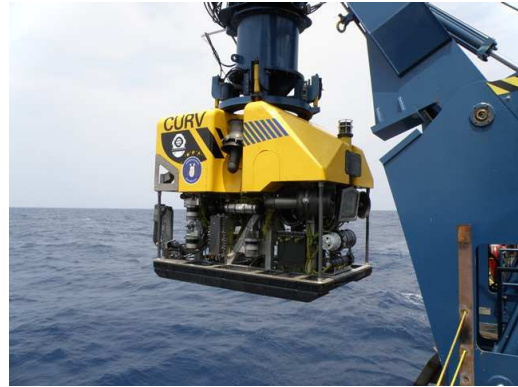
A parallel development to autonomous automobiles is autonomous *ships*, officially referred to as *Maritime Autonomous Surface Ships* or *MASSEs*. Autonomous navigation for ships, especially large cargo ships, may range from advanced autopilot functionality to full autonomy where no humans

tend the vessel or even board it at all during normal operation. At the time of this writing (2021) autonomous ships are still considered experimental, but just like autonomous automobiles promise to revolutionize certain segments of the transportation industry. As with self-driving cars, one of the goals of automating ship functions is the avoidance of accidents caused by imperfect human judgment.

The National Marine Electronics Association (NMEA) is a standards organization which oversees certifications for marine electronics technicians, including the “Basic NMEA Installer”, “Marine Electronics Installer” (MEI), “Certified Marine Electronics Technician” (CMET), and “National Marine Electronics Technician” (NMET) credentials. The CMET certification requires, among other things, prior attainment of the FCC’s GROL (General Radio Operator’s License) with Radar Endorsement.

3.4.19 Remotely operated vehicles

Remotely Operated Vehicles (ROVs) are a specialty application within the marine industry, essentially being undersea robots. These sophisticated machines are used for a wide variety of underwater maintenance and salvage operations. The oil industry, for example, uses ROVs extensively for inspecting and maintaining sea-floor wellheads. Photographs of three different ROV models used by the United States Navy appear in the following photographs:



Such vehicles contain on-board propulsion systems, sonar navigation aids, magnetic compass, manipulator arms, and connect to a surface ship using an umbilical cable that often uses optical fibers for noise-free data communications.

3.4.20 Audio/visual systems

Electronic systems designed to record and reproduce both audio and video signals are used in a variety of environments. The following photograph shows a typical control panel for a theater's electronic systems:



Jobs exist for technicians to install, maintain, and upgrade these systems, which are found in a wide range of installations including entertainment businesses (e.g. theaters and concert halls), music recording studios, public schools and colleges, business conference centers, cruise ships, and radio broadcast stations. Often a practical knowledge of acoustics is necessary to perform the tasks associated with this technology, and for music recording expertise in digital audio workstation software is also important.

3.4.21 Academic and government research

Research projects organized by universities and government agencies often require the technical expertise of electronics technicians. One such endeavor is the McMurdo Station in Antarctica where a range of scientific experiments and projects occur²³:



A former student of mine worked as a contract technician for Raytheon at the McMurdo Station. Such remote locations are not for everyone, of course, but this particular individual was an experienced mountaineer and absolutely enjoyed being in hostile wilderness such as this.

Another remote research facility dependent on electronics technicians is the HAARP (High Altitude Active Auroral Research Program) facility located in Alaska. Formerly operated by the US Air Force, it is now under the control of the University of Alaska Fairbanks. The facility consists of a large phased-array antenna²⁴ used to beam radio energy high into the ionosphere and measure the returning radio signals to better understand radio signal propagation and atmospheric physics:



²³Public-domain image courtesy of the National Science Foundation and the photographer, Mike Lucibella.

²⁴Public-domain image courtesy of the University of Alaska Fairbanks and the photographer Jessica Matthews.

Moving to warmer climates, we have one of several radio observatory facilities in the world, the Very Large Array operating in New Mexico²⁵:



Of course, scientific research requiring the assistance of electronics technicians is not limited to exploring the Earth and the stars. Research programs exist for a wide range of endeavors: particle physics, medicine, energy production and storage, supercomputing, cybersecurity, etc.

²⁵Public-domain image courtesy of the National Science Foundation and the photographer Andrew Clegg.

3.4.22 Calibration services and metrology

Metrology is the science of precise measurement, and *standards laboratories* are places housing equipment designed to serve as references for many types of measurement. A range of technical skills are necessary to maintain and utilize these metrological standards, from scientists to technicians.

The following photographs show a rack of voltage standards used to compare against voltage-sensing instruments brought in to the standards laboratory for routine calibration (left), and a Josephson Junction primary standard for electrical voltage (right):



Virtually all industries require accurate measurement, and standards laboratories are the places where calibration equipment gets checked. This process of comparing calibrations against standards of higher quality, all the way up to primary standards laboratories, is called *traceability*. Like pedigree for animal breeding, traceability documents the integrity of the “calibration chain” extending back to those primary standards.

The instruments used within standards laboratories are strange beasts compared to benchtop test equipment such as multimeters and oscilloscopes. Primary standards are especially so, devices such as the Josephson Junction array shown in the previous photograph requiring an on-staff engineer and/or scientist to maintain. A great many metrological instruments are electrical in nature, and the techniques used to connect such instruments together to measure electrical quantities such as voltage, current, resistance, capacitance, inductance, and power are far from trivial. What might ordinarily be considered “negligible” becomes of paramount importance in the metrological world: *noise* voltages, *leakage* currents, *stray* electric and magnetic fields, *background* radiation, and the like all conspire to corrupt accuracy. When one is attempting to achieve measurement uncertainties in the *parts per million* or even *parts per billion* range, these “negligible” effects cannot be ignored. Connection techniques such as the *Kelvin 4-wire method*, rooms shielded from external electric fields by copper mesh paneling, and other mitigation measures are commonplace within metrology laboratories.

3.4.23 Technical sales

While certainly not a good fit for every personality, *technical sales* is an under-explored career path for electronics technicians and engineers. This involves working either directly for an electronics manufacturer, or working for a vendor representing one or more manufacturers serving customer needs. Unlike consumer sales jobs, technical sales deals with a highly informed and critical client base. The products being sold are essential to the safe and efficient operation of critical systems, and so the technical salesperson *must* be responsive to the client's needs.

Technical sales professionals are roughly divided into two categories: *inside* sales and *outside* sales. An "inside" salesperson helps customers select technical products while working from an office, while an "outside" salesperson actually visits the field sites where the products in question are installed and serviced.

A large part of a successful technical salesperson's job is *educating* the client on specific options and capabilities of the product being sold. The client may have a very good understanding of what the technology *needs* to do, but the salesperson is the expert on what their technology *will* do. Outside salespeople often spend time at their clients' sites giving technical presentations, answering questions, diagnosing faults on installed products, etc.

Manufacturers and vendors often struggle to find good employees for this career. What is necessary to succeed in this business is an outgoing personality combined with strong technical expertise, the ability to continually learn new technologies, and the integrity to be honest with the client at all times. Salespeople accustomed to marketing consumer products (e.g. automobiles, furniture) may fail in this regard, where the client's match with the product is often subjective. In the very objective world of industrial electronics, *the only way the client is going to be happy is if the product functions as it should.*

Closely related to outside sales is *field service*, which means you are a technician (or engineer) tasked with repairing or upgrading a product on the customer's site. This may occur because the product in question has been purchased with a factory service agreement, in which case service must be done by factory representatives and not the client. It may also happen if a client orders and installs an electronic device or system, then discovers it fails prematurely or otherwise performs at an unexpectedly low level: it may cost less to pay for a factory-authorized technician to troubleshoot the problem than it would to dedicate others less familiar with the product to that same task.

Compensation in the world of sales is almost always based to some extent on commission: a percentage of the total sales volume. This is a natural incentive for the salesperson to sell more, which is precisely what every manufacturer prefers. However, there is usually a certain portion of a technical salesperson's income that is fixed and not tied to the number of items or total value of items sold. This ratio between fixed and commission varies with the employer.

Manufacturers and vendors selling *safety* technologies often enjoy a more stable revenue stream than those selling production-related technologies, because many safety standards are mandated by state and/or federal law, and as a result the purchasing of consumables and upgrades for those safety-related products is largely de-coupled from the ebbs and flows of the general economy.

3.4.24 Summary

Hopefully by this point you are convinced that the knowledge and skill set of electronics can take you very, very far as a career. Once embarked on a rigorous program of study in the fundamentals, it is good to begin exploring career options as early as you can to determine what specialized knowledge and skills (and certifications) may be necessary for the career of your choosing.

Another important lesson to take from this survey of career pathways in electronics is that the field is *vast* and *widely varied*. This is good news for multiple reasons: first, having such a wide array of different pathways to choose from means you are more likely to be able to find just the right niche for yourself if you're willing to look diligently enough. Second, if you ever desire to switch directions in your career to do something slightly different, there are a range of options to consider. Finally, it means that if you are ever laid off from a job due to some factor beyond your control, it is very likely you can "shift gears" and step into some other job that isn't exactly the same as what you did but is similar enough that most of your knowledge and skill is still a good fit.

Key to enjoying all that electronics has to offer as a career is a willingness to work hard and keep learning, because there is too much within the field of electronics for any one person to learn, let alone master, in any one lifetime. A mastery of fundamentals combined with strong work/learning ethic and a positive attitude will take you far. As a parting note, I would like to close this chapter with a quote from one of my graduates who decided to apply his knowledge of electricity, electronics, and industrial controls to a career as an HVAC (Heating, Ventilation, and Air Conditioning) technician because he liked that work environment more than the heavy industry jobs most of his classmates pursued. He wrote this just a few years into his new job, replying to a message I sent to him asking how he was enjoying his career:

Hi Tony!! Yes, I am still with (the company I hired on with at graduation). Definitely a different world, but I certainly have benefited huge from my education. It has excelled me further, faster than the average. I am now a Lead HVAC/R installation/repair technician.

I deal a lot with low voltage control systems, as well as high voltage.

You know Tony, honestly when I made the decision to go into HVAC I knew it was a gamble. But I was gambling on myself. I knew my capabilities and I was willing to take that gamble. It has added such a huge field to my capabilities.

I would tell students looking for careers, don't be afraid of going out on a limb. If you trust yourself, then go out there and prove it. I did that here, and the owner of the company has told me personally 'In the 40 years of being an employer, I don't know if I have had an employee like yourself who has the ability to do anything and learn anything.' . . . It really has been a success.

3.5 Industry equipment

Viewing images of actual equipment used in various industries can be a helpful way of learning about different career options. This section focuses on both process equipment (i.e. the machinery used to manufacture a product) as well as specific pieces of test equipment an electronics technician might use on the job.

3.5.1 Process equipment

Here we will explore some of the equipment used in industrial “processes”, a *process* being any collection of devices used to perform a processing function or to deliver a service. As we will see, electronic systems find extensive application in industries one might not think to consider!

Pressure sensors

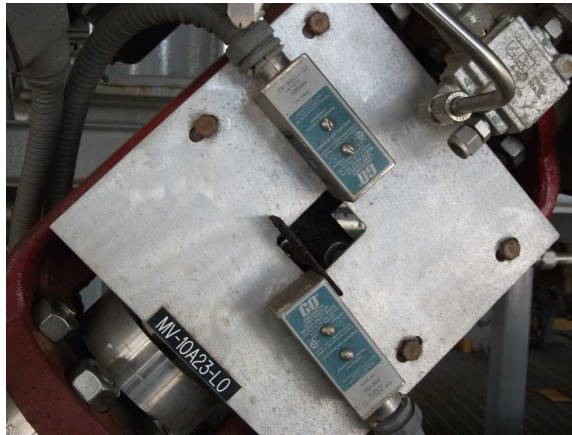
This photograph shows a pressure-sensing instrument called a *differential pressure transmitter* (on the left) as well as two pressure-actuated electrical switches (center and right). Such sensing instruments are useful for many different types of fluids, such as air, water, oil, steam, etc.:



Like all sensing instruments, these require routine calibration to ensure measurement accuracy.

Limit switches

This photograph shows a pair of magnetic “limit switches” designed to detect the position of a moving machine part. The part itself must be ferromagnetic (i.e. contains iron), and the two switches detect if that part comes near by way of sensing how a magnetic field is affected by the proximity of that moving part:



Both limit switches are manufactured by the “Go” corporation.

Level sensors

This photograph shows a sensor for liquid level at the bottom of a compressed natural gas vessel, designed to detect the accumulation of water and other condensable liquids from the natural gas stream. It uses a buoyant float inside of a stainless-steel pipe to sense the liquid surface, the position of that float detected magnetically by three sensors, one measuring its continuous position and the other two acting as on/off switches to sense if the float travels to an extreme high or extreme low position:



A completely different way of sensing liquid level is to *infer* it by measuring some related variable. In the next photograph we see a pressure sensor measuring the hydrostatic pressure created by the height of liquid in a vessel, with the product of liquid height and liquid density proportional to pressure:



Like all sensing instruments, these require routine calibration to ensure measurement accuracy.

Temperature sensors

This photograph shows a type of temperature-sensing instrument called a *thermocouple* inserted into a pipe to measure the temperature of the fluid flowing through. Thermocouples are two-wire electrical devices, generating a small voltage signal proportional to temperature:



Thermocouples themselves cannot be calibrated, but the electronic amplification circuits they connect to must be routinely calibrated to ensure measurement accuracy.

Fluid flow rate sensors

The blue boxes you see in this photograph contain electronic amplifiers and other signal-conditioning circuitry used to sense the rate of water flowing through pipes. They are based on the principle of Faraday's Law of Electromagnetic Induction, whereby an electrically-conductive substance moving through a magnetic field develops a measurable voltage proportional to velocity and magnetic field strength. In this case, the electrically-conductive substance is water flowing through a pipe, while a stationary electromagnet coil provides a transverse magnetic field through that pipe. The blue boxes provide power to energize each electromagnet coil, and also signal-conditioning circuitry to sense the induced voltage and translate that into a different type of electrical signal acceptable to a computer-based monitoring system called *SCADA* (Supervisory Control and Data Acquisition):



Here we see the “flowtube” housing the magnetic wire coils and electrodes, through which water would flow:



Like all sensing instruments, these require routine calibration to ensure measurement accuracy.

Water quality analyzers

These precision chemical analyzers are industrial instruments designed to continuously measure physical qualities of water within a water treatment system. For example, the left-most instrument is a *turbidity analyzer* using light to detect the concentration of particulate matter within water, a crude indication of how clean the water is:



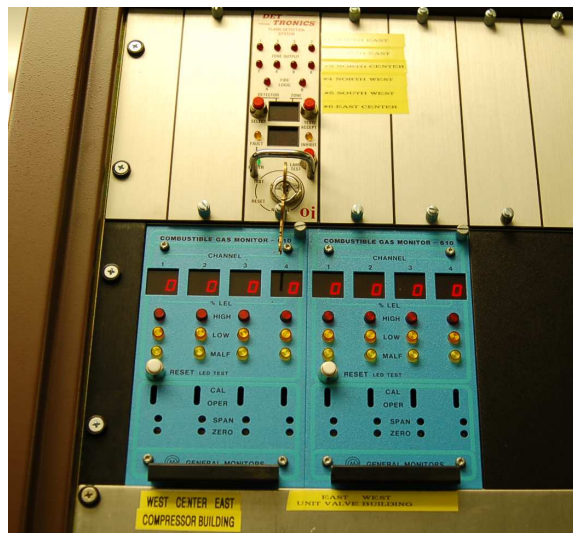
Like all sensing instruments, these require routine calibration to ensure measurement accuracy.

Gas analyzers

Some of the most complex industrial measuring instruments are those designed to continuously measure the physical properties of gases. One such device is called a *gas chromatograph*, using an extremely narrow and long tube to separate different types of molecules from a mixture of gases. In this particular example we see a gas chromatograph used to sense the amount of sulphur compounds present in a pipeline carrying natural gas. Gas chromatographs are extremely complex machines, each one equipped with its own control computer and sophisticated electronic circuits to control and monitor the passage of very small gas samples taken from the process pipeline:



Some gas analyzers exist to detect the presence of hazardous gases in ambient air, such as these combustible gas monitor systems shown below:



The combustible gas units shown in the above photograph are actually the electronic signal-conditioning units for remote-mounted gas sensors, the latter placed close to likely sources of gas leakage or inside of safety-critical areas.

Another common variety of industrial gas analyzer is the *continuous emissions monitoring system* or *CEMS*, built to continuously measure the concentrations of certain gaseous compounds present in exhaust stacks. An example of an analyzer array appears in this photograph, showing multiple analyzer units installed in a common rack, housed inside of a small shelter near the exhaust stacks at a gas-fired power plant:



In addition to being complex electronic devices, these gas-analysis instruments are also complex piping and optical systems too. Their maintenance and troubleshooting requires a high level of skill and technical knowledge spanning multiple disciplines.

Scales and weighfeeders

An important industrial process machine is a *scale*, used to quantify the weight of packages and products on an assembly line. An example of a scale appears here, weighing boxes of breakfast cereal at a baked food production facility:



Closely related to scales are devices called *weighfeeders*, which combine scales with a moving conveyor belt used to measure the flow rate of solid powder or granular materials. Here we see a weighfeeder used to control the feed rate of caustic soda ash into water at a drinking water treatment plant, along with its electronic display screen showing the status of soda ash powder flow:



Scales and weighfeeders alike typically use electrical resistance-based force sensors called *load cells* to convert the force of weight into an electrically-measurable voltage. Amplifier circuits then boost the voltage levels of these small signals to the point where they may be reliably sensed by other electronic circuits. Like all sensing instruments, these require routine calibration to ensure measurement accuracy, consisting of placing standard-weight objects on the scale or belt and making adjustments to the electronic circuits until an accurate measurement is obtained.

Some electronic weighing systems sense the weight of entire storage vessels, as a direct means of determining how full of material it is. Here we see a set of powdered-milk storage bins with force-sensing elements installed at each support column:



A close-up photo of one of these *load cell* sensors reveals a blue cable carrying the multiple wires between the sensing element inside of the load cell (called a *strain gauge*) and an electronic amplifier circuit designed to condition that signal to be appropriate for a measurement or control system:



Vibration monitors

Large rotating machinery in any industrial facility represents a large capital investment which must be protected against self-damage. If something goes awry inside of a large moving machine, one of the most reliable indicators is excessive mechanical vibration. For this reason we often see *vibration-monitoring* sensors and electronic signal-processing circuitry applied to these big machines, designed to automatically shut the machine off and save it from further damage. The following photograph shows a set of electronic signal-processing modules used to condition signals coming from “proximity” sensors monitoring the vibration of a rotating shaft on a large gas turbine engine and gas compressor machine:



A more traditional panel-mounted vibration monitor system with operator-facing displays appears below, designed to measure vibration on another large gas turbine engine at a different facility:



A more modern example of a vibration monitoring system is this “rack” chassis with plug-in cards housing individual electronic circuits for sensor signal conditioning, processing, power supplies, digital communication, etc.:



In the next photograph we see a small electric motor with several “probe” sensors detecting vibrations in the rotating shaft and the motor case:



This apparatus is for demonstration purposes only, but show the ways in which vibration probes are typically installed on a large rotating machine.

Conveyors

A very common type of machine in many manufacturing environments is the *conveyor*. This may take the form of a rubber belt, a “link belt” made of hinged metal sections, or even a vibrating sheet-metal pan that motivates powdered or granular substances along a shallow decline. Here we see two conveyors, one vibrating and one link-belt, used in a baked cereal manufacturing facility:



Conveyors of all types are nearly always driven by electrical power, often a speed-controlled motor where the motor’s speed is varied by a power electronic circuit.

Motor-driven pumps

A *pump* is a machine designed to pressurize and motivate liquid to flow through a pipe. They are ubiquitous in all kinds of industries, including water treatment as shown in the following photograph of three vertically-oriented pumps driven by electric motors:



The motors and the electronic controls sending power to those motors are what an electrical/electronics technician would be responsible for, but like all technical jobs there are inevitable “crossover” areas between disciplines. Even though your job might make you responsible for the care of a motor speed control circuit, you will need to learn what that motor does and how any changes you make to the motor controls might affect the physical process being driven by that motor.

Motor Control Center (MCC)

This is a metallic rack housing circuit breakers, disconnecting switches, relays, and other electrical equipment necessary to safely control AC electrical power to large electric motors:



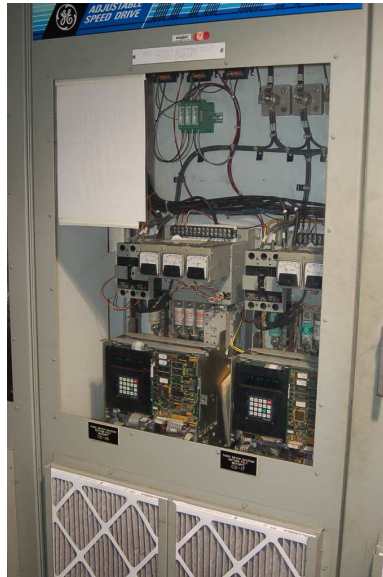
Historically electromechanical in nature, modern MCCs are heavily electronic-based, with electronic motor current monitoring, digitally networked start-stop and speed control for motors, and other features.

Motor speed controllers

Electronic circuits used to control the speed of an electric motor are used extensively throughout industry, the most common variety being a *variable frequency drive* or *VFD* used to control the speed of AC induction-type motors whose shaft speed is governed by the frequency of the AC power driving it. The following photo shows two VFDs rated at about 100 horsepower each:



Different types of electric motors require different types of electronic controls to vary their speed. Here we see a photograph of a large motor speed controller for a *DC* rather than *AC* electric motor. The industrial application here is driving parts of a paper machine which converts wood pulp into sheets of paper:



Closely related to variable-speed controllers are *soft-start modules* used to gently ramp up the speed of a starting motor, as opposed to throwing full power at the motor upon start-up. An example small enough to be held in one hand appears here:



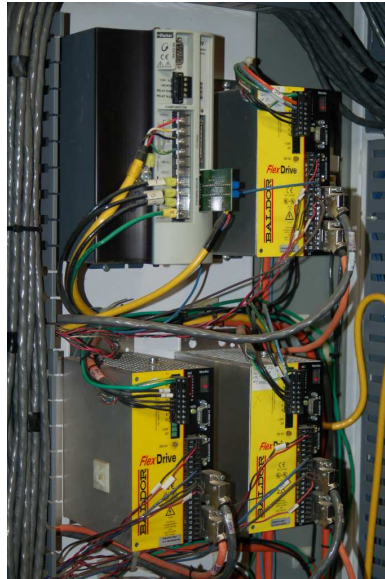
Metering pumps

In contrast to large pumps, a *metering pump* is a very small liquid pump driven precisely by an electronically-controlled solenoid coil or motor, designed to carefully dispense chemical fluids according to some process chemistry need. The following metering pump is used at a water treatment facility:



Servo controllers

A close cousin to the popular variable-frequency drive (VFD) is a *servo motor drive*: a high-power electronic circuit designed to control both the speed and shaft position of a special motor known as a “servo” motor. These special motors are used in robotics and other related motion-control systems. A set of servo motor drive units appears in the following photograph, the drives being located inside of an electrical enclosure while the servo motors themselves are remotely-mounted on the machine they’re positioning, with multi-conductor cables connecting each drive with its respective motor:



Motor-operated valves

A *valve* is a device installed in a pipe designed to control the flow of fluid through that pipe. Many industrial valves are electrically actuated, which means either a solenoid coil or an electric motor provides the operating force to make the valve mechanism open and shut. Here we see a motor-operated valve (MOV) used in a water treatment facility to control water flow through a pipe:



The electronics used within modern MOVs can be quite sophisticated, in some models implementing servo-style control of the motor for precise positioning of the valve mechanism, as well as recording diagnostic data such as motor current which may indicate impending valve mechanism problems like wear and poor seating.

Uninterruptible power supplies

Reliable electric power is absolutely essential for the safe operation of many industrial control systems. If and when utility power gets interrupted by severe weather, equipment failure, or other causes, it is essential that critical safety, control, and lighting systems remain powered so that the processes may be brought to a safe condition, much like the need for an airplane's flight instruments and controls to remain active in the event of an engine failure so that the pilot can bring the plane in for a safe unpowered landing. In the following photograph we see a large lead-acid battery bank used for this purpose at an industrial facility. Not shown here are the numerous electronic circuits responsible for properly charging the batteries, monitoring their charge status, and directing power when needed from the batteries:



Transformers

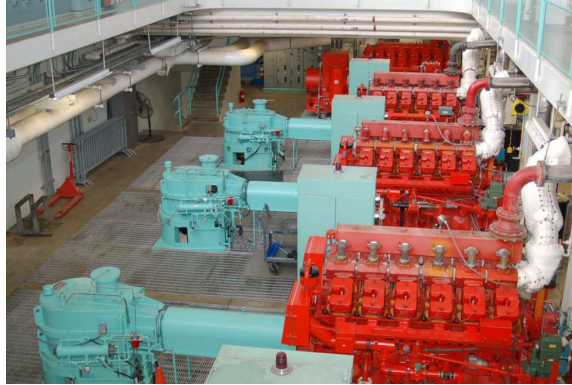
Industries consuming large amounts of electric power often have their own medium-voltage power distribution systems. One type of component found in these power systems is the *transformer*, designed to step voltage and current by fixed ratios. The following photograph shows a rather large transformer at a gas-fired power plant, this one designed to step up 13,800 Volt electricity from a set of turbine-driven generators up to 115,000 Volts for distribution:



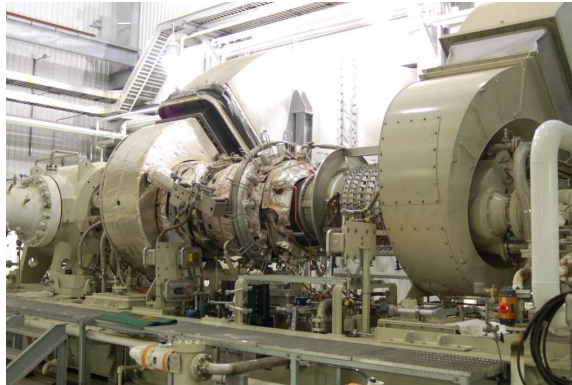
Although transformers have no moving parts, they nevertheless require periodic maintenance and troubleshooting. Maintenance often entails monitoring the chemical composition of their internal oil fill fluid, calibrating temperature sensors and temperature switches, occasionally re-wiring “tap” settings on the windings to compensate for changes in power system loading, etc.

Engines

Some industries use large stationary combustion engines as sources of mechanical power. In the following photograph we see a set of engines (colored orange) driving large vertical-shaft wastewater pumps at a large municipal wastewater treatment facility. These particular engines happen to be fueled by methane gas generated at the facility, which is an excellent example of practical energy recovery on an industrial scale:



Here we see a single 13,500 horsepower gas turbine engine, used to drive a gas compressor machine at a facility designed to boost the pressure of natural gas fuel within pipelines for long-distance distribution to points of use:



Industrial engines require substantial electronics for monitoring and control, just like modern automobile engines use electronic controls for purposes such as air/fuel ratio modulation, over-temperature detection, speed control, etc. Additionally, large industrial engines usually are equipped with exhaust emissions monitoring, vibration monitoring, and other controls not typically seen on automobiles.

Burner management systems

Combustion-based processes are common in industry, and with them come a set of well-understood hazards. In order to mitigate these hazards, specialized *burner management system* electronic packages have been developed to control the opening and closing of air and fuel valves, starting and stopping of blowers, energization of spark plugs, and monitoring of flame sensors. An example of one of these “BMS” electronic controllers is shown below, installed on a natural gas-fueled heating boiler for a small commercial building:



In addition to central control modules such as shown above, there also exist peripheral electronic amplifiers and other units designed to condition signals from flame sensors. An example of a flame sensor amplifier appears below:



Some examples of combustion-monitoring sensors appear in this next photograph (connected to the amplifier circuitry by armored cables), which happens to show their installation on a boiler fueled by sawdust from a wood mill:



Electrostatic precipitators

Industrial processes that release particulate pollution (e.g. soot) must operate with some sort of filtration on their exhaust stacks in order to meet environmental emissions requirements. One popular technology for “scrubbing” such particulate pollution from exhaust gases is called an *electrostatic precipitator*, using grids of wires energized with high voltage DC electricity. The high voltage causes dust and other particles to stick to the wires, which are then periodically washed clean by jets of water. An example of an electrostatic precipitator is shown here, the body of the vessel being made of (electrically insulating) fiberglass rather than metal:



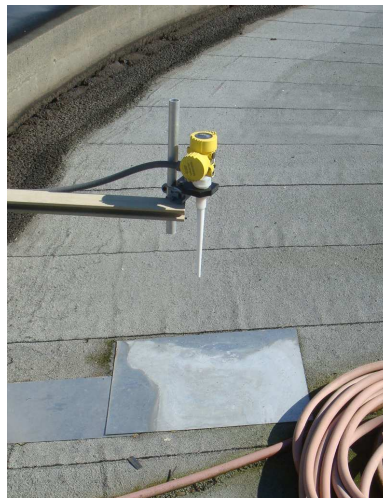
The high-voltage power supply and control circuits, as one would expect, require regular maintenance and troubleshooting.

Storage tanks

Industries focused on fluid processing often require large storage tanks to hold quantities of raw material or product fluids. Oil refineries are a good example, evidenced by this aerial photograph of a small oil refinery with several storage tanks in plain view:



At first it may seem as though a storage tank is too simple a structure to require any electronics, but this is not the case! We must sense the level of fluid filling any tank, in order to know if we are about to over-fill it or run empty. Many technologies exist for this, but a popular modern option is to use an electronic *radar* sensor to detect liquid level, firing bursts of microwave-frequency radio energy downward at the liquid's surface (or at the top of the floating roof on a floating-roof storage tank) from above and measuring the echo time, which indicates the “ullage” value of the tank, which when subtracted from the tank's known total height will yield the “fillage” value. A photograph of a radar tank level sensor is seen here:



An older tank level-sensing technology that still uses electronics employs a float connected to a long metal tape or cable, the motion of that float causing the cable to turn a small drum. The angular position of that drum is then monitored by electronic sensors and reported as a height (fillage) level for liquid in the tank. This next photograph shows one of these float-and-tape electronic sensing instruments:



Data acquisition systems

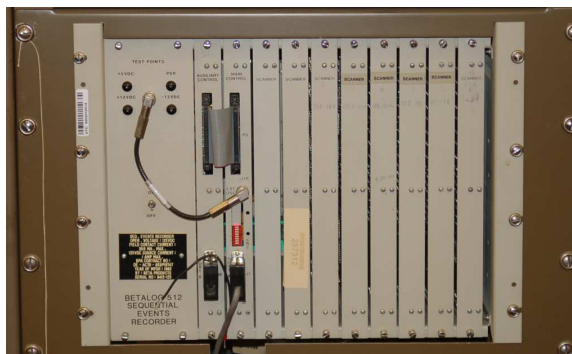
A “data acquisition system” or *DAQ* is a special form of industrial computer used to monitor, record, and/or output electronic signals. There are many different types and models and manufacturers, an example of one shown below. This happens to be a National Instruments model made from different modules plugged into a “CompactRIO” chassis:



Note the signal types represented by each of the plug-in “I/O” (Input/Output) modules installed in the CompactRIO chassis. From left to right, we see a ± 10 Volt analog output (AO) module, a ± 10 Volt differential analog input (AI) module, a 2-port serial CANbus module, and a four-channel ± 5 Volt analog input module with high signal bandwidth capability. A DAQ unit thus configured might be used to acquire data on a vehicle chassis, such as from accelerometers (into the four-channel input module) sensing vehicle vibration, the CANbus module interfacing with engine or drivetrain control computers, the other analog input module sensing vehicle battery voltage, etc.

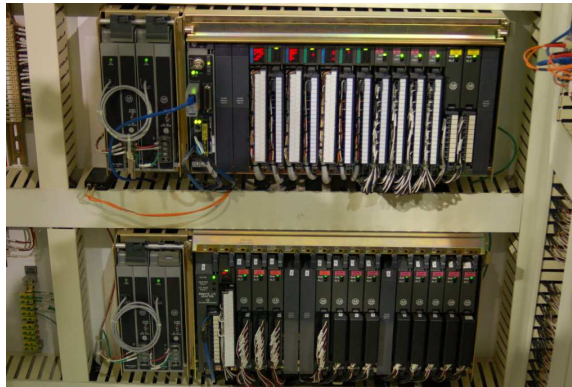
High-speed data recorders

An interesting type of specialized computer is the *high-speed data recorder*. These are used to collect data from sensors used in scientific experiments as well as “fault” events in complex systems such as electric power grids. They function much like DAQ systems only with an emphasis on accurate data collection over very fast sample rates, and usually with “timestamp” data associated with each measurement point. An example of a legacy high-speed data recorder for electric power grid applications appears here:



Programmable Logic Controllers

A “programmable logic controller” or *PLC* is a special form of industrial computer that is so popular it deserves its own category. Designed to be programmed by technical staff more familiar with hardware than software, these computers typically use a programming language called “relay ladder logic” which is graphical in form, resembling the wiring diagram of an electromechanical relay-based circuit. PLCs are *ubiquitous* throughout industry, with some technician jobs specializing in their programming, maintenance, and troubleshooting. This particular PLC happens to be an Allen-Bradley model PLC-5:



PLCs are especially designed to interface with a great many discrete and/or analog electronic devices such as sensing switches, relays, indicator lamps, analog sensors, etc.

Industrial computers of all types, but especially PLCs, are built to operate for years on end without rebooting. They have no moving parts (e.g. processor cooling fans or hard disk drives) to wear over time, and for this reason are extremely reliable and long-lived. The PLC-5 shown in the above photograph was actually over twenty years old at the time the picture was taken!

A more recent model of Allen-Bradley PLC is shown here, a Logix5000 model used to control servo motors at a wood-cutting mill:



Distributed control systems

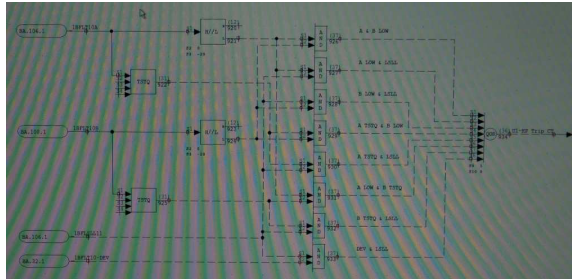
A “distributed control system” or *DCS* is a set of networked industrial computers designed to control critical processes with a very high level of reliability and redundancy. The “distributed” part of the name refers to the fact that control algorithms are running on computing hardware placed physically near the process(es) being controlled, with network cables conveying only supervisory data so that any cable failure does not cause a controller to “crash” the process it’s charged with regulating. Each controller node typically has redundant processors and redundant power supply modules for extra reliability in the event of hardware failure. The following photo shows an Emerson “DeltaV” DCS node with redundant processor and power supply modules:



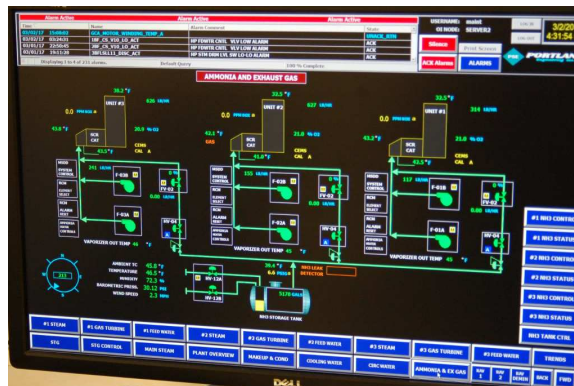
Another photograph shows a much larger-scale DCS, also consisting of electronic modules plugged into a rack:



Programming of DCS systems usually takes the form of a graphical “function-block” language, one example shown in the following photograph showing a programming screen for the Bailey Infi90 DCS shown in the previous photograph:



Operator interface displays for a DCS are often highly colored pictorial representations of the process equipment being controlled, with point-and-click mouse-driven “buttons” for commands. We see an example of this in the following photograph of a DCS display screen at a gas-fired power plant:



Green lines on this display represent pipes, connecting between vessels, other structures, pumps, and control valves at the power plant.

SCADA remote terminals

Specialized industrial computers designed to be located close to their physical processes, conveying digital data over wired or radio networks to some central location, are often labeled with the very loose term *SCADA*, which stands for *Supervisory Control And Data Acquisition*. Those SCADA nodes located close to processes are called Remote Terminal Units, or *RTUs*, while the node(s) located at the central operations facility are called Main Terminal Units or *MTUs*. Below we see a photo of a SCADA RTU formerly used for monitoring conditions at a natural gas wellhead:



There is little standardization between different SCADA system vendors and models, which means programming languages and RTU/MTU capabilities vary widely from application to application. Some SCADA nodes support multiple programming languages, such as the Fisher model ROC800 RTU shown here, which allows programming in *five* different languages (Ladder-Logic Diagram, Sequential Function Chart, Function Block Diagram, Structured Text, and Instruction List, all defined within the IEC 61131-3 engineering standard) for maximum end-use flexibility:



Another example of specialized SCADA hardware is this equipment rack located in a large electric power substation:

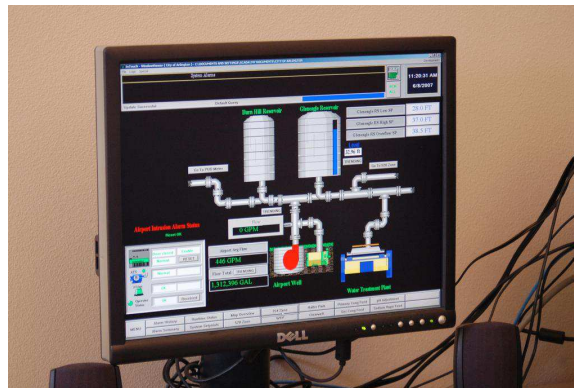


Yet another example of a SCADA node is this Motorola unit, used in a municipal water treatment facility:



SCADA operator station

In terms of hardware, this is just a personal computer running special SCADA software designed to interface with SCADA hardware throughout the facility, in this case water flowmeters and pumps as part of a wastewater treatment system:



General-purpose industrial computers

Even so-called “general-purpose” computers using the same architecture and chipsets as consumer-grade personal computers have a different look and build quality in industry. Unlike personal computers which are designed for short life (i.e. planned obsolescence) and low cost, industrial PCs are designed for very long life and high reliability. As such, they often use solid-state hard drives rather than magnetic hard drives with rotating disks, and they are often “fanless” as well to avoid one more point of potential mechanical failure. They are also commonly rack-mounted rather than placed on a desktop as is typical with personal computers:

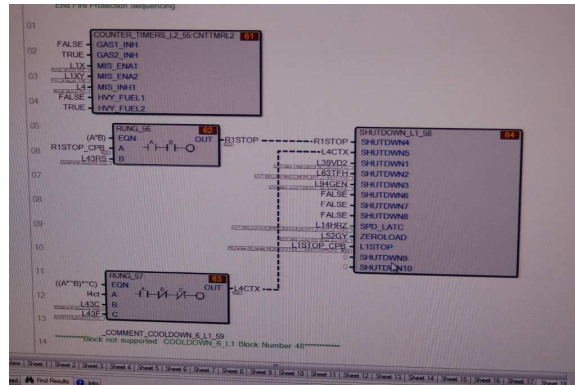


Special-purpose computer controls

Some types of process equipment are specialized enough to merit their own proprietary control systems. One such example is this General Electric “Mark V” turbine control system, consisting of multiple redundant control computers (each one in its own stainless-steel enclosure):



Here we see a screenshot of the function-block-based programming used in the Mark V system:



Unlike general-purpose computers or programmable logic controllers, a proprietary computer built for one purpose may be aggressively optimized for that application. Optimization parameters may include specialized features, signal-processing speed, advanced algorithmic controls, and/or special redundancy schemes for attaining extremely high levels of reliability. Some special-purpose control systems provide very little end-user programmability precisely for the reason of avoiding problems an end-user might introduce into the system with poorly-written code, and/or with too much access to the control system's resources.

Operator panels

Although most modern operator-interface systems use personal computers, keyboards, “mouse” pointers, and video screens, there still exist many steel-panel interfaces where individual electronic devices mount into holes cut in the panel. These custom-made panels are rugged, and are often a more intuitive user interface than menu-driven graphical displays. The photograph below shows an operator control room panel in a cement manufacturing factory:



By contrast, modern computer-based operator controls usually take the form of multiple monitors, keyboards and “mouse” devices arranged around desks, as seen below in this photograph from a gas-fired power plant:



Since these computer workstations are responsible for critical system operations rather than typical business office applications, their routine maintenance, upgrading, and software patching is usually handled by the same technicians who do other electronic system maintenance at the facility, as opposed to more traditional IT (Information Technology) personnel.

Land-line data communication systems

SCADA and other long-distance data systems require highly reliable methods of data communication between far-flung hardware nodes. Electric power systems are an excellent application, as SCADA nodes separated by hundreds of kilometers must communicate quickly and reliably. Specialized data communications equipment exists for such applications, an example being these communications equipment racks installed at a large electrical substation facility:



Microwave data communication systems

For many “long-haul” voice and data systems, an alternative to land-based copper cable and optical fiber data communication is microwave radio, using extremely high-frequency “carrier” signals to beam modulated data over long distances between antenna structures, usually located on mountaintops and other high locations. In the left photograph we see a cluster of large microwave antennas, some of which are used as part of an RF communications “backbone” for certain public services communications (e.g. law enforcement, health care, etc.), and on the right we see a group of Nokia brand microwave transceiver units at the base of a smaller antenna structure used to convey voice and data for a public power utility:



Radio broadcast systems

General public radio services, such as AM and FM broadcast, shortwave transmissions, and the like, have their own antenna structures and electronic hardware. Below we see an antenna structure with an array of FM broadcast antennas along one side:



Below we see a common set of equipment for remote-located broadcast antennas called *STL*, which stands for Studio-to-Transmitter Link. A broadcast studio plays the audio information it desires to broadcast, but if the transmitting antenna is located far from the studio for any number of reasons (e.g. poor location, zoning restrictions, proximity to airports, etc.) the system may be set up in such a way that the studio uses a small directional antenna to transmit that data to a small receiving antenna at the main antenna site, where the STL equipment at that site receives the STL signal and repeats it to a large RF transmitter unit which then sends the modulated audio signal to the main antenna. In this photograph we see legacy-generation Marti STL equipment (top) mounted in the same rack as newer-generation NiCOM STL gear:



Next we see an example of a rack-mounted 100 Watt FM radio transmitter, located inside of a shelter at the base of a commercial FM broadcast antenna:



An even larger FM exciter and power amplifier unit appears in the next photograph, with a maximum rated RF power output of 22,000 Watts. This particular unit occupies the entire 19-inch wide rack frame and stands over 2 meters in height:



Industrial data radio systems

Many industrial monitoring and control systems require radio communication over relatively short distances (e.g. a few kilometers or less), and for applications such as this there exist special-purpose radio transceivers capable of relaying digital data such as serial and Ethernet data frames. An example of an industrial radio transceiver in the form of a small circuit board with connectors for data and antenna is shown here:



Another form industrial radio communications often takes is radio transceivers built directly into the field device, rather than as an interface between some field device and a central host. Consider the following example of a *temperature transmitter* which receives an electrical input from a temperature sensor such as a thermocouple or an RTD and broadcasts the temperature data via its black-colored antenna:



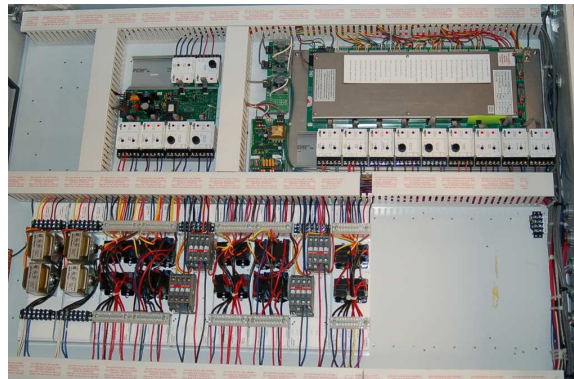
Most industrial radio systems operate in an *unlicensed* band of frequencies such as 900 MHz (in the United States) or 2.4 GHz (international) and at low power which means no FCC licenses are required to install or operate them.

Building environmental controls

Large buildings often require specialized electronic monitoring and control systems for such parameters as air temperature, air pressure, illumination, humidity, and gas concentration (e.g. CO₂ monitoring). In this photograph we see specialized computing and signal-conditioning modules used as part of the HVAC (heating, ventilation, and air conditioning) system of a large public building:



Below we see another photograph of an environmental control system, but this one is specialized for the control of *greenhouses*, made by Argus. This particular example is used at an agricultural research facility where experiments are run on plant growth:



Protective relays

A “protective relay” is a special-purpose electromechanical or electronic apparatus designed to sense abnormal conditions in an electrical power network and take automatic action such as tripping or closing a power circuit breaker. The following photograph shows a panel full of protective relays, part of the relaying system at a small gas-fired power plant:

**Electrical switchgear**

Electrical devices used to route and interrupt the flow of electricity for large-scale “grid” applications such as electrical substations are generally referred to as *switchgear*. While much of this equipment is electromechanical in nature, increasingly we see more electronic hardware integrated into circuit breakers, current sensors, voltage sensors, and other switchgear equipment. The following photograph shows one area of a 230,000 Volt substation operated by Bonneville Power Administration:



High-voltage testing apparatus

While this is an admittedly unusual work environment, it shows the breadth of jobs in which an electronic technician may find employment. The devices seen in the following photograph are part of an ultra-high voltage testing laboratory operated by Bonneville Power Administration, controlled and monitored by many electronic systems. Technicians are responsible for the maintenance and setup of these electronic systems as well as for some of the larger apparatus handling the actual high voltage:



3.5.2 Electronic test equipment

Digital multimeter

Perhaps the most common piece of electronic test equipment is the *digital multimeter* or *DMM*, a measurement device designed to accurately measure such electrical quantities as voltage, current, resistance, and quite often many more in addition:



This is generally the very first piece of test equipment that an aspiring technician learns to use. Many different models exist, some with highly specialized capabilities.

Bench-top models exist as well, generally more accurate than hand-held multimeters and often sporting features such as four-wire resistance measurement rare to find on a hand-held DMM:



Power supply

Somewhat of a misnomer, a “power supply” is an electronic circuit converting AC “line” power from a wall-mounted power receptacle into electricity suitable for powering electronic circuits directly:



Precision source

Similar to a power supply is a device called a *calibrator* or *precision source*, designed to output highly accurate amounts of voltage or current at the demand of the user, usually DC and/or low-frequency AC. Rather than provide electrical power to a circuit under test, however, a precision source is designed for *calibration* purposes, generally testing a measurement device to verify that it properly indicates the applied voltage and/or current:



Since precision sources are relied upon as standard references for voltage and/or current, they must be periodically calibrated themselves against some other standard reference with a higher degree of accuracy. An example of one of these higher-caliber precision sources is this Fluke model 5730A calibrator:



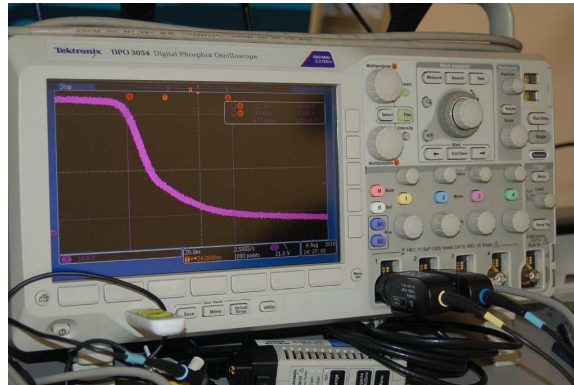
Signal generator

A *signal generator* or *function generator* outputs AC voltage signals at user-defined frequency and amplitudes, useful for many types of electronic tests.



Oscilloscope

This is an instrument capable of plotting voltage as a function of time, useful for analyzing AC and transient (pulse) signals:

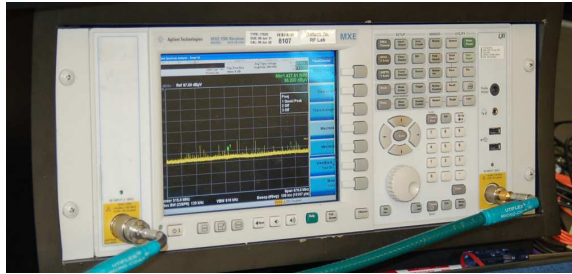


While most oscilloscopes are made for bench use, hand-held models also exist, and are quite popular for field use in industry:



Spectrum analyzer

This is an instrument similar to an oscilloscope, except instead of graphically plotting a measured voltage over time, it plots voltage as a function of *frequency*. These are highly useful in audio and RF signal testing applications, where complex signals are generally a mix of different frequencies.

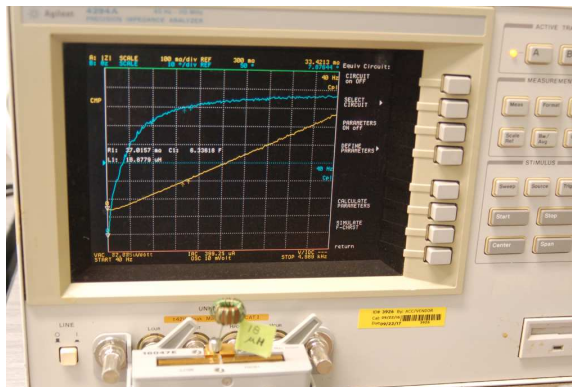


LCR meter

An “LCR” meter is a test instrument measuring inductance (L), capacitance (C), and/or resistance (R). They are especially useful for measuring components exhibiting two or more of these phenomena:



A very similar instrument called an *impedance analyzer* displays graphs of parameters such as resistance, reactance, impedance, phase angle, and others over a range of specified test frequencies. Here it is measuring the impedance of a custom-made inductor:



Vector network analyzer

A *vector network analyzer* or *VNA* is a high-frequency signal source and measurement tool built as one, capable of energizing components or networks of components with high-frequency AC signals and then analyzing the reflected or transmitted signal strengths to characterize the component or network. They are useful for measurement tasks such as impedance, phase shift, filter attenuation, etc. This particular unit uses a personal computer as the display console:



Service monitor

A *communication service monitor* is a specialized tool used for work with analog radio transceivers, capable of transmitting and receiving signals useful for the diagnosis and alignment of radio units. Here, a service monitor is being used to receive a broadcast FM radio signal at 98.5 MHz, playing the audio over a speaker while showing the RF spectrum on a small cathode ray tube display:



Electronic load

This is like a power supply in reverse: instead of supplying power to a circuit under test, an electronic load *receives* electrical power from a circuit under test. An electronic load is analogous to a dynamometer used to place an automobile under realistic load while not driving down a road. The electronic load may be configured to draw a specified amount of current, or dissipate a specified amount of power. These are very useful for testing power supply circuits:



Power quality meter

This is a special-purpose meter designed to measure parameters uniquely applicable to AC power systems. Measured parameters include phase angles (for three-phase circuits, as shown), peak voltage, RMS voltage, peak current, RMS current, harmonic content, minimum voltage (sag), and maximum voltage (rise). A Fluke model 435 power quality meter appears below:



Logic probe

A photograph²⁶ of a logic probe appears below, revealing a metal-tipped probe for sensing the logic state of a terminal, plus red and black alligator clips designed to connect to the circuit under test for powering the probe's internal circuitry and providing a ground reference for the sensed logic signal:

**Logic analyzer**

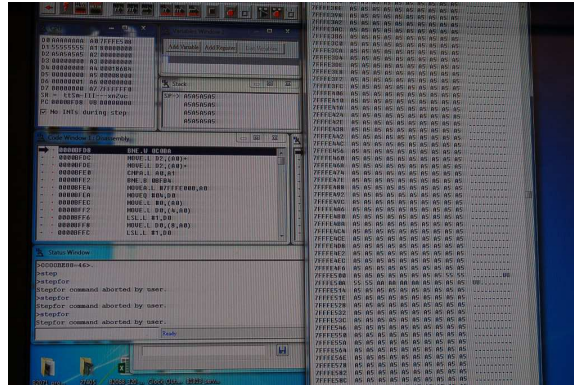
A *logic analyzer* is to an oscilloscope what a logic probe is to a voltmeter: an instrument designed to show voltage levels as digital logic states rather than as analog signals. Since each channel of a logic analyzer need only show “high” or “low” rather than precisely resolve the sensed voltage as an analog measurement, it is a simpler instrument to manufacture. This permits logic analyzers to be built with a great many input channels, many more than what is common with an oscilloscope.



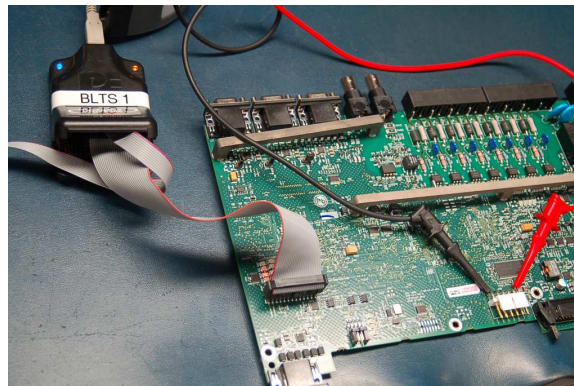
²⁶This photo is courtesy of *Plusca* who posted it to the photo-sharing website Flickr under the Creative Commons Attribution-only license (version 2).

Microcontroller “debugger”

This is a collection of computer software and interface hardware allowing a personal computer to monitor the memory contents of a microcontroller (a small “embedded” microprocessor used within many electronic products). Examining memory contents is necessary for diagnosing certain types of faults, as was the case here where the debugger was used to identify a wiring problem on the address lines of a memory circuit:



Here we see the *JTAG* interface connecting the microcontroller (located on the green-colored printed circuit board) to the personal computer:



Specialized communicators

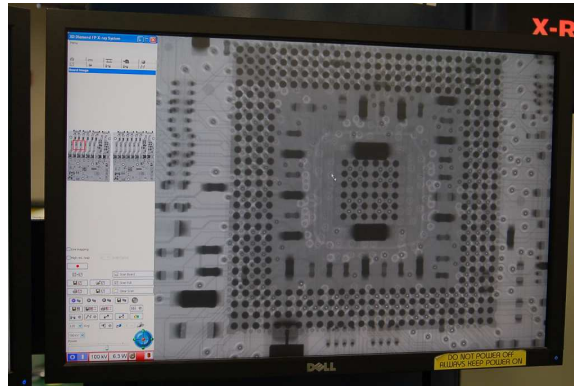
Some types of electronic equipment need to be configured or programmed using specialized interface terminals. Below we see an example of this, known as a “HART communicator” which uses the digital/analog hybrid HART communication standard:



This particular HART communicator is being used to configure an electronic control module for an industrial control valve.

X-ray camera system

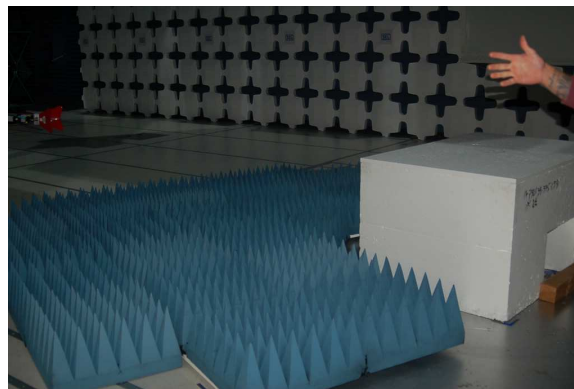
In order to identify certain faults within integrated circuits and on printed circuit boards (PCBs), an X-ray camera may be necessary. The following photograph shows the monitor display of such an X-ray machine, the board being placed inside the machine where shielding protects the user from X-ray radiation exposure:



Since the electronic device being scanned is not harmed by the low-power X-rays, the X-ray radiation may be kept on while the X-ray camera rotates and moves around the board to provide the desired views. Thus, what you see on the screen is a *live* X-ray view of the board, rather than a frozen image.

RF testing chamber

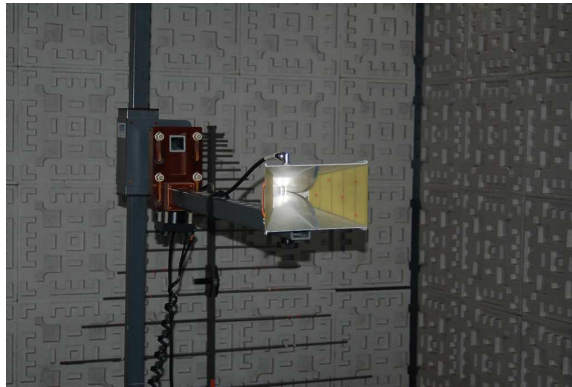
In some cases the “test equipment” necessary for certain tests includes the room itself. In the following photograph we see a large “RF testing chamber” lined with RF-dissipating tiles and electrostatically shielded so as to block radio-frequency energy from the outside world. Inside this room you would place equipment to be tested, and use special antennas to measure its RF emissions. Such emissions testing are required for FCC certification of new electronic products:



The blue foam “spike” panels are additional RF-dissipating elements which may be strategically placed around certain equipment as part of a comprehensive RF emissions test.

RF exposure chamber

Another form of radio-frequency (RF) equipment testing is *exposure testing*, where electronic devices are intentionally exposed to high-power RF energy fields to ensure they will continue to operate correctly under these adverse conditions. Rooms built for this purpose are typically smaller than RF testing chambers, and more heavily shielded because they contain much greater RF signal strengths than in testing (measurement) chambers. A photo showing a directional antenna inside of an RF exposure chamber is shown here:

**Faraday chamber**

Another special room intended for certain types of electronic testing is a *Faraday chamber* built simply to shield equipment inside from external sources of electric fields and relatively low-frequency RF energy sources while non-RF tests are done on that equipment. The room is surrounded on all sides (including the floor) with close-weave copper wire mesh connected solidly to Earth ground. Electric power wires pass through a special filter network to prevent unwanted RF energy from being carried into the room through those power conductors:



RF power testers

In order to test the output power of an RF source such as a radio transmitter, special power-measurement instruments exist for the purpose. These include the meters themselves (left) as well as “dummy” loads (right) for the RF source to energize:



Chapter 4

What Makes You Marketable?

The longer I live, the more respect I gain for the field of Economics. Economics is not just the study of money, but it is the study of risk and reward, of cost and benefit, of consequences both intentional and unintentional. Underpinning most economic theories is the belief that people generally act in their own self-interest, and that the actions of many people individually following their own self interest constitute complex economies. This unflattering yet honest view of human nature helps explain a great many things, not the least of which being those qualities which will secure a career for you in the field of electronics.

Every business relationship is a *mutually beneficial contract*. Employers offer financial compensation and benefits in exchange for the employee offering their knowledge, skill, and labor. Like all commodities, expertise is valued in proportion to its demand and inversely to its supply: this is the *Law of Supply and Demand*. That is to say, the only reason an employer pays a premium wage is for an employee offering something that is both necessary for the enterprise *and* rare to find. This is the zone you want to be in to maximize your earning potential: whatever is in high demand *and* low supply. The same is true for the self-employed, but on a more granular scale. Instead of working under the terms of a single long-term contract, the entrepreneur earns their living by establishing separate contracts of mutual benefit with different clients, but the underlying economic principle remains unaltered: the only reason a client pays a premium for some good or service is if that good or service is both necessary to them and rare.

The question of what makes a technician valuable in a free-market economy is therefore a matter of leveraging supply and demand. Simply put, you want to create for yourself a set of skills and professional habits that are both necessary and uncommon. It is here we find another important principle of economics helpful to our understanding of value in the labor market: *human capital*. Simply put, human capital is the sum total of all knowledge, skills, abilities, habits, and traits enabling a person to optimize their own quality of life. The value of human capital varies with environment: the knowledge, skills, abilities, etc. which make a person able to survive in the wilderness with nothing more than the clothes on their back, for example, varies greatly from the set of knowledge, skills, abilities, etc. that enable success as an accountant. Within any particular career there will be a particular set of knowledge, skills, abilities, etc. considered valuable and worthy of compensation, because the nature of compensation for work is that the employer pays for the privilege of enjoying the employee's human capital.

Human capital, more than any other reason, explains why some people get compensated more than others. To be sure, some people find themselves in jobs that either pay well above or well below their own human capital by accident, but on the average this is not how compensation works in a free market. Where workers are free to apply for and accept other jobs, people tend to move where they will be best compensated: an under-paid employee will find a better job, and an over-paid employee will eventually get replaced by someone willing to work for less pay. When companies suddenly go out of business and lay off all of their employees, it is striking to note how closely those employees' new jobs mirror their old both in scope and compensation. If compensation were merely a function of luck, you would see most peoples' circumstances change after a layoff like the ordering of playing cards in a well-shuffled deck. Instead, you see most of the richly-paid people finding new high-pay jobs, and most of the poorly-paid people finding new low-pay jobs. What makes this difference is the human capital carried by each person.

While certain aspects of human capital can be career-specific, others are quite general. *Inattentiveness*, for example, is a deficit no matter what one's station is in life: an inattentive wilderness adventurer is less likely to survive just as an inattentive accountant is less likely to properly balance the credit and debit balances for a company. *Intelligence*, as another example, is a trait positively associated with success no matter the environment. It lies within your own best interest to identify which aspects of human capital are most associated with success in your environment, specifically within electronics-related careers, and work to improve those aspects you can.

Here are some specific aspects of human capital considered valuable in most careers, listed in no particular order:

- **Integrity** – being honest and forthright in your work, so that people will trust you to do your job. Trust is the lifeblood of any relationship, and this includes business relationships.
- **Curiosity** – wanting to know *how* and *why* things work is key to solving challenging problems and staying abreast of new developments. Young children are naturally curious creatures, but a great many people lose their sense of curiosity as their interests drift toward baser concerns.
- **Attention to Detail** – details usually matter, especially within technical careers. Typographical errors, skipped steps in procedures, and other “small” oversights can cause big problems.
- **Conscientiousness** – making sure the job is done correctly, every time. This requires a certain degree of humility in recognizing one's own capacity to make mistakes, and habitually double-checking your own work as a direct consequence of that recognition.
- **Persistence** – not giving up when faced with challenges.
- **Resourcefulness** – being able to make good use of whatever resources one happens to have to get the job done. The opposite of this is someone who can only function within an optimum environment and access to ideal tools.
- **Communication** – the ability to express complex ideas in clear language. At the root of effective communication is the ability to perceive how others will interpret what you say and write. This is why checking assumptions and considering alternate viewpoints are useful habits for good communication.

- **Initiative** – not needing to be told what to do, but self-starting on necessary tasks. The value of this from an employer’s perspective should be obvious: the more self-directed an employee is, the less work it is to oversee them. For an entrepreneur whose livelihood depends solely on their own effort, initiative is absolutely essential.

As an instructor at a technical college, I enjoy a privileged view on the aspects of human capital valued by employers because employers routinely contact me to find qualified technicians. I have witnessed interviews conducted by employers visiting the college, served as a reference for graduates applying for work in this field, received feedback (both good and bad) from both graduates and from employers, and served on numerous committees where employer recommendations were taken to either build new technical education programs or improve existing programs.

When employers contact me to inquire about a graduate they are considering for hire, the first metric they want to know is that person’s *attendance record*. At first this may seem odd, as class attendance has nothing to do with technical knowledge or skill. However, it is a crude indicator of *work ethic*. Someone who is habitually late or absent is most likely not a motivated individual, and will therefore make a poor employee regardless of knowledge or skill. Simply put, good attendance is a remarkably valid indicator of some of the most important aspects of human capital for this field.

It surprises many students to hear that employers are generally disinterested in grades, but are much more interested in details of their performance such as resourcefulness, interpersonal communication, teamwork, and curiosity. Employers understand that many factors unrelated to human capital may affect course grades, and that this is especially true for adult students balancing demands of family, part-time career, and other obligations common to adult life.

My job as an instructor also gives me a privileged view on the various expressions of human capital in student performance, because my position allows me to correlate student performance with career performance: after closely observing students for the better part of a calendar year, I get to see who does better in their new careers. These observations have taught me to pay close attention to the following “red flag” indicators when exhibited by students:

- **Failure to heed schedules** – when a student fails to note what date a class begins on, when the class meets, and where on campus it is located, it almost always indicates future problems securing employment. When all this information is clearly shown on the student’s class schedule, such failures point to a lack of attentiveness and self-discipline which dramatically reduce one’s human capital in this field.
- **Inability to work alone** – coursework requiring students to independently complete certain tasks are excellent indicators of employment readiness. The task itself need not be complex, just something with a firm deadline, and something requiring solo planning and effort. Early indicators include assembling a collection of personal tools and writing a résumé.
- **Inability to work with others** – coursework requiring students to complete tasks as teams also serve as excellent indicators of employment readiness. Regardless of how a person rates themselves as a “team player”, the truth becomes manifest when they must actually work with other people to achieve a shared goal.
- **Excuse-making** – people who habitually present excuses for their lack of accomplishment

are people who do not accept responsibility for their actions. They believe trying is all that counts, which will come as a rude awakening when they *try* to find a job.

- **Absences without contact** – all students, adult students especially, will need to miss class from time to time for reasons of illness, important appointments, emergencies, etc. The mere fact of absence itself is not necessarily a problem, but I always make clear to students the importance of contacting their instructor as well as their teammates by the start of class if they know they will be absent. The practical reason for this is so that their team can shift their work plan based on an estimate of when their absent teammate will return. The need for contact in case of absence has proven to be a reliable indicator of a student’s sense of personal responsibility: responsible students have no problem making prior contact, irresponsible students typically make contact late or not at all.
- **Procrastination** – this is when a student knows when work is due, but waits until the last minute to complete that work. This is an example of poor judgment, as any human being old enough to attend college is old enough to expect the unexpected in life: unforeseen events are simply *inevitable*. Waiting until the last minute invites failure, because procrastination naively assumes the unexpected will never occur.
- **Addictive behavior** – it is the nature of an addiction to control a person’s behavior, to override rational judgment, to hamper their ability to function in a healthy way, all in a single-minded attempt to satisfy the craving. Substance abuse is just one form of addictive behavior, but there are many others: people may be addicted to social media, computer gaming, gambling, eating, melodramatic relationships, frivolous spending, etc. Addictions severely degrade human capital because of their all-consuming nature.
- **Emotional outbursts to classmates** – sadly, I have witnessed this behavior in students of *all* ages, and it never bodes well for their career success.
- **“But I’m a different person outside of school!”** – when a student exhibits poor habits, such as failing to arrive to class on time, failing to take initiative, etc. and when confronted they claim this sort of problem *only occurs in school* but never in any other context, it is a *guaranteed* sign of future trouble. This person not only lacks important facets of human capital, but is unwilling to admit as much and therefore will do nothing to remedy their deficit.
- **Entitlement attitude** – this can take many forms, but whenever a student implies or declares they *deserve* something, it is usually a sign of trouble. At the risk of offending readers, let me make the following point crystal-clear: *anything you enjoy in life is either received as a gift, or it has been secured by someone’s hard work – absolutely nothing is deserved*. Even things as precious to modern civilization as human rights and the rule of law aren’t really entitlements at all: they are values for which *some* people are willing to fight to maintain, and *will* be lost unless enough people exercise and fight to maintain them. Entitlement seeks unilateral benefit, not mutual benefit. Nobody wants to work with such people, and most supervisors are particularly skilled at detecting this undesirable trait because they have had to suffer its consequences on the job. I have witnessed interviewers repeatedly (and accurately) detect entitlement attitudes in student applicants, and so I can say with confidence that this trait is responsible for a large number of failed attempts to get hired.

When I witness graduates who struggle to succeed in their chosen careers, it is rarely due to a lack of intelligence, knowledge, or skill. Career trouble usually stems from a deficit in the “softer”, non-technical elements of human capital. Anyone choosing a technical career needs to bear this in mind, and begin working to improve their “soft skills” wherever possible. A good educational program for this field directs students’ attention to *all* aspects of human capital necessary for career success, but ultimately things such as poor habits cannot be undone without the individual’s full consent and focused effort.

Employer surveys are useful sources of information for identifying specific aspects of human capital valued in jobs. Consider the results of the January 2013 Washington State Workforce Training and Education Coordinating Board’s survey gathering input from over 2800 employers in the state of Washington spanning a range of industries. One of the questions asked by this survey polled employers for areas of difficulty they had experienced with new employees (i.e. people freshly graduated from school):

Knowledge/Skill Area	Percentage experiencing difficulty
Solve problems and make decisions	50%
Take responsibility for learning	43%
Listen actively	40%
Observe critically	38%
Read with understanding	32%
Use math to solve problems and communicate	31%

This data tracks well with national surveys, including the Manufacturing Institute and Deloitte Development LLC’s 2011 survey polling 1123 employer respondents with a very similar question (“*What are the most serious skill deficits in your current employees?*”):

Knowledge/Skill Area	Percentage experiencing difficulty
Inadequate problem-solving skills	52%
Lack of basic technical training	43%
Inadequate “soft skills” (attendance, work ethic)	40%
Inadequate computer skills	36%
Inadequate math skills	30%
Inadequate reading/writing/communication skills	29%

Do you see any patterns here? Obviously, general problem-solving is a deficit for *approximately one-half of all new employees*. Communication (listening, reading, writing) is also problematic, as is mathematics. Lest anyone think that the 36% dissatisfaction rate for computer skills is generational, believe me when I tell you they aren't referring to social media or computer games here: the computer skills I've seen employers demand are things such as *spreadsheet use, word processing, design software* such as CAD, as well as general *operating system* use (e.g. archiving files, installing new software applications, uninstalling applications, sharing data on network drives, copying and deleting files). A majority of the incoming students I encounter lack these skills regardless of their familiarity with entertainment-based software such as social media applications and video games.

Interestingly, the 2013 Washington state board survey also provides a sobering statistic regarding on-the-job training. One of the questions on this survey read, "Did your firm provide at least 4 hours of on-the-job training under a written plan for any employees in the last 12 months?" The responses were only 31% yes and **69% no**. You will find that this is fairly typical within industry: technical training opportunities are often few and far between, with the responsibility for ongoing professional development usually left to the employees.

Training is expensive, not only in its direct costs but also in the need to pull workers away from their regular duties to give them time to train. A progressive approach to training sees this expense as an investment, but this is only true if the training is relevant and effective. Far too often the topics of training are limited to those mandated by regulation (e.g. safety, legal, environmental compliance) with few controls to ensure each and every participant gains real knowledge.

Even when an employer has a robust training program for their employees, the topics of training is typically limited to whatever is specifically needed for that employer. The reason for this is obvious: if the employer views training as an investment, then it is in their own interest to get the best return on that investment. This means training on topics that will help the employer first and foremost, and avoiding topics that might make employees more valuable elsewhere (lest they leave and go to work for someone else). For this reason, one should never look toward employer-based training as a sufficient way to advance one's own *career*, but merely to improve skill for the *job at hand*. In order to build your own human capital as broadly as possible, so that you will have employment options beyond your current employer, you will need to educate yourself in ways other than the training offered to you on the job.

The bitter truth about training for technicians is that *you and you alone are responsible for driving your own professional development*. Your employer will provide you with some training, but it will not be sufficient for the development of a full career in this or any other complex field.

You should note that this chapter of the career guide, accurately titled "What Makes You Marketable?", contains nothing specific to the field of electronics. Its advice is entirely generic. While specialized knowledge and skill is no doubt important for gainful employment in this career, these factors have more to do with a person being *qualified* to do a job than with being truly *valuable* within that job. Work hard to accumulate knowledge and hone skill, but don't neglect to become the *type* of person people want to do business with.

Chapter 5

Locating Employment

Identifying employment opportunities within the field of electronics is more complicated than it should be. Electronic technologies are central to a wide range of modern endeavors, yet *careers* in electronics are widely misunderstood by the general public, and even among some industry professionals. Many factors contribute to this problem, including:

- The career itself suffers from an anachronistic public perception, stemming from the once-popular field of consumer electronic device repair. Once upon a time this was a popular career option for people with electronics skills, but as consumer devices have dropped in relative price and become less repairable these jobs have all but disappeared. When most people old enough to remember these jobs think of “Electronics Technician” they think of someone fixing broken televisions and radios, and therefore are likely to conclude the career no longer exists.
- The technical field of electronics in the United States is wildly diverse, with few standardized licenses, certifications, etc. across the range of industries served. It is almost impossible to accurately describe the work of an “electronics technician” across all industries, and in many cases the job isn’t even listed under that title at all.
- Education for this line of work used to be common, but has become much less so due to schools failing to adapt to market changes.

Another problem is that the job titles of *technician* and *engineer* are often blurred within some industries. This is problematic, as bona fide engineers require at least four years of intensive education and (often) state licensure – a different educational path than technicians – and are best suited for the creation of innovative designs as opposed to troubleshooting, development support, and testing.

It is often the case while reading job descriptions provided by employers that one must pay close attention to the minimum requirements of the job in order to tell whether or not the title of that job actually represents the work of a technician. For example, if the job requires a four-year accredited engineering degree (e.g. Electrical Engineering, Software Engineering), and especially if the job requires possession of a state engineering *license*, then it is likely suited for a true engineer rather than a technician. Further confounding the problem is that fact that some employers “bend the rules” of their own minimum requirements and will accept unusually skilled technicians to do engineering work (so long as a state license is not strictly required).

Another confounding factor is the expansion of job duties, which is more often the case at smaller companies where staffing is limited. Whereas a technician may have a fairly specific role to play at a large manufacturing facility where there is sufficient electronic systems in use to warrant staffing specializing in *just that*, a technician working at a small-scale manufacturer may be required to perform routine mechanical maintenance (e.g. lubricating bearings, changing broken or worn belts, aligning machine shafts) and electrical work (e.g. wiring electric lamps and motors, troubleshooting motor control circuits) in addition to maintaining electronic systems. The good news here is that a competent technician is a very versatile worker: it is not too much of a stretch for someone knowledgeable in electronics fundamentals, test equipment usage, soldering, and microcontroller programming to rebuild an electric motor, or to configure an electronic motor speed controller, or to replace a broken drive belt. The converse is not necessarily true, and in fact employers often bemoan the fact that it is quite difficult to find mechanics and electricians adaptable enough to learn the intricacies of electronics.

It is important for graduates of a technical program in electronics to begin working in their chosen career *as soon as possible* after graduation. Gaps of a year or more between education and related employment are generally viewed with skepticism by employers, because it suggests the person in question is either unmotivated or has unrealistically high expectations. My general advice is as follows: *take the first electronics job that pays your bills, and do good work there for at least a year before even thinking about going somewhere else*. More doors will open up for you by doing this than by idly waiting for your dream job¹ to present itself.

The following sections in this chapter describe some of the means available to you for locating employment in the field of electronics. Some of these strategies take the form of looking for *any* jobs that are available, while others are more targeted at finding work with an identified employer. Still others are focused on locating employers who *might* hire technicians. These should all be considered in your own job search. Limiting yourself to just one or two strategies means closing yourself off to opportunities.

¹By the way, dream jobs don't exist. *Every* job you will ever have is a mix of good and bad, some better than others, but nothing perfect. Moreover, if you're just beginning your career within electronics, it's quite likely you don't even know yourself what kind of a job you would most like. Remember that this is an incredibly diverse career!

5.1 Job search engines

A variety of internet-based search engines exist specifically for jobs. These include `monster.com`, `indeed.com`, and many others. Job search engines are generally the fastest and easiest way to locate employment, once you get past the problem of which terms to use in describing electronics. However, this is a double-edged sword: what is simple and convenient is what becomes over-used by job seekers, which leads to employers receiving a flood of applications through this medium. When you submit your application based on a job search engine result, yours is likely to be one among a great many. This means your résumé needs to be really powerful in order to stand out.

Many online search engines provide the means to automatically send email messages to you listing current job openings in your area of interest. This, of course, is a powerful tool for job searching as it allows you to monitor available jobs without having to duplicate effort.

An important caveat for job search engines is that their postings are not always current². Since advertising is a source of revenue for job search engines, there is a financial incentive to list jobs for longer than they are actually open in order to gain greater viewership. Do not be surprised if you encounter job opportunities on these search engines that are already taken!

5.2 Corporate websites

Virtually every company hiring technicians has a website, and somewhere on that website is a “Careers” tab or page listing current job openings. This is a valuable way to identify employment opportunities if you already know something about that company. These same websites are also one of the best resources available to you for researching a company, as a part of your résumé-writing process³.

5.3 Employment agencies

Some organizations exist expressly for the purpose of helping job seekers connect with local employers, operating as non-profits, as governmental functions, or some combination. These agencies are fantastic resources, as they not only post open job positions, but also provide services such as résumé-writing assistance, mock interviews, and help building professional portfolios.

One such agency operating on a national level is CareerOneStop (www.careeronestop.com) which is sponsored by the US Department of Labor.

²I have seen postings on job-search websites that were filled *over a year* prior, so beware!

³Remember, it is imperative in these modern times to ensure your résumé accurately addresses the knowledge, skill, and/or experience requirements *as stated in the job posting*. You cannot simply write one generic résumé for yourself and expect it to stand out above all the others, because of how companies now screen résumés against their published job descriptions.

5.4 Recruiting firms

These organizations are private, for-profit firms poised to link employers with job-seekers. Their services are typically funded by the employer, so as to not pose a financial burden to those unemployed persons who need to find work.

5.5 Union halls

If you become a member of a trade union, you have access to jobs posted at the local union hall (also known as a *hiring hall*). This benefit comes with certain limitations which must be clearly understood. As a union member you must pay regular dues, and you are expected to support your fellow union members and any collective action (e.g. strikes) they may engage in. You are also placed on a list which the hall will use in determining who is called next for open positions, and this list may or may not be adjusted by merit (i.e. technical competence).

The benefits of being in a union include certain benefits (insurance, pension), and generally high wages when there is work to be found. Employers also benefit from a union hall with a list of qualified tradespeople ready to work at a moment's notice.

5.6 Classified advertisements

Most newspapers have a "Classified" section in which companies and individuals may submit advertisements for free. The term "classified" refers to the fact that these newspaper sections are organized according to different advertisement categories: one for jobs, one for real estate, one or more for automobile sales, etc. These postings are necessarily short due to character-length restrictions imposed by the newspaper, but they remain a good source of information on employment opportunities.

Since most modern newspapers have an internet website to complement their paper versions, you may easily search classified job listings for areas outside of your own. This is especially useful if you are interested in moving to a particular region and seek employment in that area.

Don't discount websites such as craigslist.com which consist *mostly* of classified listings. This particular website allows you to search by major city in the United States, and will return listings for that city as well as for surrounding areas.

5.7 Trade periodicals

Another “legacy” resource for job seekers are trade journals and other magazine-style publications. Not only do these generally list companies offering a variety of technical services, but the articles contained within cite projects and products associated with a range of employers. When referencing trade periodicals for employment purposes, one must “read between the lines” to find what you’re looking for. Very rarely will an article end with “ABC Incorporated is looking for technicians!”, but instead you will have to infer employment opportunities based on descriptions of what that company has done and what it is currently doing. In other words, trade periodicals function more as a listing of *employers* than it does a listing of *jobs*. It remains your responsibility to take the next step, which is to investigate companies of interest to you.

A more direct line to employment is often found by consulting the internet websites of trade periodicals, which commonly host job boards where one may search for employment opportunities.

5.8 Word-of-mouth

A surprising number of open positions get filled simply because one person tells someone else. This is especially true within the world of contract electronics work, where one’s reputation becomes known among the employers very quickly. I have spoken with the owners of electrical contracting companies new to electronics work, who desire very much to “get in” to this word-of-mouth network so that they may hear about the next jobs, the best workers, etc.

Of course, in this digitally-connected age we live in, *word of mouth* consists of much more than just verbal communication. Mobile telephone text messaging, social media messaging, and the like now serve as online channels for people to communicate what they used to be able to say only in-person or over telephone. For those graduating from a formal program of instruction in this field, it is rather easy to set up your own “word of mouth” community with classmates: a means for classmates to share job openings with each other during and after their education.

5.9 Chambers of Commerce

Every major city, as well as many smaller cities, maintains a *Chamber of Commerce* where registered businesses in that area advertise services and connect with clients. These are excellent resources for locating employers, and consequently employment opportunities, within geographic areas of your choosing. Simply do a general internet search for the Chamber of Commerce within the city you’re interested in living, then visit that Chamber’s website to search for employers. After locating promising employers, visit those employers’ websites to search for openings (on the “Careers” page).

Many cities also have business-centered periodicals such as newspapers and journals which you may obtain through Chambers of Commerce. These publications showcase local businesses and business leaders, alerting you to new projects, persons of interest, and industry sectors within that region.

5.10 Tours

An easy way to learn about employment opportunities at specific sites, or even within an entire industry sector, is to *tour* a representative facility. Many large industrial employers offer regular tours (sometimes referred to as *open-house* events) where members of the general public may sign up to go through the facility on a specified date and learn about that operation from tour guides.

One need not wait for a public tour, either. Many companies are surprisingly receptive to the idea of giving tours to interested individuals and small groups. In fact, the very act of contacting a company to arrange a tour demonstrates initiative, which of course is highly desirable in any employee. If you know of a particular company you are interested in working for, do not be afraid to contact them about tour opportunities.

5.11 Jobshadowing and Internships

A common experience, especially for people enrolled in a technical program of study, is to spend time on a company's premises learning about their business and the work of a technician without being formally employed by that company. Two common terms used to describe this experience are defined as follows:

- **Jobshadow** – an informal invitation to follow, or “shadow”, one or more employees at a job site, usually without pay and usually for a short duration (a week or less).
- **Internship** – a formal arrangement, usually made between a student, their school, and the employer, to provide realistic work experience for little or no pay over some pre-determined span of time.

Either type of experience is extremely valuable for people new to a career, and also looks really good on a résumé. Making yourself known to an employer by means of a jobshadow or internship experience is a sort of *pre-interview* because it demonstrates to that employer what kind of an employee you will likely be, and does so in terms that are more easily believed than what a person claims during an interview. In a phrase, *actions speak louder than words*, and jobshadows/internships are a chance for you to demonstrate who you are by your actions rather than merely by your words.

Schools often assist students in obtaining either jobshadows or internships, but these experiences are also possible to set up without such assistance. In fact, I often have students who set up their own jobshadows without any help from myself, simply by contacting the company they're interested in jobshadowing at, explaining what it is they wish to do there, and arranging times and dates for the jobshadow to occur.

5.12 Informational interviews

One might think of an informational interview as a normal job interview, except in reverse: instead of an employer interviewing you, you are interviewing the employer. The purpose of an informational interview is to learn about the company, identify any job opportunities for you there, and determine if it would be a good fit for you.

The beauty of an informational interview is that it is set up by you. Rather than submit an application and wait (and hope!) for an invitation to be interviewed, an informational interview is something initiated and arranged by you. Of course, the employer must be willing to participate in the interview, but you might be surprised how willing many employers are to do this.

Human Resources (HR) personnel are the ideal point of contact for setting up an informational interview. While it is possible to interview supervisors and other technical employees of a company, Human Resources personnel specialize in identifying talent and are usually more willing to participate.

Prior to requesting about an informational interview, you should do some research on that company and on the specific site whose personnel you wish to interview. No one wants to divert valuable time on the job to answering questions that could have and should have been answered by a simple perusal of the company's website. Simply put, *do your homework first!*

Here is a list of potential questions to ask in your informational interview, and it is by no means exhaustive. Bear in mind that this is a generic list, and that some questions may not be appropriate for the specific employer⁴ you are interviewing:

- What is the employment outlook like in your specific industry? How much demand is there for technicians in this company? *Note: do not be surprised if you find yourself needing to explain what an “technician” is, especially if interviewing a non-technical person who may not be familiar with the details and titles of all jobs at that facility!*
- What special certifications, licenses, or credentials are required (or preferred) for technicians to hold?
- Can you estimate future needs for new technicians at this facility?
- What are the typical entry-level job titles and functions (e.g. different “levels” of technicians with different responsibilities)?
- What do you feel is the best educational preparation for this career?
- Have you heard of (*insert your college's name here*), and the electronics program here?
- Does this company offer training to upgrade technicians' skills?
- What are the most significant characteristics of this industry?
- What are the growth markets of this industry?

⁴For example, if the employer you are interviewing is a municipal water treatment facility, it would be foolish to ask “what are the typical production hours for this facility?” because such a facility is obviously running 24 hours a day.

- What are some of the ways in which your industry is changing?
- How do economic cycles affect this industry?
- Does the company have plans for expansion (new buildings, facilities, etc.) in the near future?
- How quickly is this industry/company/site growing?
- What challenges do you see inhibiting the company's profitability or growth?
- What is the typical entry-level salary for a technician in this company?
- What are the salary ranges for higher levels?
- Does this company offer a 401K or other savings plan(s) such as employee stock options?
- Is there opportunity for technician advancement into engineering and/or management?
- What skills or personal characteristics do you feel contribute most to success in this industry?
- What trends in the field would be most likely to affect someone just entering this career now?
- What is the most important thing that someone planning to enter this career should know?
- What are the typical production hours for this facility?
- What are the typical working hours for a technician?
- Is shift work involved? If so, what is the typical shift schedule?
- Do technicians work weekends or non-day shifts?
- Are technicians expected to be on call during off-hours?
- Do the technicians do most of their work independently or within teams?
- How much travel is involved for technicians at this company?
- Does the company offer tuition reimbursement for employees pursuing advanced degrees?
- How does the company recognize outstanding accomplishments of its employees?
- How does the company encourage innovation and creativity in its employees?
- What is the average length of time for an employee to stay in the job you hold?
- What practical experiences would help a new graduate qualify for an entry-level technician position (jobshadowing, internships, etc.)?
- Does this company offer jobshadow or internship opportunities to interested students?
- Will this company help technicians maintain professional memberships in organizations such as ETA International (Electronic Technicians Association) ISCET (International Society of Certified Electronics Technicians)?

- Do you have any written job descriptions of positions in this industry/company you could share?
- What is the best way to apply for a technician position at this company?
- What is the best way to learn of job vacancies at this company?
- If you were conducting a job search today, how would you go about it? Where would open positions be posted?
- If I wanted to apply for a job here, who would the best person to contact?
- Are you currently accepting applications for work?
- Which areas of the company would be most interested in hiring people with my background?
- Would you be willing to answer more questions, by phone or in person, if I need additional advice in the future?

When attempting to contact potential employers, you will usually encounter automated telephone answering systems where you must leave a message for someone to listen to later. One problem with voicemail messages is that they tend to sound unprofessional: vocalized pauses (“um”), meandering sentences, and missing information may leave a bad “first impression” with the person you are trying to contact.

One helpful way to overcome this is to have a *pre-written paragraph* ready to read aloud when leaving a voicemail message. This will help you overcome anxiety when faced with having to leave a voicemail message (“What do I say?”), shorten the message by eliminating wasted time, and ensure no critical information is omitted.

Your message should contain the following information, at minimum:

- Your name, and how (and when!) you may be reached (e.g. phone number)
- The purpose of contacting this company (to explore career options there)
- (Optional) *a statement describing your interest in this company*
- Conclude with a repeat of your contact information (e.g. phone number)
- A friendly sign-off (e.g. “Have a nice day”)

5.13 Digital “smokestacking”

I once read an article in a technical journal written by a technical salesperson discussing the “good old days” of traveling sales in the 1970’s, when many of his first contacts were done in person rather than by telephone, and nothing called the “internet” was even close to being available. This salesperson fondly remembers driving his car along major highway roads looking for tall smokestacks, which served as markers for any number of heavy industries. Once a smokestack was spotted, he would pull off that road, locate the facility, and knock on their front door to begin a conversation with personnel there who might have been interested in his products.

This practice was called “smokestacking” and apparently it worked well enough for some technical salespeople to sustain a living. While this may seem quaint in our age of digitally connected individuals and businesses, and perhaps even irrelevant to the problem of locating employment, this concept should not be dismissed out of hand. If you wait until a job becomes posted somewhere (e.g. in a job search engine, classified advertisement, or by word of mouth), you will miss out on many opportunities. Searching out prospective employers and making first contact with them is a valid strategy for job searching, and to do that you must first identify where those employers are located. Smokestacking is one way to do this.

What I’m referring to as *digital* smokestacking consists of using satellite-mapping applications on the internet to find large commercial and industrial sites. My personal favorite is **Google Maps**, which also allows simple searches by industry type and company name. This technology will surely become more powerful as time goes on, making it ever more useful for locating prospective employers. A satellite view of an industrial site can be extremely informative, revealing such details as:

- Production capacity (based on the acreage of the site)
- Employment capacity (based on the size of the parking lot)
- Transportation modes (e.g. truck, rail, ship, pipeline) for feed and product
- Energy sources (e.g. combustion furnaces/boilers, electricity)
- Communication infrastructure (especially antenna arrays)

5.14 Summary

As you can see, there are many alternatives to using job search engines and classified advertisements when searching for employment opportunities. The existence of so many alternatives mean many of them are relatively unexplored by job seekers. This is good for you because these less-popular means are less likely to be saturated by others looking for work.

An important principle to bear in mind when actively reaching out to companies is that the more personal the contact, the more effective your efforts will be. As I like to advise my students, *“A telephone call is worth a thousand email messages, and a personal visit is worth a thousand telephone calls”*. No matter how sophisticated our communications technology becomes, in the end the goal of all employment searches is to make a persuasive connection to a live human being. Never forget this essential human element.

I would like to end this chapter with an anecdote from my own life. Shortly after beginning a two-year program at a technical school I began a search for part-time work to help pay for living expenses. I was willing to do almost anything, but I preferred something technical because at that time I had a strong background in electronics as a hobby and I was studying a technical subject at school. My first stop was at a Radio Shack store, where I inquired about work as a repair technician. To my pleasant surprise, the store’s owner was immediately interested because his former repair technician left his job to work for another company in town (which he mentioned by name), and he really needed someone else to fill that job. My heart sank, though, when he told me the only working hours fell during my school day.

Walking away from the Radio Shack store, I made a mental note to look up the phone number of that other company when I got home. I figured anyone qualified enough to do that job well would only leave for something better, which likely meant an equally or more technical job for more pay. When I reached my apartment I got my phone book and found in it a single phone number and street address for that company. It happened to be located between the school I attended and the apartment where I lived, and so I planned to stop by the next day.

When I visited this facility, it was a plain sheet-metal building located on the edge of the local airport runway. As it turned out, this was only one out of several facilities run by this particular company, some of the others being larger and better-equipped. Walking inside, I immediately smelled cutting oil and tool coolant: evidence that this was a machine shop. The receptionist told me there were no open jobs at the time, but that they do periodically hire machinists and other skilled persons, and recommended I complete a job application for their files. At the time I didn’t have much to offer in the way of ability except for general familiarity with machine tools and a hobbyist’s background in electricity and electronics.

The very next day I received a telephone call from the maintenance foreman of that facility asking me to return for an interview. As it so happened, he was overseeing a major machine tool retrofit project and needed someone to do soldering and other basic electrical work. He had not yet posted a classified advertisement for such a person, but was planning to. When I arrived for the interview, we had a very pleasant conversation about the project, the facility’s products, my interest in their operation, my availability for work, and other details. At the end we shook hands, and Monday of the next week I was officially hired.

This was not, to put things lightly, my idea of a dream job. Although the opportunity to have an income and to gain valuable technical experience was certainly appreciated, the working conditions were less than ideal. The job paid only \$6 per hour (in the year 1987), provided no benefits, and

the company was run by a fellow who openly mocked⁵ his employees. However, working at this job turned out to be key to landing my *next* job, as it seemed most industrial employers would have been extremely reluctant to hire a 19-year-old technician without any work experience. It was also a great experience because of my co-workers who were friendly, helpful, and taught me many practical skills. This was another valuable life-lesson for me: opportunities are rarely perfect, but they don't need to be in order to pay off handsomely in the future.

There are many different lessons one could draw from this story, but the one I would like to emphasize is that you just never know what job opportunities you may miss if you limit yourself to *posted* jobs. Here was a job that paved the way for my future career while paying a good portion of my living expenses while in school, which I may never had even heard of had I not taken initiative to knock on their door.

This lesson is not an isolated incident, either. Time and time again I have witnessed my own graduates do the same: land a job simply because they took initiative to make first contact with an employer. Of course this strategy doesn't always result in getting hired; in many cases the applicant discovers no positions are available. However, it has proven successful often enough⁶ for me to advise this as a strategy to all my students. Honestly, what do you have to lose by trying?

⁵He would occasionally visit our facility, referring to us as "children" and to our breaks as "recess". The times he spent in jail for tax evasion were welcome, because things always seemed to run smoother when his wife took over operations for him. According to my co-workers this state of affairs was a considerable improvement over earlier years, when in addition to these offenses it was commonplace for employees' paychecks to bounce. At least no one had to rush to the bank on payday anymore to cash their check before the account ran out!

⁶An oft-quoted statistic claims that approximately 80% of jobs are unpublicized, but this seems to be more fiction than fact, especially in the internet age of job search engines where posting open positions far and wide has become very easy for employers to do. However, I can tell you that taking initiative in making first contact with an employer you're interested in working for is productive in the following scenarios: (1) when the company in question is small and lacks a recruitment budget, (2) when a company knows they need to hire more people but they haven't advertised that need *yet*, and (3) when a positive contact inspires an employer to hire someone to fulfill a need they were not yet consciously aware of.

Chapter 6

Résumés and Cover Letters

A résumé and cover letter exist for one purpose: *to convince an employer to give you an interview*. The specific purpose of a résumé is to concisely summarize your abilities, while the specific purpose of a cover letter is to express your interest in working for that employer. In other words, a résumé conveys what you have to offer to them, and the cover letter conveys what you find appealing about working for them. Both the résumé and the cover letter should be limited to one single-sided page of text each¹. The résumé and cover letter together serve as a starting point for that interview, providing specific examples to discuss of your interest in and qualifications for the job. This exploration of résumés and cover letters will assume a job in the field of electronics, and will contain specific guidelines for this career.

Before exploring the details of these documents, it is worth noting that students generally underestimate the importance of good résumé and cover letters to their own peril. An interesting fact to ponder is that *the quality of these documents is significantly more important to your chances of obtaining employment than the quality of your course grades!* Why is that? Part of the reason is undoubtedly the phenomenon of *grade inflation* and general poor quality of technical education in the United States, where for many schools a student's grades indicate nothing of their employability. However, a more compelling reason is that unlike grades, a résumé and cover letter directly the individual's attention to detail and ability to clearly communicate, both of which are highly prized in this career. Scrutiny of this document during the interview process furthermore reveals how honest the candidate is, something grades generally do not indicate.

The important point you as a student needs to understand is that your résumé is likely the most important document you will ever write in your life in terms of career success. I have seen many a talented student rejected by employers – never even given the opportunity to interview – because their résumés were hastily drafted, contained typographical errors, and/or seemed inauthentic to the reader. Plan on investing at least twenty hours of effort writing your first résumé!

¹Unless you have extensive work experience and other relevant accomplishments to note in your résumé, a single page (one-sided) should be considered maximum. My own résumé based on over three decades of technical work experience is only two pages long (i.e. one sheet of paper, printed on both sides).

Let's begin our study of résumés with these two lists:

Essentials of a good résumé

- Your name and contact information
- Your relevant educational qualifications
- Your relevant work experience
- Details of your knowledge and experience *directly applicable to this job*

Prohibited items on a résumé

- Spelling errors, grammatical errors, and incorrect technical terms
- Inconsistent or messy formatting
- Use of colored text or novelty fonts (typefaces)
- Information irrelevant to the job sought
- Any embellishments or otherwise inaccurate statements
- Self-assessments (e.g. “Hard worker” or “Resourceful”)

Always bear in mind that *content* is more important than *format*. Many résumé guides elaborate on formatting styles, but my universal experience with employers hiring technicians is that résumé style counts for little. If you were applying for a job at a newspaper doing page layout, style and formatting would be very important, but not in this field.

One notable exception with regard to formatting is your choice of font, or more properly *typeface*², which greatly affects the presentation of your documents. *Serif* typefaces with their small “tail” adornments at the vertices are easier to read when printed on paper, while *sans-serif* typefaces lacking these additions are easier to read on illuminated screens:

Serif typeface

T

(best for print)

Sans-serif typeface

T

(best for screens)

Examples of good serif typefaces include Garamond, Cambria, and Bookman Old Style. Times New Roman is also a serif typeface, but is over-used and considered by some to be ugly. Examples of good sans-serif typefaces include Helvetica, Calibri, and Arial. Always avoid cursive-style (“script”) typefaces, monospaced typefaces such as Courier, and novelty typefaces such as Comic Sans. Font size should be 12-point, except perhaps for your name and/or section titles which may be larger.

Please note the last bullet-item on the “Prohibited” list: *self-assessments*. This may strike you as odd, given that the purpose of a résumé is really self-promotion. However, only a moment's

²Typeface refers to a “family” of characters. Font refers to modifications of those characters within a typeface family, such as *italic*, **bold**, and sizing.

worth of thought is necessary to discover why positive self-assessments look bad on a résumé: they are worthless because *of course people will say great things about themselves!* In other words, self-assessments are worthless because the source is biased.

How then do you accomplish self-promotion on a résumé without self-assessment? The answer is simple: cite concrete examples of accomplishments *proving* those same qualities. If you think you are a hard worker, for example, show that to be true by citing actual experiences where your hard work was necessary to the achievement. If you consider yourself to be resourceful, prove it by citing examples of when your resourcefulness was on full display. If cannot recall any life experiences illustrating such attributes, then you need to begin engaging in activities which will develop and showcase these traits, and do it *now*.

Veterans of the armed forces in the United States automatically have access to a document listing training and assignments while serving. This is called a *DD214* form³, and copies of it should be ready to mail or hand in person during an interview.

A sign of the times with résumés is that any submitted to an employer in electronic format (e.g. Word or PDF document) will likely be scanned by a computer before any human being sets eyes on it. This computer will be sifting through your document looking for words and phrases matching the posted job description. Many résumés will be rejected based on low match scores, which means if you ever want your résumé to hit the desk of an actual human reader it's going to have to be tailored to the specific job you are applying for. The reason for this is rather simple: electronic job applications mean employers are inundated with more résumés than they ever faced in the days of paper submissions, and this necessitates a screening mechanism which won't burden their Human Resource departments⁴. An easy way for employers to cull this virtual pile of résumés is by letting a computer figure out who among the applicants actually bothered to read the job description and write something relevant to it. Federal agencies use a similar strategy to cull applicants: force all of them to complete an application form containing dozens of pages and hundreds of entries/selections. Those who can't accurately complete the form are automatically rejected prior to any interviews taking place.

It should go without saying, but just to be clear: *tailoring your résumé and cover letter to a particular job description does not grant you license to embellish or otherwise misrepresent yourself!* Absolutely everything you write on your résumé and cover letter needs to be completely true⁵

³The official title of this military document is a *Report of Separation, DD form 214*. It details such information as the entry and release dates of the service member's service, home address(es), last duty and rank, education, specialized training, decorations and awards, and discharge status.

⁴This is assuming the employer even *has* an HR department. A common trend is downsizing of HR staff, which means companies often outsource their HR needs to third-party services which handle job application screening for multiple clients. This is another sign of the times, and it is a point of frustration for many job seekers because it also tends to slow down the screening process. It is not uncommon for my graduates to receive positive responses from companies *five or six months following their application!*

⁵One memorable anecdote on résumé accuracy comes from my own experience. As graduation neared for my classmates and I at the technical college, we all set to work drafting résumés and cover letters. As is natural for students to do, we often compared each others' documents in order to get ideas on presentation and format. Something that struck me from these observations was that nearly every one of my classmates mentioned *microprocessor architecture* as something they learned in school. This puzzled me, as our only direct experience with microprocessors at school was developing simple assembly-language programs for the Intel model 8080 (8-bit) processor. The term "architecture" deals with the internal organization, data flow, and overall design of the microprocessor chip itself, which was well beyond the scope of writing simple code. Our textbook, however, had one chapter in it with that title, and so it seemed many students were willing to list that as a knowledge area when in fact we had learned very little on that topic. Perhaps they believed it sounded impressive. Whatever the case, it is very risky to list something on a résumé or in a

and demonstrable. What is meant by “tailoring” is rather omitting details of your education and experience that are not as relevant to the particular job being sought, so that the precious space may be devoted to your *most* relevant qualifications.

Elements of both good and bad résumés will be highlighted through examples. These examples will be shown in ugly monospaced typeface simply for the purpose of illustrating how content is more important than formatting. Your résumé should *look* nicer than any of these examples, but remember that technically-minded people care far more about substance than style.

Cover letters, similarly, have essential and prohibited elements:

Essentials of a good cover letter

- Addressed to a specific person at the company
- An explanation of how you discovered the company and/or job opening
- A description of your interest in working for this company
- Details revealing you have researched this company well
- An expression of appreciation for their time and attention
- Your name and contact information
- Your personal signature

Prohibited items on a cover letter

- Spelling errors, grammatical errors, and incorrect technical terms
- Inconsistent or messy formatting
- Use of colored text or novelty fonts (typefaces)
- Information irrelevant to the job sought
- Any embellishments or otherwise inaccurate statements
- Self-assessments (e.g. “Hard worker” or “Resourceful”)
- Informal verbiage or tone
- Repeated sentences beginning with first-person pronouns (e.g. “I” or “My”)

cover letter for which you are not completely competent. Technically savvy interviewers *will* ask you to elaborate on qualifications claimed in your documents, which means you had better only list things you’re strong in, or risk failing an interview for overstatement. Also bear in mind that people have been fired from their jobs after their employers learned they lied on their résumés, so the risks of misrepresentation don’t end after a successful interview!

A cover letter is first and foremost a *business letter*, and should follow all the conventions of such. It should be *highly* specific to the job or company you are interested in, even more so than your résumé⁶. Like all well-written letters, it should sound professional when read aloud: the presentation should be similar to how a person might actually speak to another in a business environment.

In summary, the purpose of your résumé and cover letter is to secure an interview. The résumé explains why the company should be interested in you, and your cover letter explains why you are interested in working for that particular company.

⁶While customizing your résumé to the job in question is important, there are likely portions of any good résumé that will be generic to all electronics jobs. A cover letter, on the other hand, needs to be highly specific to one job: addressing a specific person at that company, describing how you learned about the position or the company, etc.

6.1 Résumé examples for recent graduates

Here is an example of a good résumé for a recent graduate of an electronics program, with no prior technical work experience, applying for a job at a manufacturer of solar electric power equipment:

Megan A. Symons
1234 Main Street (City, State)
(123)-555-1212 megans_94@gmail.com

EDUCATION:

Sep 2015 - Jun 2017 Centerview Technical College
ATA degree in Electronics Technology
GPA = 3.21/4.0, perfect attendance

TECHNICAL KNOWLEDGE AND SKILLS:

- * Test equipment setup and operation, including multimeters, oscilloscopes, function generators, electronic loads, power supplies, and signal generators
- * Surface-mount and through-hole component soldering
- * PIC 16F84A microcontroller and Motorola 68000 microprocessor programming
- * Troubleshooting faults in electronic systems built and documented in lab
- * Network theorems, phasor diagrams and calculations, Boolean algebra, power conversion circuits, NFPA 70E electrical safety
- * Experimental design, test setup and documentation, project management
- * Software: AutoCAD, PSPICE circuit simulator, LabVIEW, KiCad

WORK EXPERIENCE:

Jan 2013 - Jun 2017 Saucy's Pizza -- Night shift supervisor

- * 40 hrs/week prior to school; 30 hrs/week during
- * Manage crew of 5 employees, organize work schedules, maintain inventory, open and close store
- * Implemented principles of Lean Manufacturing into store procedures (2016)
- * No work absences for the last three years

Mar 2012 - Jan 2013 Saucy's Pizza -- Waitress

- * Waited on customers, cleaned tables, prepared beverages, placed orders, operated cash register, balanced till at end of every shift

OTHER SKILLS AND QUALIFICATIONS:

- * Fluent in conversational Spanish
- * Certified in First Aid and CPR (Feb 2016)
- * Maintain current US passport, willing to travel
- * Academic transcript and project portfolio available upon request

Reviewing this résumé, we find many positive aspects worth highlighting:

- Note how the applicant’s name and contact information is prominently featured at the top of the document, easy to read and difficult to miss.
- Note the perfect spelling throughout. This is particularly important for technical terms (e.g. phasor, oscilloscope, microcontroller). Mis-spelling any of these terms signals unfamiliarity to any reviewer familiar with electronics, making it look as though the résumé writer simply inserted words into their résumé that might sound impressive.
- Note the excellent grammar throughout. The tense (past, present) of every verb is appropriate to each statement: past accomplishments use past-tense verbs (e.g. implemented, cleaned, placed,), while present activities use present-tense verbs (e.g. manage, maintain).
- Consistent use of punctuation: each bullet-item lacks a period at the end. Placing periods at the end is fine, and so is omitting them, but inconsistent use betrays a lack of attention to detail and just looks ugly. If any line contains multiple sentences, you *must* use periods!
- The work experience, while admittedly not industrial or technical in nature, is relevant because it highlights the applicant’s ability to maintain schedules, be punctual, manage subordinates, and in general bear substantial responsibility within a business environment.
- Note how the knowledge and skill section mentions test equipment, components, principles, and software one might expect to encounter at a business manufacturing solar-electric systems. Nothing in this section appears extraneous to the job. Specific topics from the applicant’s education in electronics germane to electric power conversion (e.g. network theorems, phasor calculations, NFPA 70E electrical safety) reveal the applicant understands the nature of the industry and the relevance of her technical studies. In other words, *it is obvious she has done her homework on this employer*, and this speaks well for her potential value as an employee.
- Note the complete absence of any subjective claims. The applicant never describes herself as a hard worker, but she shows this to be true through her outstanding attendance and work schedule concurrent with being a full-time student. She also demonstrates responsibility and initiative through her work experience. Her possession of a passport and willingness to travel, as well as her multilingual capabilities speaks to her ability to learn different cultures and her openness to new experiences. Even if the job never requires travel or communication in a language other than English, these traits are still valuable in other ways.
- Note how the applicant also has her academic transcript and project portfolio ready to show employers. It is not necessary to say “references available upon request” anymore, since checking references is standard operating procedure for the vast majority of employers. However, one should always have a list of professional references ready to submit to an employer when seeking work.

Here is another example of a good résumé for a recent graduate of an electronics program. In this example the writer has no paid work experience at all, and is applying for the same job at a manufacturer of photovoltaic power systems:

Jonathan L. Chang
5220 Main Street (City, State)
changj_00@yahoo.com (222)-555-8787

EXPERIENCE:

- * Interned at Dryson Controls during January 2015, a licensed Siemens products distributor and UL 508A panel shop. Wired electrical control panels and installed Siemens variable-frequency motor drives.
- * Designed, coded, and built a custom weather station for inclusion in the WeatherUnderground online network. Used an Arduino microcontroller to measure temperature, rainfall, wind speed, and relative humidity, broadcasting data to the website at 10-minute intervals.
- * Participated on an interdisciplinary team of students in a regional Battle-Bot contest. Designed, prototyped, and tested the power-control and microcontroller interface circuitry for the robot's four drive motors. Coordinated with Mechanical Engineering students on drivetrain design, and also with Welding students on body design.
- * Set up multiple PC networks for online gaming events: configuring routers, setting IP addresses, using PING to diagnose network connections, testing connection bandwidth, and providing technical support to teammates over telephone.

TECHNICAL KNOWLEDGE AND SKILLS:

- * Power electronic circuit design and testing.
- * DC and AC motor characterization and control.
- * Analog signal conditioning and data acquisition techniques.
- * Diagnosing electrical circuits using multimeters and oscilloscopes.
- * Microcontroller programming in assembly and C.
- * Microsoft Word, Excel, Access, Powerpoint.

EDUCATION:

Sep 2015 - Jun 2017 Centerview Technical College
ATA degree in Electronics Technology
GPA = 3.53/4.0

OTHER SKILLS AND QUALIFICATIONS:

- * Served on Centerview Technical College ASB Senate Sep 2016 - Jun 2017

For someone in this position, the biggest challenge is to convince an employer to take a chance given a complete lack of actual job experience. This is not an impossible task, but it is not easy. Note how this person addressed that problem in his résumé: by beginning with *experience* rather than with education. Although all of this experience was gained in school (and on an internship) rather than by working an actual job where he received a paycheck, it is still practical experience which is the point which needs to be strongly conveyed to any technical employer.

Note also how the internship is featured prominently in this résumé. For people lacking work experience, jobshadows and internships can be game-changing experiences. Not only do they provide practical experience prior to employment, but doing good work during a jobshadow or internship may lead to good references from supervisors and co-workers at the company. Again, the emphasis here is on *experience*: how to gain as much as possible, and how to clearly communicate what you have gained to an employer who may be skeptical of your lack of direct employment experience.

This example résumé models practical ways to communicate experience to an employer. Note how in the internship line we read details of the company (Dryson Controls) meaningful to any electric power system manufacturer: it is a licensed distributor of Siemens products (Siemens being a major electrical component), and it is also a UL 508A panel shop (a certification that this facility is authorized to design and construct panels meeting Underwriter's Laboratories standards for industrial electrical controls). The work done at this shop is practical as well: wiring motor control panels with VFDs.

The next two bullet points under the "Experience" section of the résumé highlight specific projects completed by this person while they were a student in technical college. Pay close attention to the level of technical detail conveyed in these points, which is far more than what we saw in the previous (good) résumé. Again, the idea here is to convey to any prospective employer that this person has actual experience working with industry-standard equipment and systems, and can speak to the technical details of doing so. A common tendency among graduating students is to simply make bullet-point lists of study topics and course names from school, but descriptive paragraphs of technical projects convey all the same points while also communicating *hands-on experience* to the reader. Also note how most of the experience cited implies good team-working skills, from the internship at Dryson Controls to the Battle-Bot competition to the online gaming events.

Regarding the video game experience, it is critically important to note how Jonathan uses this to showcase technical competence applied (and possibly gained) outside of school. It would be a bad thing to simply document video game *playing* experience, but here we see this hobby has practical merit in the form of personal computer (PC) network configuration, testing, diagnosis, and technical support delivered over telephone. Again, the over-arching principle at work in this résumé is to leverage any and all hands-on experience as compensation for a lack of actual paid work experience.

Finally, under the "Other Skills and Qualifications" section of this résumé we see the writer has cited their participation in the Associated Student Body (ASB) governance while at the technical college. While this at first may seem to be completely unrelated to the field of electronics, the relevance is with "soft skills" rather than "hard" technical skills. Serving as a Senator means having to communicate with constituents, maintain deadlines, attend meetings, listen carefully, and other very important skills any employee should possess. Again, this may not be exactly the same as paid work experience, but for a person in this position who has no such work experience it is the next best thing. Volunteer experience is similarly useful both for gaining experience and as a "selling point" on a résumé.

In summary, if you are in the same position as the writer of this résumé, you have two tasks to complete: (1) gain as much practical experience as you can while in school, and (2) document that experience as clearly and as compellingly as you can when applying for jobs.

Here is an example of a poor résumé for a recent graduate of an electronics program, applying for the exact same job as the other recent graduates (Megan and Jonathan):

Robert F. Worthington
4321 Main Street (City, State)
(123)-555-2121 reeferdude420@yahoo.com

EDUCATION:

2015-2017 Centerview Technical College
Electronic degree
GPA = 3.61/4.0

2007-2011 Centerview High School
* Track and Field varsity team

TECHNICAL KNOWLEDGE AND SKILLS:

- * Studied ohms law, kirchhof's law, theerems, AC, 3 phase, digital, analog
- * Meters
- * Signal generators
- * troubleshooting
- * Printed circuit bords
- * English 101, Psychology 105
- * Rhino 3D, excel, word. adobe pdf, autocad; ardwinio, plcs

WORK EXPERIENCE:

2014-2015 Safety watch for Burgess Construction
* Hard worker, reliable

2011-2012 NAPA Auto Parts
* Detail-oriented
* Customers liked me

2012-2014 Joes Garage and Detailing
* Learned lots about engines

OTHER SKILLS AND QUALIFICATIONS:

- * Welding, painting, sheet metal work
- * Tune-ups on cars
- * Hot work permits
- * Standard and metric tools

Reviewing this résumé, we find many problems worthy of note:

- Note how the applicant’s email address is grossly unprofessional.
- Also note the abundance of spelling errors (e.g. *theerems* instead of theorems, *ardwino* instead of Arduino, *bords* instead of boards) and punctuation errors (e.g. inconsistent capitalization, use of semicolon and period where comma would be correct). In our modern era with spell-checking and grammar-checking features standard in every word processor, there is really no excuse for these mistakes in a business document. Furthermore, while the causes of chronic misspelling and poor punctuation are varied, one easily-understood cause is a *lack of reading*. Therefore, anyone seeing a document filled with such errors is likely to assume the author doesn’t read very much, and is therefore someone they would rather not hire for a technical position where reading complex documents is routine.
- The title of the degree is incorrect. While the previous two résumés correctly listed the degree as an ATA in Electronics Technology, this résumé simply says “Electronic degree” which gives the reader the impression that Robert doesn’t even know what program he’s enrolled in.
- Note the technically vague terms listed (e.g. analog, digital, with no elaboration on those two broad categories of circuits).
- Note the informal wording (e.g. “learned *lots* about engines”). This might be how you converse with friends, but it is definitely not the way you communicate in business.
- Note how the employment listing is not in chronological order. This might be appropriate if the ordering is based on relevance to the job sought, but there are no details suggesting why this would be true. Instead, it just looks as if the applicant didn’t pay close attention to how their employment details were listed.
- This applicant’s work experience, while possibly more relevant to a technical field like electronics than the prior applicants (Megan and Jonathan), is so lacking in detail that it conveys little merit. Any reviewer comparing Megan’s résumé against Robert’s would consider Megan’s work experience in the pizza restaurant to be more compelling than Robert’s work experience in the auto parts store, mechanic’s garage, and construction company. Her work experience demonstrates responsibility and professionalism, while his suggests little more than collecting a paycheck. This is a missed opportunity for Robert to showcase relevant experience. The same may be said of his Other Skills and Qualifications section which is similarly vague.
- Another notable detail about this applicant’s work experience is the lack of detailed starting and ending dates. There is no need to list specific *dates*, but failing to list the year *and month* each job began and finished may be viewed by some employers as a means to hide employment gaps⁷.
- This applicant’s educational achievements reveal some important details. His GPA is good, and in fact better than Megan’s, but there is no mention of attendance which is generally given greater consideration by employers. Note also how there is no overlap between work

⁷Gaps in employment are frowned upon by most employers of tradespeople. While not always the case, periods of unemployment can indicate poor motivation or work ethic. If you have any employment gaps, prepare to be questioned about them during interviews!

and school, which suggests he was not burdened with working a job while studying electronics (unlike Megan who worked part-time while going to school). This applicant's mention of high school, as well as being on the varsity Track and Field team, is completely irrelevant to the job at hand. Secondary education, unlike technical college, is something everyone does. For all the reviewer knows, making the varsity team had more to do with natural athletic ability than to any positive character traits.

- Note how the knowledge and skill section is sparse and lacking in detail. Employers aren't interested in bullet-point lists of topics studied, *unless that list demonstrates an understanding of the education's relevance to the job being sought*. Compare Megan's knowledge and skill list to Robert's: Megan connects specific topics learned in school to the applications found at an air separation plant, while Robert merely lists generic topics. Jonathan's "Experience" section is even better, in how it provides very detailed descriptions of the work done in technical school.
- All points listed in the knowledge and skill section need to be specific to the job. No technical employer cares that you took English 101 or Psychology 105, although they *do* care about your ability to read and write well and your ability to work well with others. Remember that you only have a single page of text to make your best case for why you should be hired – don't waste any of it describing coursework *every graduate* completes.
- Note the subjective claims in the Work Experience section, which *might* be true but are rendered moot by the fact they come from a biased source (Robert). The best way to demonstrate positive attributes is by citing actual *accomplishments* where these attributes are necessary, like Megan did in her résumé and like Jonathan did in his. This is another missed opportunity for Robert.

You will note that none of these résumés included an *objective*. Generally speaking, an objective statement is not necessary unless the position sought is highly specific and/or liable to be confused with another open position. An objective becomes completely redundant in the presence of a well-written cover letter, the purpose of which is to express why you are interested in the position.

6.2 References

One of the final steps an employer takes prior to hiring a new employee for any job bearing significant responsibility is contact people who have worked with that person in the past. These people are *references* for the prospective employee, and what they say can make or break the deal. It used to be customary for résumés to say “References available upon request” near the end just in case the employer wished to contact references, but now the practice of contacting references has become so common that it is expected all applicants will have a list of references ready upon request.

When an employer contacts a reference, their goal is the same as when reading résumés and cover letters: to ascertain the fitness of the prospective employee to the job. The major difference with references is that the source is far less biased, and therefore more likely to yield an honest answer. Questions that will likely be asked of the reference are similar to questions asked during an interview, and may focus on behavioral tendencies, technical skill, or more likely than not some combination of those two.

It is very important that you carefully choose who you list as references. First and foremost, you must contact each and every listed person to obtain their consent. Listing someone as a reference without first acquiring their permission is a huge mistake. Few things look worse for the applicant during a job screening process than a reference who was unaware they were cited as a reference⁸. When asking permission to list someone as a reference, be sure to inquire whether you need to sign any release form legally permitting that person to comment on your performance. Professional educators, for example, are required to have a FERPA⁹ form signed by the student in order to release certain details of that student’s educational record to anyone outside of the school.

Each of your references should be able to speak in detail to your technical capabilities, work ethic, general attitude, creativity, and other important facets of who you are as an employee. Direct supervisors, co-workers, and college instructors generally make good references. Family members, friends, and acquaintances do not. For young adults lacking significant work experience, one of the best references you can have is a supervisor at a company where you have “jobshadowed” or interned doing electronics-related work. Professional observation and testament of your knowledge, skill, and character in action constitutes one of the major benefits of participating in jobshadows and/or internships.

Three is generally considered to be the minimum number of people to cite as references, with five as a maximum. Try to have broad representation on your reference page: don’t list only instructors, or only co-workers, or only supervisors. Also, it is good to collect more letters than this when applying to many jobs for two reasons: first, having a collection of letters to choose from makes it easier to pick those most applicable to the specific position sought; second, not relying on the same three people for every application means those people are less likely to be overwhelmed by employers checking those references. Each of these people should be given a copy¹⁰ of your résumé for their own reference.

⁸I once had a student who set up an informational interview with an employer, then listed the person they interviewed as a reference when applying for a job at that company! This was grossly unprofessional, seeing as how that person didn’t know anything about the student’s capabilities or character, and was never asked to serve as a reference. In this particular case the result was disastrous for the student: he was told to never apply to that company again, *ever*.

⁹The Family Educational Rights and Privacy Act of 1974.

¹⁰Just one copy is sufficient, even though you will be tailoring each of your résumés to each job you apply for.

A job reference form from the early 1900's¹¹ used by the Weston Electrical Instrument Company reveals what was, and still is, the purpose of a reference:

EDWARD WESTON, Pres. HENRY E. NIESE, Vice-Pres. L. M. RUST, Treas. E. F. WESTON, Secy.

WESTON ELECTRICAL INSTRUMENT COMPANY,

MANUFACTURERS OF
Electrical Measuring Instruments and Appliances,
 OFFICE AND WORKS, WAVERLY PARK, NEWARK, N. J.
Long Distance Telephone 1900 Newark, Cable Address, "WESTLEC." Telegraphic Code, "A. B. C."
Connecting all departments.

WAVERLY PARK, NEWARK, N. J., _____

In your reply please refer to _____

_____ has applied to this company for
 employment _____ and claims to have
 been employed by you as _____
 under _____
 during _____

Will you please furnish us with the information requested below,
 and greatly oblige,

Yours very truly,
 WESTON ELECTRICAL INSTRUMENT CO.
 Per _____

How long in your employ? _____ Date of leaving? _____
 Occupation at which employed? _____
 Were services satisfactory? _____ Does he apply self? _____
 Honest? _____ Sober? _____ Capable? _____ Are you related? _____
 Reason for leaving your employ? _____
 Would you reemploy? _____
 Remarks: _____

 _____ Day of _____ 190 . Signed _____

As you can see, this reference form begins with claims provided by the job applicant regarding their previous employment. The reference first and foremost verifies that all the claims are indeed correct, and then proceeds to comment on the applicant's important qualifications: competence, motivation, honesty, etc.

¹¹This gem was located on page 111 of volume 31 of *Cassier's Magazine* published in the year 1907, in an article entitled "Modern Factory Management" written by Egbert P. Watson.

Here is an example of a reference page for the graduating student with the well-written résumé. All reference pages should follow this same general format, listing at least three people listed who can reliably attest to your character and fitness for the responsibilities of employment:

<p>Megan A. Symons 1234 Main Street (City, State) (123)-555-1212 megans_94@gmail.com</p> <p>REFERENCES</p> <p>Jacob Williams, instructor Centerview Technical College (City, State) (555)-303-4452 [office] jwilliams@cvtc.edu</p> <p>Miranda Knight, owner Saucy's Pizza (City, State) (442)-821-7092 [cell] miranda@saucyspizza.com</p> <p>Evangelista Carlos, instructor Spanish department Toonica High School (City, State) (920)-826-3302 [office] e_carlos@ths.edu</p>

Note how the reference page, just like the résumé, begins with the applicant's name, address, and full contact information. The goal here is to leave no doubt whatsoever in the employer's mind who you are and how to contact you!

It is common practice for employers to check references, but even so it is customary to omit the reference page when submitting your résumé and cover letter. When the time comes to check references, the employer will contact you to request references. You should always bring a copy of your reference page, as well as other supporting documentation¹², to any interview.

Similar to references are *letters of recommendation*. Such a letter is written by someone with the same qualifications as a reference, who explains clearly in their letter why you should be considered for employment. Letters of recommendation are typically generic, and therefore suitable for any job

¹²e.g. Unofficial transcripts, attendance records, awards and recognitions, project portfolios.

you might apply for. You would not, for example, request multiple letters of recommendation be written by the same person, each one targeted toward a different job.

Beware anyone who offers to sign their name to a letter of recommendation you write for yourself. A letter of recommendation needs to be an honest account of your capabilities written by someone who cares enough to take the time, not a self-assessment made to look like someone else's attestation. If someone offers to sign a letter you write for yourself, decline the offer and find someone else who is willing¹³ to invest the time in writing their own letter of recommendation for you. Make copies of any letters of recommendation so that you will not have to approach the letter-writer(s) to ask for more should you need them for additional job applications.

One final note on the subject of references: after obtaining each reference's permission and providing them with a copy of your résumé, *leave them alone*. Do not contact them later to ask whether or not they have been contacted by any employers. Do not ask them to divulge questions they were asked by the employer(s). Send them a thank-you card once you are hired if you wish, but meanwhile trust that each of them will represent you fairly and honestly, and that they will contact you if necessary.

¹³Think about this carefully for a moment. Why would you trust someone to represent you well if they are so lazy and/or unethical they won't even write you a short letter to help you get a job? If you need further reason to reject this unwise course of action, consider what will likely happen if the employer decides to contact the supposed author of that recommendation letter to clarify specifics. A reference will remember what they wrote, but probably won't remember what *you* wrote, and this will become painfully evident during that conversation.

6.3 Cover letter examples for recent graduates

Here is an example of a good cover letter for a recent graduate of an electronics program, with no prior work experience, applying for a job at a radio communication business.

4321 Main Street
Blue Falls, OH 43001
(123)-555-2121 doug_c_tanner@hotmail.com
July 14, 2017

Ms. Elaine Carter
Director of Human Resources
Plumbum Communications, LLC
8822 Midvale Road
Venada, OH 43004

Dear Ms. Carter,

Last week I read the posting on Indeed.com for an RF technician at Plumbum Communications. Electronics Technology is my focus of study at Centerview Technical College, detailed in my enclosed resume.

I was interested to learn that Plumbum Communications provides two-way radio systems service to all of our local law enforcement and emergency services organizations. In addition to the interesting technical challenges I'd experience at Plumbum, I am also motivated to help those organizations our community most depends on during its times of need. My interest in public service began when I became a member of the Blue Falls Amateur Radio Club four years ago, providing volunteer communications during our local "Head To The Hills" relay race event.

You may reach me by email or phone, ideally between the hours of 3:00 PM and 6:00 PM when I am between school and work. I look forward to the opportunity of being considered for this position, and will contact you in 7 to 10 days to follow through.

Sincerely,
(Signature)
Douglas C. Tanner

Enclosure

Let's review the good features of this cover letter:

- Note the proper business letter format: the writer's full address and contact information on top, followed by the recipient's name, title, and full address, followed by a professional salutation ("Dear . . ."). The letter ends with the word "Sincerely" followed by a handwritten signature and the writer's printed name. The word "Enclosure" reminds the reader of the résumé referenced in the body of the letter. If this letter were to be electronically communicated to the Human Resources department (e.g. email, fax) rather than printed on paper, the proper word at the end would be "Attachment" rather than "Enclosure".
- Note the perfect spelling and grammar throughout.
- Note how only two of the sentences begin with a first-person pronoun: and "I".
- The **first paragraph** opens with a brief explanation of how the writer first learned of the open position and why they believe they are qualified for it.
- The **second paragraph** explains why the writer is choosing to apply for this particular position at this particular employer: *specifically why the writer wishes to work for this company.*
- The **third paragraph** expresses appreciation and provides details regarding future contact between the writer and the recipient.

This cover letter example, while certainly acceptable, may be improved by elaborating on one's *desire* for the career/employer/location, beyond simply expressing interest and qualification:

- A declaration of interest in the general career (i.e. *what is it, generally speaking, about a career in electronics that excites you?*).
- A declaration of interest in the geographic area (i.e. *why do you want to live in this area?*). This is remarkably important for many employers to know, because an affinity for living in a particular region is a generally reliable indicator of long-term employment.

Here is an example of a not-so-good cover letter for a recent graduate of an electronics program, with no prior industrial experience, applying for a job at the same radio communication business:

7324 Main Street
Blue Falls, OH 43001
(123)-555-3333

Director of Human Resources
Plumbum Communications, LLC
8822 Midvale Road
Venada, OH 43004

To Whom it May Concern,

I saw the Indeed.com posting for a radio tech at your company and I want to work for you. I study electronics at Centerview Technical College. I like to play around with circuits.

I am a very hard worker and fast learner. I know I would do an epic job for you if you hired me. I earned high grades in school and I studied really hard. In school I learned about circuits, Ohm's Law, series, parallel, bridge circuits, transformers, inductors, resistors, capacitors, diodes, SCRs, transistors, integrated circuits, AND gates, OR gates, opamps, bias, linux, oscilloscopes, oscillators, function generators, NIST, autocad, sensors, soldering, power, three phaze, terminal blocks, fuses, breakers, resistors, switches, relays, connectors, breadboards, chips, etc.

Plz call me at 123-555-3333 as soon as you can because I want to interview for this great position and I thank you for your time and attention because I know you must be a really busy person with a ton of responsibilities and you have lots of other people to interview to. Have a great day!

Yours truly,
(Signature)
Samantha L. Goebels

Let's review this train-wreck of a cover letter:

- Nowhere does this cover letter convey *why Samantha wishes to work for the company*.
- The quality of writing is quite poor in general, with run-on sentences in addition to unusually short sentences.
- Note how many sentences begin with the first-person pronoun "I".
- Note the spelling errors: *phaze* instead of *phase*, *to* instead of *too* (after the word "interview").
- Note the use of informal, non-business terms such as *Plz* instead of *please*, *ton*, *lots*, *tech*, *epic*, and *play*.
- Note the self-assessment statements (e.g. "I am a very hard worker and fast learner") which are inappropriate because they originate from a biased source (the author).
- The list of topics is formatted as a run-on sentence, and belongs in a résumé anyway rather than a cover letter.
- The casual tone of the letter is entirely inappropriate in business: e.g. "Yours truly" instead of "Sincerely" at the close, the overly-friendly "Have a great day!" at the end.
- Note how the letter is not addressed to anyone in particular. If at all possible, identify an appropriate *individual* at the company and address the letter to that person. If this is not possible, at least address the letter to the *title* of that person (e.g. "Dear Director of Human Resources,"). Never address your cover letter to an anonymous pronoun (e.g. "Whom", "Sir", "Madam", etc.).
- The letter does not end with a reminder of an enclosed or attached résumé. Remember, if you are sending the letter and résumé as printed (paper) copy, the cover letter should read "Enclosure" at the end; if sending electronically rather than by paper it should read "Attachment".

Unlike résumés which are very succinct summaries of educational and work experiences, a cover letter must actually be a *letter* written in such a way as to convey genuine interest on your part and an appropriate level of respect to the recipient and to the company at which you hope to eventually work. As mentioned previously in this tutorial, a well-written cover letter should sound good when read aloud. This letter clearly fails that test.

Many students find cover letters difficult to write because they are unaccustomed to writing in general. This is a sad commentary on the state of our public education system that so many high school graduates cannot craft a professional letter. This deficit is also easily remedied through regular practice: write often and solicit feedback from good writers you know. Our internet-connected world offers many ways to practice writing, and I would encourage everyone to treat every email message and every post they write on social media as an opportunity to practice a more formal and grammatically correct style of writing. *This is a skill born of practice*, so start today!

6.4 Job description examples

A *job description* is a formal declaration of basic responsibilities, required qualifications, and other information specific to a particular position of employment at a company. These vary considerably from employer to employer, but all contain some common information. In order to write your résumé and cover letter to target a particular job, you will need to reference the posted job description to identify skills and other qualifications necessary for consideration. Job descriptions also provide some of the information necessary for you to make an informed decision on whether or not you would even want to work in that capacity.

Perhaps the most misleading element of any job description within the field of electronics is the section describing *required* qualifications. Unlike the job summary which is typically very accurate, the “required” qualifications are often more flexible than the job description might suggest. Contributing factors to this flexibility include the technical diversity of technician jobs, the shortage of qualified applicants, and often a lack of clear understanding from the employer’s perspective on what makes a person qualified¹⁴. At large companies where electronics is a well-understood field and where multiple technicians are already hired, this may not be so much of a problem, but at smaller companies where few technicians are employed and electronics duties are often blended with other maintenance duties, the company is more often than not willing to compromise on their “required” qualifications in order to get anyone who can do the job at all.

One of the most flexible qualification parameters is *work experience*. While some companies maintain a hard line on minimum work experience, most employers are willing to consider a talented applicant with less experience than what is stated in the job description. In fact, have lost count of the number of fresh graduates who have landed jobs with experience requirements such as “5 years minimum”!

Some qualifications, however, are much more rigid. Requirements for specific certifications such as state electrical licenses, security credentials, and licenses specific to the industry (e.g. operator licenses for water treatment, nuclear power plants) are non-negotiable for maintaining¹⁵ employment.

The majority of job descriptions you read will likely bear no mention of pay. Some will simply say *DOE* (Depends On Experience), while others say nothing at all. This means you will need to decide whether or not to apply for the job based strictly on the duties and challenges it provides. Of course, compensation *is* important, but most employers don’t want that being the sole criterion by which someone decides to apply and so they choose to omit it from their job descriptions.

¹⁴I have had conversations with employers who list the possession of a Bachelor’s degree a “necessary” qualification for their technicians, and the reasoning usually goes something like this: they tried advertising for technicians, and nobody they interviewed with a two-year degree was qualified enough, so won’t four-year degree holders be better? The fact is that Bachelor’s programs are predominantly focused *engineering* rather than hands-on technician work, and so it is the rare four-year engineering graduate who would do well as a technician. This is precisely why I have found myself having these conversations to begin with: these employers got frustrated at not finding qualified people even after raising the academic bar on their required qualifications.

¹⁵However, some employers will be flexible on possession of said licenses or credentials upon *initial hire*. A good example of this is with trade licenses, which may be waived for a specified period of time to allow the new employee to gain the experience necessary to qualify for that state license, after which they must maintain that license to remain employed. Electrical licenses are a prime example of this, because it is frankly difficult to find licensed electricians possessing a robust knowledge of electronics. As such, many technicians get employed with the proviso that they obtain their state electrical license within a set time, their tasks during that probationary time apprenticeship-level duties not explicitly requiring the license.

One more note: do not be surprised to find job descriptions with spelling errors, grammatical errors, and other problems. While it may seem grossly unfair to have your résumé and cover letter scrutinized for grammatical correctness while applying for a job where the Human Resources department obviously didn't even bother to run spell-check on the document before posting, this is simply the way of the world. *Get used to it.*

Here is an example of a multi-page job description for an electronics technician working at a manufacturer of electronic flight-control systems for aircraft:

Electronics Technician 1

DEPARTMENT: Research and Development

REPORTS TO: Electrical Engineering Manager

FLSA STATUS: Non-Exempt

SCHEDULE:

Day shift, subject to change according to business needs. Some overtime required during testing phase of new product development.

JOB SUMMARY:

Perform routine technical functions related to the design, testing, and troubleshooting of new flight control systems.

ESSENTIAL FUNCTIONS, DUTIES AND PERFORMANCE RESPONSIBILITIES:

- * Work from schematics, diagrams, written and verbal descriptions, layouts or defined plans to perform routine testing, checkout, troubleshooting, and simple developmental engineering tasks.
- * Identifying appropriate test points within both analog and digital systems.
- * Execute functional and conformance tests on new products.
- * Diagnose and isolate malfunctions down to the component level.
- * Conducts defined engineering tests and collects data as assigned. Utilizes common test equipment such as DMM's and capacitance/inductance meters.
- * May support SMT activities such as applying solder paste, loading parts feeders, programming pick and place machines, inventorying parts kits, reflowing parts in oven, and manual assembly such as epoxy mixing and application.
- * Write reports to document system failures, remediations, and diagnostics.

JOB SPECIFICATION/QUALIFICATIONS:

Education:

- * Required: High School diploma or GED
- * Preferred: Associate Degree (AA) in electronics and/or strong electronics background with the ability to troubleshoot to component-level

Experience:

- * Required: Minimum one year electronics experience
- * Preferred: IPC J-STD-001

Knowledge:

- * DC and AC circuit theory
- * Discrete and IC amplifiers
- * Servomechanisms
- * Test equipment usage (DMM, oscscope, curve tracer, LCR meter)
- * Signal shielding and cable termination types
- * Digital logic and microprocessors

Skills:

- * Strong schematic interpretation skills
- * Written and verbal communication at all levels of the organization
- * Ownership of the process from start to finish
- * Familiarity with Acculogic Flying Scorpion Probe Tester preferred

Physical Requirements:

- * Must be able to work at a bench for long hours.
- * Must be able to handle small SMT components.

COMPENSATION AND BENEFITS:

- * Pay DOE
- * Excellent benefit package available: medical, dental, vision, disability, life insurance, FSA, vacation, PTO, holiday pay, 401k subject to applicable eligibility and waiting periods.

Let's review some of the salient points of this job description, shall we?

- First, note the *FLSA* status. This refers to the Fair Labor Standards Act of 1938, which among other things defines whether or not an employee is eligible for overtime pay. A “non-exempt” employee is entitled to overtime pay as stipulated in the FLSA if they exceed their normal working hours, while an “exempt” employee does not enjoy that protection afforded by the FLSA. We can see in this case that the job is non-exempt, which means any overtime worked must be accompanied by overtime pay (at a rate equal to 150% the normal hourly wage, which is often called “time-and-a-half” pay).
- Note some of the other acronyms found in this job description: *DMM*, *SMD*, *IC*, *LCR*, etc. It is incumbent upon you to research what these mean so that you may fully understand what the job description is saying. General internet searches are often the most useful way to define acronyms, although you will likely have to apply educated guessing in order to determine which definition best fits, as many acronyms have multiple uses. Some of these terms are common throughout a range of industries (e.g. “DMM” means Digital Multi-Meter; “SMD” means Surface-Mount Device; “FSA” means Flexible Spending Account which may be used to for health care expenses; “PTO” means Paid Time Off) while other are more specialized (e.g. “IPC J-STD-001” refers to a particular standard for printed circuit board soldering).
- This job seems to be limited to bench-work and routine operation of automated soldering equipment, suitable for an entry-level electronics technician.
- The work experience threshold is quite modest, asking for only 1 year of experience in electronics. This bodes well for fresh graduates, who may be able to negotiate based on a solid track record in school (managing complex projects) and/or a solid work record in some other job.
- Communication with technical and non-technical personnel alike is important to this job. This means you will be scrutinized on your ability to clearly convey thoughts, expectations, and ideas. If your résumé, cover letter, or interview betrays inaccuracy, confusion, or lack of clarity, you will have a hard time convincing them to hire you.

Next up is a job description that is *not* appropriate for a technician:

Standard Oil -- I&E Reliability Engineer -- Otisville Refinery

FLSA STATUS: Exempt

DESCRIPTION:

The I&E Reliability Engineer provides technical support for routine maintenance of the refinery's electronics and electrical assets while improving these areas. This position requires a proven problem solver and equipment owner serving as the site's leading technical resource for electrical infrastructure.

RESPONSIBILITIES:

- * Participating and promoting all aspects of refinery safety programs.
- * Visibly demonstrating commitment to workplace safety and the health of employees and contractors through personal engagement and sound decisions.
- * Maintaining the site's Electrical Safety Program and ensuring on-going compliance with NFPA 70E and regulatory codes.
- * Providing routine maintenance engineering and troubleshooting support for electronics, analyzers, and electrical equipment.
- * Overseeing the electronics asset base which includes field measurement sensors, transmitters, analyzers, Honeywell Experion DCS, and control valves.
- * Overseeing the electrical asset base which includes medium-voltage transformers, distribution lines, circuit breakers, electrical motors up to 5,000 HP, disconnects, power factor correction capacitors, batteries, generators, lighting, heat tracing, motor control centers (MCCs), and protective relays.
- * Creating and evaluating preventive maintenance plans, procedures, and training programs.
- * Designing, recommending, and implementing new equipment solutions.
- * Evaluating and recommending improvements to critical spares inventory and storage solutions.
- * Ensuring electrical design specifications, construction, and testing of electrical equipment are in compliance with electrical codes, regulations, standards, and company-wide good engineering practices.
- * Maintaining and reviewing electrical power coordination for the refinery including load flow, voltage drop, relay settings, motor starting, arc flash, and equipment duty using software models.
- * Ensuring schematic drawings and NEC 500 area classifications are up to date.
- * Participating in knowledge share with other sites within the company by serving as the site's core member in both the electrical and electronics networks, and serve as a primary contact with the electrical utility provider.

- * Effectively communicate and engage with other functional groups at all levels from craftpersons and operators to refinery management.
- * Initiate and evaluate Management of Change (MOC) process and also lead and assist with incident investigations.

BASIC QUALIFICATIONS:

- * Legally authorized to work in the USA.
- * Bachelor's degree in electrical engineering from an ABET-accredited program.
- * 2 or more years of power experience within an industrial environment.
- * Intermediate level of working knowledge of NEC and NFPA 70E.
- * Must currently hold or be able to qualify to receive a Transportation Worker Identification Credential (TWIC) card. Note, information regarding TWIC qualification standards may be found at www.tsa.gov/whatwedo/layers/twic/index.shtm
- * Ability and willingness to perform/comply, with or without a reasonable accommodation, with the following: climbing, standing, crawling in confined space areas; maneuver through process areas containing pumps, towers, compressors, and piping systems; wear refinery required Personal Protective Equipment (PPE); work in outside weather conditions including cold and heat; maintain shaven face daily so that a respirator/face mask can seal properly; be available for on-call support 24/7/365.
- * Possession of a current state Driver's License.

PREFERRED QUALIFICATIONS:

- * Professional Engineering (PE) license.
- * Maintenance experience with medium voltage power distribution systems and utilization equipment.
- * SEL, ABB, and GE digital protective relay configuration.
- * Ability to write reports, business correspondence, and procedure manuals.
- * Strong verbal, written, and interpersonal communication skills.
- * Demonstrates strong problem-solving skills.
- * Accepts ownership, is accountable and delivers on commitments.
- * Strong technical knowledge and ability to apply practical field solutions.
- * Ability to work effectively with standard computer applications involving word processing, spreadsheets, and relational databases.
- * Ability to work extended shifts and respond to after-hours call outs.
- * Experience working with both electronics and electrical equipment.

In order to be considered for this position you must complete the entire application process, which includes answering all pre-screening questions and providing your eSignature on or before the requisition closing date.

Candidates for regular US positions must be a US citizen or national, or an alien admitted as permanent resident, refugee, asylee or temporary resident under 8 U.S.C. 1160(a) or 1255(a)(1). Individuals with temporary visas such as E, F-1, H-1, H-2, L, B, J, or TN or who need sponsorship for work authorization now or in the future, are not eligible for hire.

Standard Oil is an EEO and Affirmative Action Employer of Females/Minorities/Veterans/Individuals with Disabilities.

Requisition ID: 84331

Department: Otisville Refinery

Location: United States

Job Field: Engineering

As previously mentioned, this job description does *not* fit that of an electronics technician. I show it in order to help distinguish electrical/electronic engineering work from technician work, which unfortunately tends to be blurred in some industries. Let's see why this particular job description fits engineering better than technician work:

- Perhaps the clearest clue that this is a bona fide engineering position and not a technician position is the basic qualification of a Bachelor's degree and the preferred qualification of a Professional Engineering (PE) license.
- Furthermore, the job description never actually states that the person will perform physical work with the equipment. The actual verbs used to describe the engineers work include *overseeing, designing, evaluating, and recommending* which are all more abstract than technician-centric verbs such as *testing, troubleshooting, and assembly*.
- Certain job responsibilities listed in this job description essentially *establish safety practices* at the worksite. An example of this is ensuring *area classifications* are kept up to date, which refers to hazardous areas (Classes/Divisions or Zones) used to define the potential for fire or explosion as the result of an electrical spark. A technician may need to ensure the correct (certified) equipment is used within these areas, but would never take action to *redefine* the boundaries of those areas within the plant. Another example is maintaining the site's Electrical Safety Program to ensure compliance with various codes. A technician is of course required to *follow* the site's safety protocols, but would never be responsible for single-handedly altering them as an engineer would have to do if non-compliance were determined.
- Certain job responsibilities imply a level of responsibility foreign to a technician's role. An example of this is serving as the site's *primary contact* with the local electrical utility.

It is interesting to note that many of the responsibilities listed in this electrical engineering job description overlap the responsibilities of many electrical/electronics technicians, so blurred are these categories in industry. These include: protective relay configuration, report writing, computer application use, accessing confined spaces and wearing PPE, working knowledge of NEC and NFPA 70E, troubleshooting, creating and evaluating procedures, and maintaining accurate documentation. The lesson here is that when evaluating a job description for appropriateness to your capacity as a technician, it is not enough to discover positive matches within the job description to your knowledge and skill set; you must also be looking for *clear and unambiguous mis-matches*¹⁶ where you would most definitely *not* be qualified for the job.

¹⁶One of the most difficult mis-match to identify is the requirement for a four-year Bachelor's degree. One would think this would be an immediate disqualifier for a graduate of a two-year Associate's degree program in electronics, but I have seen enough two-year electronics graduates obtain jobs listed for "four-year" degree holders to give me pause on this point. Now, it is impossible to obtain a state engineering license (PE) with only a two-year degree, but if the possession of that license is not an absolute requirement, some companies are willing to let a two-year graduate do engineering work.

The following job description is one more suited to a technician, although it carries the title of Engineer:

JOB SUMMARY:

Voltron Industries is a dynamic company in the field of health, agricultural, and performance chemicals. Our culture is built on mutual trust and respect for all employees so that we can focus on providing the best products and solutions to our customers.

Voltron Industries is currently seeking an Automation Engineer to work out of our Washburn manufacturing facility. This position is responsible for troubleshooting, calibration, upgrade, and repair of sensors and control systems regulating flow, pressure, temperature and level. This position is also responsible for the installation and maintenance of all plant electrical equipment and wiring systems.

RESPONSIBILITIES:

- * Assist Engineering Manager with project work to include PLC program development, assembly and maintenance.
- * Configure, calibrate, install, and troubleshoot the following electronics: Level, Pressure, Temperature, Flow, Switches, Relays, Solenoids, and Valve positioners from various manufactures.
- * Diagnose problems in 480 volt three-phase motor control circuits.
- * Comply with Lockout-Tagout (LOTO) Program and all relevant safety codes.

QUALIFICATIONS:

- * Degree in Electronics, electronics, Electrical Engineering Technology or a related field.
- * Prefer candidates with 3+ years field experience with electrical and mechanical controls.
- * Must be able to read, follow, and markup electrical drawings and electronic schematics.
- * Expected to work with Engineering in PLC development, assembly and maintenance.
- * Understanding of Ethernet networks, switches, and hubs.
- * Experience with Toshiba VFDs is a plus.

Clues indicating the suitability of this job to a technician rather than to an engineer include the following:

- Diverse degrees accepted for the job (Electronics, electronics, *or* Electrical Engineering Technology¹⁷)
- The job tasks are almost all hands-on activities: *troubleshooting, calibration, repair, etc.*
- Expectations are that this person will *work with* Engineering suggests there is a separate Engineering department at this facility populated by degreed (and perhaps licensed) engineers.

¹⁷The inclusion of Electrical Engineering *Technology* is a strong indication that they are *not* looking for a full engineer. These “technology” degrees are considered insufficient for engaging in the Professional Engineering license process (FE and PE exams), and anyone unqualified to take the FE/PE exams cannot be considered an “engineer” in the fullest sense of the word.

Chapter 7

Interviews and the Screening Process

Let's begin with an honest admission: *interviews are about as much fun as dental surgery*. The reasons for this fact are not difficult to grasp. Few circumstances in life subject you to more scrutiny at the hands of complete strangers than a job interview. Given the typical number of applicants to any one open position, your odds of landing the job based on head-count alone are not good either. Add to this unsavory mix the novelty of the interview process and you have a situation no sane person looks forward to.

There is reason, however, to take heart. Like dental surgery, job interviews are experiences most people in life have not only survived, but have actually managed to emerge in a better condition than when they entered.

Interview questions take two general forms: *technical* and *behavioral*. Technical questions focus on all the trade-specific knowledge and skills you should have learned in college (or from self-study, or from previous employment). Behavioral questions focus on general “soft skills” such as teamwork, time and resource management, organization, work ethic, and attitude. The balance between technical versus behavioral questions in any interview seems to be random – some employers exclusively ask behavioral questions, others are almost entirely technical, but most are a mix.

Like any performance art, successful interviewing is a test of composure and stress-management skills. As an performer knows, dedicated *practice* is the key to gaining confidence. Fortunately for job-seekers, a variety of resources exists to help prepare for interviews. Employment agencies often offer *mock interviews* for those desiring more confidence during interviews. If you are enrolled in a school preparing you for employment, the Career Services department of your school more likely than not offers the same. Another resource is to simply have your friends and/or family stage a mock interview for you¹.

¹The last time I applied for a job, I had two good friends do this for me. Even though their questions were not technical, they were still able to query me with challenging behavioral questions and also give valuable feedback on my performance. One such detail they noted was that I had a bad tendency to fidget with my wedding ring as I answered questions. Thanks to their help, I successfully avoided this habit during my real interview!

Aside from practice, another helpful strategy is to enter your interview(s) fully *prepared* in terms of what to say. You should carefully study common behavioral questions asked during interviews, as well as know your résumé and cover letter extremely well. You should always bring extra copies of your résumé and cover letter just in case any people on the interview panel lack copies of their own, plus your reference page and any other supporting documentation such as letters of recommendation and project portfolios.

7.1 Sample technical questions

Here is a list of sample technical questions related to electronics. Note that many of these questions are purposefully vague, so that they may support multiple correct answers depending on the context in which they are interpreted. This is by design, as the interviewer(s) want to know what your *assumptions* are as much as they want to test your *knowledge*²:

- Describe the purpose and steps involved in configuring the *trigger* settings on an oscilloscope.
- Explain what *hysteresis* is.
- Explain how *fiber-optic cable* works.
- Explain what *RS-232* is.
- Explain what *negative feedback* is.
- Explain what *positive feedback* is.
- Explain what *lockout-tagout* means, and why it is important.
- How do you switch the direction of a three-phase electric motor, and why does that work?
- What is a *VFD*, and what purpose does it serve?
- What is a “Lissajous figure” useful for?
- Describe how you would test a *transformer* for internal faults.
- Describe how you would test a *diode* for proper operation.
- Describe how you would test a *bipolar transistor* for proper operation.
- Describe how you would test a *field-effect transistor* for proper operation.
- Describe how you would test an *SCR* for proper operation.
- Explain the purpose of an *overload heater* in a motor control circuit.
- Identify multiple types of electronic sensors.
- Identify the consequences of improperly terminating a transmission line.
- Explain how a DC motor works.
- Explain how an AC motor works.
- Explain how *parity bits* function.
- Explain why a 50 Ω resistor in series with 30 Ω of inductive reactance does not make a total of 80 Ω .

²In all cases it is recommended to answer the questions as thoroughly as you can. Giving too short of an answer gives the impression you are afraid to elaborate for fear of revealing ignorance!

- Calculate the wavelength of a 150 MHz radio wave.
- Provide one example of a network theorem, and explain its usefulness.
- Define *tolerance* as it applies to electronic components.
- Explain what *arc flash* means, and why it is dangerous.
- Explain the difference between *common-mode* and *differential* voltage.
- Describe the effects of electric *shock*, and appropriate first-aid for it.
- How would you test the gain of an amplifier?
- What kind of electricity comes out of a standard wall receptacle?
- Explain why power transformers sometimes experience inrush when initially energized, but not every time.
- What is an FFT and what is it used for?
- What is an “eye diagram” useful for?
- What is a “Karnaugh map” used for?
- Sketch a diagram for a *full-wave bridge rectifier* circuit.
- Explain what *CMRR* is, and identify the type of electronic component it applies to.
- Design a voltage divider with a ratio of _____.
- How would you test the cutoff frequency of a filter built by someone else?
- Explain why it is generally bad to connect an ammeter in parallel with an electrical source.
- Explain why it is generally bad to connect a voltmeter in series with an electrical source.
- Identify the color-code pattern for a 33 k Ω resistor.
- Describe how to properly terminate a wire prior to inserting it into a terminal.
- Identify multiple reasons why two devices connected together on an Ethernet network might fail to communicate with each other.
- Explain what *aliasing* is, and how to avoid it.
- What is an MOV used for?
- How would you test for “switch bounce” in a digital logic circuit?
- Describe the diagnostic steps you would take to troubleshoot _____.
- Explain why we always use *flux* when performing electrical soldering.

- Examine this schematic diagram (provided at the interview) and identify all errors you see in it.
- Examine this schematic diagram and predict the amount of voltage/current you would expect to measure *here*.
- Convert the decimal number _____ into binary format.
- Calculate the necessary size capacitor to connect in series with a 22 μF capacitor to achieve a total capacitance of 18 μF .
- Explain how to use a multimeter to locate a short between two wires of a multi-conductor cable.
- Explain how to use a multimeter to locate a open along a wire of a multi-conductor cable.

It is important to realize that you will most likely be asked some technical questions beyond your ability to answer, at least while sitting in the interview room. The interviewers' job is to push you to the limits of your technical knowledge, and it is your job during an interview to handle this inquisition with grace. Just because you cannot answer *all* their questions doesn't necessarily mean you won't get the job! If you find yourself stumped by a technical question, a good way to respond is to tell them you don't know the answer (yet), but then go on to explain how you would go about answering it. Hint: doing a Google³ search is not the answer they want to hear!

³Internet search engines are very useful tools, but widely over-used. Doing this as a first, or worse yet *only* step is a lazy person's answer. It is better to refer to a specific technical reference you know is related to the question at hand, such as one of your textbooks, or to a user's manual, than to trust an internet search engine for the information you need. Be aware that many employers are aware of this habit and generally look upon it with disdain. One employer in particular told me he has no interest in hiring *Google techs*, meaning technicians who rely exclusively on internet search engines like Google to acquire new information.

7.2 Sample behavioral questions

Here is a list of sample behavioral questions you may be asked during an interview for a technician position, but are actually generic to most jobs. Perhaps the most important element of your response to most of these questions is that it must refer to a real event in your life, not an hypothetical answer⁴. This is true even if it sounds like the question is hypothetical! In other words, the interviewer wants to *know* how you actually behave, not how you *think* you would behave, or how you would *like* to behave. Any relevant scenario from your life is permitted – it does not have to be an event from the workplace if you have never encountered such a thing on the job:

- Identify specific strengths you would bring to this job.
- Describe a situation where you changed your mind about something very important.
- How do you handle disagreements with colleagues?
- What do you do when things are slow at work?
- What is your approach to managing conflict between people?
- Suppose you needed to research information needed for completing a job. What resources, besides an internet search engine, would you consult?
- Tell me about a situation where you made a big mistake, and what you did afterward.
- What would you do if you became aware of a co-worker stealing from the company?
- Describe how you are able to tell when a job you've completed is well-done.
- What is your experience working in teams?
- Describe your favorite ways to learn new information or new skills.
- Explain how you are able to effectively manage long-term goals.
- Describe your ideal of a workplace leader.
- How do you cope with a co-worker who is under-performing in his or her job?
- Identify the types of people you find difficult to work with, and explain why.
- Identify the types of people you find easy to work with, and explain why.
- Have you ever had to complete an important task without leadership from others to guide you?
- Describe a situation where the scope of a project you were involved with changed significantly over time, why that was, and how you handled that change.

⁴There are some questions which are obviously hypothetical. The question “How do you see your role as a technician fitting into the larger vision of the company?”, for example, requires an hypothetical answer because you do not yet work as a technician at that company!

- How do you identify and maintain priorities?
- Describe your typical schedule and study habits during school.
- What do you expect to achieve during your first 30 days of working here?
- Describe how your contributions at your last job improved the business from what it was before you were hired there.
- Where has teamwork proven most effective on the job? What factor(s) led to this happening?
- Describe a project initiated and managed by you. Were others involved? If so, how many, and what were their roles in completing the project?
- Have you ever seen a team become ineffective? What factor(s) led to this happening?
- Have you ever been given an impossible task? If so, what was that task and how did you handle it?
- Have you ever had to make an unpopular decision on the job? What was it, and how was that tension resolved (if at all)?
- Describe your ideal for professional development.
- Where do you see your career heading in 5 to 10 years?
- How do you manage stress on the job?
- Describe an incident where a plan of yours failed, and explain how you were able to recover from that failure.
- What inspires you to do your very best work?
- Describe how you would proceed to write a Standard Operating Procedure (SOP) for testing an electronics system.
- Have you ever needed to persuade a co-worker to do something necessary that they didn't want to do? How were you able to accomplish that?
- Describe a work situation in which you felt uncomfortable.
- Have you ever held a position of authority over others?
- Describe a condition where extra work is necessary to truly complete a job.
- How much follow-up documentation would you define as being "a lot" to do upon completion of a task?
- Have you ever had to be the bearer of unpleasant news on the job? What was the news, and how were you able to effectively deliver the news?
- Describe a situation where you were proven wrong. What was the topic, and how did you handle this?

- What are some of the most important things you have learned through work?
- Identify information that you would consider *privileged* or *confidential* on the job.
- How do you define *respect* on the job?
- Is there a time you ever disagreed with your immediate supervisor? What was that disagreement about, and how did you handle it?
- Describe some of the challenges faced when managing purchases and expenses on the job.
- Describe what you enjoyed least about your previous job.
- Describe what you enjoyed least about school.
- How do you verify that someone has clearly understood instructions you have given to them?
- Describe a “healthy” workplace culture.
- Identify a workplace situation in which negotiation would be considered appropriate.
- Identify a workplace situation in which negotiation would be considered inappropriate.
- Suppose you need to give instructions to an adult on how to use a telephone, when that person has never seen or heard of a telephone in all their life. What would you say to them?
- Describe a situation where miscommunication led to problems on the job. What, specifically, could have been done differently to avoid the problem?
- Have either your words or intentions ever been misunderstood on the job? If you could go back in time and change what you said or did, what would you do differently?
- Describe a situation where you made an extraordinary contribution on a job.
- What do you consider to be your greatest accomplishment?
- Describe a situation where you helped to resolve an interpersonal conflict. How did you accomplish this feat?
- How comfortable do you feel presenting in front of large groups?
- Describe a situation where workplace politics were a major factor.
- Explain how to coordinate multiple busy peoples’ schedules to be able to work together.
- Suppose you need to explain something complex about electronics to a non-specialist. How do you communicate this information to someone unfamiliar with the terms and principles? How do you ensure they have understood what you told them?
- If there was one thing you could change about your last job, what would that be, and why?
- Have you ever been asked to do something on the job you believed was unsafe? Describe how you responded to that request.

- Have you ever been asked to do something on the job you believed was unethical? Describe how you responded to that request.
- How do you see your role as a technician fitting into the larger vision of the company?
- What is your greatest weakness?⁵
- Have you ever been convicted of a crime?

A useful model for responding to questions of how you have handled actual challenges is called the *STAR* method, and it consists of explaining the following four things: the *Situation* requiring attention, the general *Task* you needed to complete, the specific *Action* you took in completing this task, and the *Result* of all your efforts. This should not be too formulaic in your responses, but it is important to address all those points with each of your answers.

Here is an example of an inexperienced graduate might use the STAR method to answer a typical behavioral question related to work, even though they have no actual work experience: *How do you manage stress on the job?*

“I’ll relate an experience managing stress at school, because I don’t yet have any job experience. Six months ago I was assigned a very challenging project: programming a microcontroller to count the number of objects passing by on two different conveyor belts, and make speed adjustments to one belt so that their rate of objects delivered per minute would be the same. At that same time I came down with a bad cold and was having trouble sleeping because I was so congested. This combination stressed me out really bad. I knew this project was important, and that I needed to get it done by the deadline even though I was sleep-deprived. In addition to taking a decongestant to help with my sleep, I found ways to take short naps between classes, and I also cut out television from my life to give me more time to work on the programming problem. I also found comfort by talking with close friends who had gone through similar stressful experiences when they were in college. At the end, I was able to get the rest I needed as well as finish the project in time. To be honest, I only earned a ‘B’ grade on that project because there were some documentation details I ran out of time to complete, but I feel very good about being able to manage the stress of that time.”

Note the four elements of STAR present in this answer:

1. **Situation:** Challenging school project plus a bad cold leading to stress
2. **Task:** Getting the work done, getting more sleep
3. **Action:** Take medicine and daytime naps, cut out television from life, talk with friends
4. **Result:** Project completed, less stress!

⁵Despite this being a commonly asked question during job interviews, I have heard some professionals debate whether or not this is truly beneficial to ask. Given the rather obvious fact that most people feel extremely uncomfortable revealing their most significant flaw to complete strangers, this question seems useful only if your intention is to determine how well the applicant is able to lie. First, remember that the question deals with *work* and not your personal life – you are never under any obligation during an interview to reveal private information. Choose something you have found to be a significant challenge on the job (or in school, if you have no prior work experience) and describe that challenge, being sure to follow up with effective strategies you have applied to overcome that problem. My personal favorite (sarcastic) response to this question? *My greatest weakness is impatience with foolish questions!* Feel free to say this, of course, only if you don’t care about getting the job!

7.3 Inappropriate and/or illegal questions

Some types of questions should *never* be asked by interviewers. These include:

- Any question of an explicitly personal nature, unrelated to work. These include questions related to protected classes among others:
 - Race or Ethnicity
 - National origin
 - Religion
 - Medical condition or disability⁶
 - Gender
 - Sexual orientation or habits
 - Marital status
 - Pregnancy
- Questions about specific⁷ criminal convictions.
- Your age
- Your weight
- Questions about your friends or family
- Questions about controlled substance use (whether legal or illegal)
- Questions about why you left (or are leaving) your previous job

Although it is unlikely you will encounter any of these forbidden questions, it is good to prepare yourself anyway to handle this with professionalism. If you are very confident the question is illegal to ask or is wildly inappropriate⁸, you may simply reply that you don't believe that question is

⁶It is reasonable to ask the applicant if any accommodations will be required for them to perform the job, and it is appropriate for an employer to have you undergo a physical examination as well as a physical fitness test prior to offering employment.

⁷It should be noted that general questions regarding criminal status are permitted, and that background checks will likely reveal any such status.

⁸I have been blessed with a number of inappropriate and/or awkward situations during job interviews. During one interview, I was taken out to lunch where the interviewer did nothing but watch me as I ate. During another interview, I was flatly insulted by the interviewer who told me I had wasted my time enrolling at a technical college when I should have joined the Navy. During another interview, I was asked to analyze a simple RC (resistor-capacitor) circuit and was "corrected" by one of the interviewers whose suggestion to test that circuit would have resulted in capacitor exploding. At the start of yet another interview I found myself entering the interview room with a group of men dressed in dirty work clothes staring at me slack-jawed for having dressed in business casual attire. This same interview dwelt largely on thermocouple applications, with the men asking me repeatedly to describe any *real-world* work experience I had with thermocouples, and me replying every time that I was still a student and had not yet worked at a facility using thermocouples, but that I was ready and willing to learn. Please note that this interview was set up by my instructor at the technical school at least four months in advance of graduation, because he specifically recommended me to the employer. Needless to say, I didn't get that job, nor did I want it by the end of the interview. On a final note, I wrecked my car on the return trip when I hit black ice in the interstate and flipped the car in the median – just the "cherry on top" I needed after that interview!

relevant to the job. However, as you might guess there are many “grey areas” here where one version of a question is considered illegal yet another is considered appropriate. One example is criminal conviction: it is flatly illegal for an interviewer to ask you if you have ever been arrested for drunk driving, but it is permissible for the interviewer to ask whether you have ever been convicted of a crime. A good strategy to employ if you are ever faced with an interview question you *think* might be inappropriate but you’re not sure, is to answer the spirit of the question but not the letter of the question. For example, if you are a young-looking adult and someone asks you your age, you may reply that you are a “legal adult” rather than reveal your chronological age.

Furthermore, sometimes a questions that would be considered inappropriate for most job interviews is relevant for the particular job you’re seeking. These are referred to as *BFOQs* or *Bona Fide Occupational Qualifications*. While these are uncommon for technicians, they include examples such as age for careers such as working for the FBI as a Special Agent⁹.

7.4 Disclosure

A question I often receive from students preparing to apply and interview for jobs is the degree to which they should reveal details of certain misdeeds, especially legal troubles in their past. You will note, for example, that it is illegal for an employer to ask a prospective employee about a *specific* criminal conviction, but that does not mean they cannot ask a *general* question about a person’s criminal history. A significant number of students I’ve met have some incident in their past where they ran afoul of the law, usually some time during their younger and foolish years, and they are worried this may cause problems for them as they attempt to start a career in electronics.

The easy answer to this question is to simply “*Be honest*”. However, honesty and disclosure are not the same thing. To answer honestly is to give a factual answer to a direct question. Disclosure, on the other hand, represents a *volunteering* of information. An interview is not the time or place to be volunteering information that could damage your prospects of getting that job, but it is absolutely the time and place to answer all direct (and legal) questions with full accuracy.

If the employer in question is going to run a background check after the interview and prior to offering any position (as *most* do in this industry), it is wise to prepare yourself for answering more detailed questions about the result of that background check.

⁹At the time of this writing (2017) the FBI still maintains strict limits on age for Special Agents: between 23 and 37, with exceptions for older military veterans. And yes, the FBI *does* hire people with electronics skill-sets, working on advanced electronic communication and surveillance systems!

7.5 Confidentiality

When you interview with an employer, what is said within that room must be considered confidential information. It is literally nobody else's business but yours and the employer's, and should not be shared with any other employer or any other job-seeker. This is especially true given the fact that employers must be consistent when interviewing a batch of candidates for a job: many, if not all, of the questions asked during an interview will be word-for-word identical for each candidate. Sharing interview questions with anyone compromises the integrity of the interview process because it gives an unfair advantage to future candidates.

As an educator I need to be especially sensitive to this problem. My work brings me into contact with a wide range of employers, and has on occasions even placed me in the same room during interviews. I have also had employers consult me when crafting their own entrance exams, going so far as to use my open-source technical writings as exam question sources. Maintaining confidentiality is a responsibility I do not take lightly, because the consequences of breaching this trust are severe¹⁰.

¹⁰I was made aware of an instructor at a technical college years ago who blatantly violated this trust in the following manner: after one particularly high-profile employer interviewed his students, he would debrief those students to determine the exact questions they had been asked during the interviews. He would then compile this list of questions and give that list to students for their study. The result was a steadily increasing hiring rate with this one employer, because all of his students knew exactly what they would be asked . . . until one fateful year. Someone at the company decided to completely change all the interview questions, and that year when the employer went to the college to interview this instructor's students, hardly any of them passed the interview. The instructor panicked when he realized his students had been studying for the wrong interview, and in a breathtaking display of foolishness decided to wait outside the interview room to query the next student exiting. As it so happened, the person leaving the interview room wasn't one of his students, and rightfully balked at the instructor's request to divulge interview details. While this exchange was taking place (just outside the door of the interview room, no less!), one of the interviewers stepped out of the room to give this instructor a quick lesson in professional ethics. Shortly thereafter, that employer stopped interviewing students from that technical college.

7.6 Background checks

Although not strictly a part of the interview process, a background check usually takes place after a successful interview. Background checks may include any of the following criteria:

- Criminal records (local, State, and/or Federal)
- Traffic violations
- Sexual offenses
- Terrorist charges or watch-list status
- Drug screening
- Credit report
- Health care sanctions
- Education records
- Employment history
- Professional license and certification verification
- Social Security Number (SSN) verification
- Public social media posts

Remember that the field of electronics is one where personal integrity matters quite a bit because of the level of trust invested in each and every technician to do a very complex job with high stakes. What every employer looks for here is *good judgment*, which is why checks for criminal activities, traffic violations, and drug screening are commonplace.

Any thorough background check is very likely to reveal if an applicant has misrepresented themselves in terms of legal history, prior employment, education, etc., and so the applicant must be absolutely honest when asked to disclose such history. Nothing stops an application process in its tracks faster than an employer discovering the applicant lied about their background. Furthermore, misrepresentation discovered after an employee has been hired is sufficient basis for immediate termination.

Another form of background check imposed upon many technicians is the requirement to hold special security credentials as a condition of employment, with these credentials usually requiring their own background checks. A common security credential following the terrorist attacks of 11 September 2001 is the *TWIC* (Transportation Worker Identification Credential) administered by the TSA (Transportation Security Administration) and required of all who work on the sea or at a United States facility with its own sea port. TSA conducts its own background check as part of the screening process for each TWIC card holder.

Some electronics jobs have even more stringent security requirements, such as work within the nuclear industry. The Department of Energy (DoE) and the Nuclear Regulatory Commission (NRC) governing nuclear operations within the United States have their own security clearance processes

similar to those used by the US Department of Defense (DoD). The DoE “L-clearance” is equivalent to the DoD “Secret” security clearance, while the DoE “Q-clearance” is equivalent to the DoD “Top Secret” clearance. These security clearances are extremely detailed and strict, may require months to complete, involve interviews of friends and family members in addition to all the standard criteria screened in a regular background check, and typically cost the employer several thousand dollars to execute.

7.7 Drug screening

Abuse of alcohol and other drugs is a deal-breaker for most employers of technicians, and for rather obvious reasons. a technician needs to have a clear mind while on the job, and these substances by their very nature impair thinking. Furthermore, the abuse of these substances represents poor judgment, and as mentioned before employers only want to hire people with good judgment.

Drug tests are commonplace both during the screening process and on the job (at random intervals, or following a mishap on the job). Depending on the type of drug and the test involved, it is possible for the test to reveal drug consumption at a level of sensitivity that cannot distinguish between harmless recreational use and impaired function on the job. What you have to know is, *employers will assume the worst in every case*. If a hair-follicle test for THC (the intoxicating substance in marijuana) is sensitive enough to detect a single use *months* in the past, any employer looking at the results of that test will assume you used marijuana that morning.

This can get especially tricky when laws for certain substances are inconsistent, or inconsistently applied. At the time of this writing (2019), for example, marijuana is approved for recreational consumption by several states within the United States, but it is still a controlled substance in the eyes of the Federal government. When such a disparity exists, employers will often err on the side of the stricter law. This means someone who thought they were legally consuming marijuana might find themselves ineligible for a job in that same state.

Even a legal substance such as alcohol can be problematic for employment. Certainly, showing up at work while drunk will get you fired, but some jobs are so strict in their standards of decorum that even a single alcohol-related conviction (e.g. a “Driving Under the Influence” conviction) is enough to prohibit you from ever working there¹¹.

Another way people may cause trouble for themselves relating to drugs is by consuming drugs on someone else’s prescription. Pain-killers such as Vicodin are popularly prescribed by doctors to help patients manage chronic pain, and these prescriptions place controlled substances within reach of those close to the patient. “Borrowing” someone else’s pain medication is very risky because it is not cleared by a doctor *for your use*.

¹¹A great example of this is work in the nuclear industry where security clearances are required of technicians. One time an employer came to the college where I teach to recruit students, and their service was inspection of heat exchangers at nuclear power plants, a job for which security clearances were necessary of all their technician. The recruiter announced to the group of 20+ students that even a single DUI on their record would disqualify them from ever applying for that job. I swear, you could have heard a pin drop in that room!

Chapter 8

Growing your career

I have some good news and some bad news for you. Let's begin with the bad news: *there is no such thing as job security anymore*. The days of hiring in with a company fresh out of school and remaining there until retirement (earning a nice pension, of course) are long past. In our global economy where whole corporations are bought and sold on a whim, the economic landscape changes so rapidly that one cannot count on any employer to *always* have a job available for them.

What's the good news? Well, the next best thing to job security is *career* security, and this is much more attainable despite the uncertainties of the labor market. Simply put, "career security" means the ability to maintain one's own career despite forced changes in jobs. The field of electronics in particular tends to exhibit a very strong potential for career security because the skill set required to be a competent technician is applicable to a diverse set of job titles spread over a range of industries. Furthermore, a technician open-minded enough to continue learning new things easily adapts to related careers such as electrical power work, precision mechanical work, computer programming, data network management, quality control, and data analysis.

Maintaining career security does not come automatically for technicians, though. Like any career, it is possible to become too specialized, or simply close off one's mind to learning new things¹, within the field of electronics. This chapter outlines some helpful strategies for making the most of this amazing career.

¹Some jobs within electronics make this nearly impossible, as the basic job requirements force you to always learn new things. However, most jobs (regardless of field) will permit some degree of intellectual stagnation, and this erodes career security.

8.1 Building a career path

My general advice to anyone first entering this field, usually as they exit some college-based technical program, is to take the first electronics job that pays the bills and stay at that job for two years before considering a move elsewhere. Some college graduates make the mistake of being too picky as they look for their first job, passing up good opportunities as they wait for the “perfect” job to come along. This is a fatal mistake. Any graduate of *any* professional or vocational program should regard at their degree as having a one-year expiration date stamped on it. Waiting more than a year to secure a job in your chosen career field usually signals a lack of motivation to prospective employers. If you were hiring technicians for your enterprise, who would you prefer to hire: someone who landed a job immediately upon graduation, or someone from the same graduating class who took a year to accept their first position? All other factors being equal, the choice is obvious.

Once you have accepted your first job as a technician (or something closely related in terms of technology and required skills), you should adopt a sense of humility about your own value to the company. A fresh graduate of any electronics program is much more of a liability than an asset, simply due to everything they do not yet know about that industry and that facility (e.g. procedures, unique safety hazards, facility layout, management structure, policies, etc.). Learn everything you can about working safely and effectively, always knowing that your employer accepted a substantial amount of risk in hiring someone as inexperienced as you. This is one of the reasons behind my advice to remain at your first job for two years: *you have a lot to learn about the industry when you first graduate*, and this period will help give you the perspective necessary to make wise choices in the future.

Given the distinct likelihood you won't be working at your first electronics job until retirement, you will need to consider when to secure the next job in your career, and the next one after that. This, of course, depends greatly on the opportunities available to you: both in your current job and also in terms of what other positions are open. If your goal is to maximize career security, you should choose subsequent jobs on the basis of broadening and deepening your capabilities because this alone will raise your value in the technical labor marketplace.

Of course, what most often causes people to switch jobs is the promise of better compensation and/or quality of life. This is hard to argue with, as these are the principal reasons we work at all! If someone finds a new job paying far better, with better benefits, and/or a more desirable work schedule, why shouldn't they pursue it? One caveat to consider is the possibility of professional stagnation. Remember what I said about corporations being bought and sold on a whim? The threat of a great job being yanked away from you due to circumstances such as this which are beyond your control is very real. This threat is commonly realized in less-skilled careers: a person with little to offer in the labor marketplace happens to land a job with great pay and benefits, and proceeds to stagnate for many years. Then one day the rug gets pulled out from under their feet with the news that this great job is ending, and there they find themselves once again with little to offer in the labor marketplace but now with debt and other obligations incurred over years of living with a comfortable income. Although less commonly seen, this can happen to technicians too: you take a job offering great pay and benefits, and you decide to remain at that job long after you cease expanding your professional skill set, then one day you find yourself needing to find another job because your company is folding. Always bear in mind: *there is no such thing as job security anymore*. Plan accordingly.

The drive to maximize your professional knowledge and skill must be balanced against the hazard

of “job-hopping”. Remember, the goal here is to maximize your *value* as a technical service provider, and this value includes the quality of reliability. Someone who abandons a job at the first suggestion of new opportunities elsewhere will not be seen as reliable, and this makes them less valuable to anyone seeking stable employees. Again, my general advice to any graduating student of electronics is to take the first electronics job that pays the bills, and remain there for at least two years before considering a different job.

Of course, there are exceptions to nearly every rule, and the advice to remain at your first electronics job for two years is not etched in stone. It would make sense to leave a new job if the working conditions place you in an unreasonable amount of danger, if the employer is unethical, if the job turns out to be something very different from what was promised during the interview, etc. Just make sure if you are leaving your first job for the right reasons, and not just because you sense a better opportunity elsewhere. Always remember that *you have a lot to learn* as a new technician, and there are worse things in life than remaining at a sub-optimal job for two years.

A well-executed career should *make sense* when viewed as a series of jobs. Your career path should not appear chaotic or otherwise nonsensical. This is all the more important considering the fact that interviewers are not supposed to ask why you left (or are leaving) your job. The reason(s) for your desire to find new employment should either be obvious to anyone reading your résumé or be logically and ethically defensible should you opt to volunteer this information.

A piece of advice my father once gave me is to always strive to remain at your current job longer than at your previous job. Adopting this mind-set will force you to carefully consider each move, because wanting to stay at the next job longer only makes sense if that job will truly be better for you.

If I were to attempt to lay out the “ideal” career path for a technician, it might look something like this:

1. Begin your career doing contract electronics work for a few years, experiencing multiple industries with diverse technical exposure
2. Transition to a permanent maintenance position at a facility with high maintenance load for five to ten years, where you can really hone your troubleshooting skills
3. After having mastered construction and maintenance skills, consider a specialty job where you may deeply explore a particular technology and/or industry sector
4. Grow beyond technical work to become a planner, supervisor, or educator
5. End your career doing consulting work

Of course, this is just one suggested career path. Many others exist, but the real point here is to *always grow* in your professional capabilities. If you optimize your capabilities, the compensation and quality-of-life everyone seeks through gainful employment become much easier to attain. If you ignore professional development and focus solely on compensation, you may find yourself rudely surprised by circumstance.

8.2 Continuing education

The field of electronics is characterized by never-ending technological advancement. In order to remain relevant and marketable in this field you must continually learn. Sometimes the job itself forces you to learn new things, but more often than not the onus of responsibility for continuous learning falls on the individual.

It is important to realize that private, for-profit corporations do not care about your professional development *unless that development profits them*. Therefore, the educational opportunities they extend to you will be limited in general to what serves *their* interest. This is simply the nature of capitalism. Always bear this in mind, so that you will not become complacent by believing your employer's required training and work assignments are sufficient to ensure your own career security.

With these facts in mind, the following subsections outline different methods useful for continuing education in your chosen career.

8.2.1 Find mentors

A mentor is anyone willing to give good advice to someone less experienced. As a technician, you will find potential mentors among fellow technicians, among engineers, among operations personnel, and among others at your workplace. Technician mentors will help you understand how the principles you learned in school apply to the actual work environment. Engineer mentors will help you see beyond the scope of your work as a technician, to learn what is involved in organizing and designing a complete process. Operator mentors will teach you how the existing process works and what information they need in order to most effectively do their jobs.

Foster these relationships. Not only will they augment your career, but you will likely forge lasting friendships as well.

In addition to mentorship, it is always beneficial to develop good working relationships with all personnel at the facility where you are employed. Being able to get along with others and to freely share information is key to being able to get work done fast and efficiently. In particular, you should forge strong relationships with the people you serve: primarily front-line operations personnel. Always remember that as a technician it is your job to make their job as safe and as efficient as possible. They are your "internal customers" at the facility.

8.2.2 Accept any and all training offered to you

Most companies offer some form of technical training to their technicians on a regular basis. This may be initiated by regulatory compliance, by acquisitions of new equipment and technologies, and/or according to a professional development schedule linked to pay raises.

My advice is to take any and all training opportunities extended to you. Regardless of quality, it is all *free* education to you, and you would be a fool to pass it up.

8.2.3 Attend industry conferences

Tradeshows and technical conferences are valuable sources of information and also professional networking. Some of these conferences tend to be manufacturer-centric (e.g. SEMICON) while others are centered around professional societies (e.g. IEEE conferences).

Like industry training, such events are usually not cheap to attend. However, as with training it is common for employers to pay for their technical employees to attend industry conferences. As with employer-paid training, you would be a fool to pass up any form of free education.

8.2.4 Professional societies

The IEEE is the preeminent society for electrical and electronics engineering, offering much in the way of published literature and formal training. It is a group catering to engineers rather than technicians, but their resources are outstanding and of value to all. Different “societies” within the IEEE focus on specialty areas (e.g. Aerospace, Computers, Magnetics, Signal Processing, etc.).

The ISCET (International Society of Certified Electronics Technicians) caters to technicians and offers widely-recognized certifications.

ETA International (Electronics Technicians Association) is another technician-centric professional society offering educational resources and recognized certifications.

8.2.5 Earn certifications and/or licenses

Professional societies such as the ISCET and ETA International offer recognized certifications as well as training for those certifications. State agencies manage licenses (particularly, electrical licenses) which range from valuable to absolutely necessary² in your career as a technician.

8.2.6 Challenge yourself on the job

Volunteer for work assignments that will challenge your skills. Do not opt for the comfortable and familiar when given a choice.

Always strive to learn the *principle* behind the *procedure(s)* used to perform a task. This, in fact, is one of the differences between an excellent technician and a merely competent technician: the excellent technician can explain *why* things are done a certain way, while the merely competent technician only knows *how* things are done.

8.2.7 Read, read, read!

The most detailed and technically accurate resources for self-directed learning in this field tend to be in written form rather than video. This is the primary reason I focus so strongly on technical reading as an educator in this field, because my graduates must be good readers in order to stay current.

Sources to read include:

- **Trade periodicals**, useful for learning about the latest industry trends, regulations, and challenges

²Some states require electronics technicians who work with building/facility signal wiring to also be licensed electricians. Oregon happens to be one of those states.

- **Equipment instruction manuals**, useful not only for learning procedures, but also principles of operation for equipment
- **Patents**, easily searched online and a wealth of information on innovative technologies and techniques.
- **Manufacturers' tutorials**, very often well-written guides to how and why their technology functions
- **Scientific whitepapers**, very detailed and technical explanations of new principles and applications
- **Accident reports** (e.g. US Chemical Safety Board), for learning what *not* to do!
- **New and legacy textbooks**, useful for gaining perspective on technological development

Build up a library of technical literature for your own reference, whether in paper form or digital. Having relevant technical resources at your fingertips is extremely helpful when you need to research something. Do not rely on internet search engines to find what you need when you need it, as these often lead to questionable sources or dead-ends.

8.2.8 Be a scientist

When possible, run experiments on equipment to further your knowledge on how it functions, beyond reading the manual. Many electrical and electronics maintenance shops will have areas designed to set up and test equipment prior to installation in the field, and you can learn many valuable things (including undocumented features!) about equipment in this way. Furthermore, the testing techniques you hone on the bench will serve you well to diagnose faulty systems in the field!

8.2.9 Share your knowledge

Let's just begin with this statement: *knowledge-hoarding is not a good strategy!* Remember that your true value in this career is based on what you can *do*, not what you *know*. While it is possible to secure a meager form of job security by hoarding information, this is never a successful strategy in the long term. Information has a way of getting free whether you like it or not, and if the security of your job hinges on nobody else knowing what you do, your days in that privileged role are truly numbered.

Another reason for avoiding the hoarding of knowledge is reciprocity: if you don't share with others, those around you will be less willing to share with you. In a complex field such as electronics where no one person knows it all, you *need* others' help, and this help will not be offered if you refuse to help others.

Chapter 9

Managing Finances

Electronics can be a very lucrative career. This is both a blessing and a curse: obviously making a lot of money is helpful to modern living, but if you have poor self-discipline a large income can create more problems than it solves. The latter is often the fate of young people entering the field of electronics as their very first career, who have never had to manage adult responsibilities before¹.

Despite devoting an entire chapter to the very important topic of financial management, my coverage of this subject will be brief. I am not a financial advisor, nor would I ever presume to be competent in advising individuals what to do with their money. My advice will be general, but sound.

In short, what every person working a good-paying job *needs* to do is set aside a portion of every paycheck for savings. For some people, whose careers barely cover their basic needs, this might not be possible. However anyone working in the field of electronics should have enough income to ensure consistent contributions to savings.

When I say “savings” I do not simply mean interest-bearing bank accounts. A far more effective strategy for long-term investment is to take advantage of 401k or 403b plans through your employer: these plans allow you to deduct a percentage of every paycheck *prior to taxation* to invest in a range of mutual funds, bonds, or other investment options which will become available once you reach a certain age. The general term for this sort of investment is *tax-deferred*, which means that money is not taxed now as it would be if paid to you in full, but rather will be taxed at some

¹This is a sad commentary on the state of parenting and public education in the United States of America. In my humble opinion, American youth are unnecessarily sheltered from the realities of adulthood far too long, making their teenage years a protracted adolescence rather than the preparation for adulthood that it should be. Well-intentioned labor laws prohibiting teenagers from working in any capacity other than menial employment contribute to this same destructive isolation, preventing young people from learning a wide range of practical trades which would serve them well throughout life. I for one am thankful I was raised in a rural environment, where our family farm and workshop was a playground for welding, machining, equipment repair (and modification), and electrical work of all kinds. I’m also thankful for elementary school teachers who taught us about practical finances including compound interest, specifically my 6th grade teacher Mr. Beatty who had every student calculate payments, interest, and principle values for simulated mortgages over the span of the school year. Far too many practical domains are excluded from the American primary and secondary education systems, and far too many American parents fail to take responsibility for the practical education and discipline of their own children. I see this problem every single year as I teach electronics at the college level: young men and women in their 20’s lacking self-discipline in matters of time management, finances, and general direction in life.

later date² when you eventually withdraw from that investment. Many companies offer “matching” plans, which means they will contribute additional funds to your chosen investment, proportional to the percentage you invest from your own paychecks. For example, a “100% match” plan means the employer will match your 401k/403b contributions dollar-for-dollar up to a certain percentage limit, essentially *doubling* the real percentage of your paycheck contribution. Less-generous plans match a specified fraction of your contribution. In either case, these matching funds are essentially *additional income* you get from your employer which you would not receive otherwise if you did not participate in the 401k/403b plan.

Even in the case of companies which do not match pre-tax investments at all, a 401k or 403b plan is incredibly beneficial for your own financial future for the following reasons:

- Your contributions to the investment(s) are *pre-tax*, which means the money you invest is more than it would be if you invested in any other funds or bonds after the paycheck had been deposited in your bank account.
- Since these contributions come out of your income before government taxes are calculated, what they do is effectively reduce the income value seen by the government (i.e. your Taxable Gross Income), which means you pay less income tax every year.
- Most importantly, pre-tax contributions from your paycheck is money you never see in day-to-day living, which means it is money you cannot waste.

That last point bears some elaboration. The fundamental problem of financial management is similar to many other problems in life in that is essentially a matter of enforcing *delayed gratification*. Immediate gratification seems to be the default condition of the human psyche, which in financial terms means people tend to spend whatever they have (and sadly, often more than they have through credit). Rare is the person self-disciplined enough to maintain a strict budget year after year after year without fail. The plain fact of the matter is most people adjust their lifestyles to consume whatever they can afford, which is why most people will tell you they “never make enough money” regardless of their station in life, and why some highly-paid people find themselves paradoxically living paycheck-to-paycheck. Immediately signing up for an investment plan based on pre-determined payroll deduction accomplishes what your own self-discipline is probably not strong enough to do: regularly invest a portion of your income regardless of how you happen to feel or what you happen to crave. This is why it is so important to start your career with this plan: *so you never see the money that’s getting diverted from your paycheck into the investment(s), and therefore you will never miss it.*

Even if there were no such thing as a tax-deferred investment plan, automatic payroll deduction toward some form of investment would be beneficial for this same reason. It is difficult to downgrade your lifestyle after becoming accustomed to a higher standard of living. It is easy to create a lifestyle suited to a lesser income if you never experienced what that paycheck would “feel” like without the investment. Again, *you cannot miss what you have never experienced.*

This same strategy of automatic payroll deduction also works very well for charity. Contributing part of your earnings for the benefit of your fellow human beings is an important facet of any healthy culture, as there will always be people in need for no fault of their own. Whether this be emergency shelter, food, crisis intervention, educational support, counseling, care services, etc.,

²And often, at a lower tax rate!

many people stand to benefit from even the smallest charitable donation. Just like investing, charity is unappetizing when you perceive the loss to your own income. If you set up an automatic payroll deduction toward the charity(ies) of your choosing early in your career, you will not experience the same sense of loss and therefore will have an easier time shouldering that social burden.

Be warned that tax-deferred plans such as 401k and 403b typically do not carry over from one job to another. This means if you have invested money in one of these plans and you happen to leave that employer for another, you may need to *roll over* that invested money into a private plan that will maintain its tax-deferred status. If you fail to do this within a limited amount of time, all that money will be immediately subject to taxation at the current rate, which means you will lose a large percentage of it in taxes. Roll-over options are best discussed with a financial advisor, ideally well in advance of you leaving that job. Another option, sometimes available to you, is to leave the invested money in the previous employer's plan after you leave to work elsewhere.

Some people are so incompetent at managing their own finances that even payroll deductions toward investment cannot help their condition. These are people who *compulsively* spend money. If you are that kind of person, and you're entering a lucrative career, your problems are sure to multiply unless you receive help. For these people, my recommendation is to hire a financial manager to handle your money for you. Whatever you pay this manager for their services will be worth it in the end, because they will do for you what your own self-discipline is not capable of doing. Many options exist for this, but essentially you will be given an "allowance" based on some fraction of your income upon which to live, the rest of your income being wisely invested or spent on essentials by the manager.

The services of a professional financial manager are also useful for people doing contract work, where jobs come and go on an unpredictable schedule. This is a career sector demanding greater-than-normal financial discipline, because you will be making great money while you are working but nothing at all when the job ends. I have known many people possessing enough self-discipline to manage this quite well on their own, but have known others who fell into financial ruin as a result of highly lucrative but highly cyclic contract work.

If you happen to do international work, it is advisable to hire a tax preparation consultant to help manage your income taxes. I have been told by colleagues doing international contract work that the IRS tends to scrutinize such large foreign income streams via regular audits. An IRS audit is no fun, even if all your records are in perfect order, so having a professional's service to assist you in this event is a great relief.

On a general note, I strongly recommend avoiding debt wherever possible. The one area where debt is nearly impossible to avoid is purchasing a home, where the market value of the home and property greatly exceed most peoples' liquid (i.e. cash-able) assets, however most other debts can be avoided with good planning and disciplined effort. This runs contrary to popular American culture, which seems to encourage debt at every turn.

The problem with debt is very simple to explain: *it is a guaranteed loss*. An investment is a gamble, in that you may win or you may lose. A debt, by contrast, is an absolute guarantee you will pay more for something than what it is actually worth when you bought it, due to the *interest* paid with that debt. Another debilitating effect of debt is the psychological burden of knowing you owe money. This kills your economic freedom, and you don't want that.

Debt is especially bad when the asset in question depreciates (i.e. loses market value) over time. This is why car loans are stupid: you pay interest to borrow money to purchase something that is already guaranteed to lose value over time. Always pay for a car in cash. Always. If you can't afford that, carpool or use public transportation until you can afford your own vehicle, then upgrade vehicles *only* when you can afford to do so via outright cash purchases.

Credit cards are an optimized tool for incurring debt, which is why banks aggressively promote them to people. If you have ever run up so many charges on a credit card that you could not pay off the balance, then you lack the self-discipline to use a credit card and you should get rid of it. If you must use a card for certain purchases, use a *debit card* which draws directly out of a banking account and will not let you over-spend.

Interestingly, credit cards are also expensive for the merchant, from whom you make purchases. Any merchant accepting credit cards must pay a fee to the credit card company for that service, and this increases their cost of offering products and services to you. If you wish to support a particular merchant, pay by cash or check, as this saves them the credit card processing fee and gives less of your money to banks.

Electronics is a career in which it is entirely possible to *retire* after just a few decades³ of work, but this is only possible if you manage your finances wisely. Learn how to do so, and implement those lessons *immediately*.

³As I write this paragraph (in August of 2018) I cannot help but reflect on the status of a former technical school classmate, who entered the petroleum industry as a technician at the age of 20 and just a few months ago retired at the young age of 50. He took advantage of every investment and savings opportunity offered to him, spent money wisely, and now will enjoy a life of leisure most Americans can only dream of. Based on his social media posts, he now spends a lot of mornings working out at the gym, and most afternoons doing whatever he wants. Isn't this why we go to work? Isn't this the kind of life you would prefer for yourself?

Chapter 10

Cautionary Tales

An intelligent person learns from their own mistakes; a wise person learns from others' mistakes.

In each of these cases, the names and places have been changed (or left unspecified) to protect identity. Each of the circumstances outlined in the following sections are true-life events, some which happened to me and others which happened to colleagues or former students of mine.

10.1 Your First Job

10.1.1 All-day interview

Nancy and Will are soon-to-be graduates of an electronics program at a technical college, and have been summoned to an on-site interview at a large chemical processing plant after successfully passing a pre-screening test. Two other applicants from a different technical college are also summoned to the on-site interview on the same day. After all the individual interviews are complete, the shop supervisor takes all four applicants out to dinner.

The dinner is served at a popular restaurant in town, and as one would expect the server asks the guests if they would like to order any beverages in lieu of water. Both of the applicants from the other college opt to order beers, and proceed to achieve a mild state of inebriation by the end of the evening. Nancy chooses to drink only water, and Will orders a single glass of wine for the evening. The supervisor has several glasses of wine himself.

One week later this chemical company makes their hiring decision: Nancy and Will are both offered jobs, while the two applicants from the other college are declined.

The two failed applicants' excessive drinking during the after-interview dinner was absolutely¹ a factor in this company's decision. The lesson here is very simple: the actual interview begins the moment you make contact and doesn't end until you have parted ways with any and all representatives of that employer. Always bear in mind that one of the major characteristics any employer looks for in any employee is *good judgment*. In fact, judgment often carries more weight than technical prowess for prospective technicians, because technical knowledge and skill is much easier

¹I can say this as a fact, being privy to some details of this particular hiring event.

to develop over time than bad judgment is to correct. The dinner engagement was an intentional part of the interview process, designed to see how the four applicants conducted themselves in a less formal environment than the interview meeting room.

10.1.2 Ask for references!

Karen is a student of electronics, about two months away from graduation. She sets up an informational interview with the Business Development Manager of an electronics sales company where she would really like to work. After talking with the Manager for about 45 minutes on the telephone, Karen edits her résumé to emphasize her knowledge and skill areas that are most closely aligned with that company's needs.

After completing the résumé edits, Karen decides to update her References page. Having reached out to the Business Development Manager for the informational interview, she decides he knows her well enough to be one of her references.

Shortly after receiving Karen's résumé, cover letter, and References page, the Manager sends an email message to both Karen and her instructor at the college where she studies electronics. The email is brief and to the point:

Please do not cite contacts as references without permission, and please do not bother applying for a job at this company again. Ever.

10.1.3 The importance of showing up

Jeff was hired at an appliance manufacturing firm, but was let go after 6 months. The principal reason given for his firing was tardiness: he showed up late to work exactly four times within that period. All four times Jeff apologized for his tardiness, but was dismissed nonetheless.

10.1.4 Do your homework

Samantha applied for a general maintenance position at a power plant, which specified some electronics-related work within the job description. Six months after hiring on Sally grew tired of doing mostly mechanical maintenance and decided to apply for a different job, one promising a greater focus on electronics work.

The shop manager was furious with Sally's decision, because she was well-informed at the beginning that this job at the power plant would not be 100% electronics-related, and she had agreed to those terms nonetheless. Her departure from this employer meant lost investment as well as interrupted business, as she had been hired to help ramp up staffing in a maintenance department that was already too lean.

Had Sally remained on the job for at least a couple of years, the shop manager would have been understanding of her decision. It's one thing to accept a job that isn't perfect in order to gain experience for the next job, but it is quite another to jump ship prematurely simply because what you *hoped* the job might be wasn't what the job actually was (or was advertised to be).

10.2 Keeping a job

10.2.1 When to disobey your boss

Jack is a newly-hired electrical technician assigned to do a routine visual inspection of buswork² on a medium-voltage (4160 Volt) motor control center (MCC) in a large water treatment facility. To do this job, Jack must first request operations personnel to shut off all electrical loads powered through this system, then he must shut the breaker off, rack it out³, and apply a safety lock and tag (lock-out/tag-out). After that, Jack will need to verify the absence of electrical potential by examining voltmeters on the MCC panel and by attempting to re-start electrical loads fed by that panel. Only then it is considered safe to remove the access covers to expose the copper buswork for visual inspection.

After removing the sheet metal covers over the busbars, there is one more safety check to perform prior to commencing the inspection: testing voltage from each busbar to ground using a high-voltage voltmeter. Despite the prior safety precautions one can never be too careful when dealing with such lethal voltages!

Ray, who is the foreman for that section of the maintenance shop, directs Jack to use a “tic-tracer⁴” for that final voltage check rather than the approved voltmeter. Jack protests, knowing that a tic-tracer needs to be placed in close enough proximity to the conductor to pose a hazard⁵ at the 4160 Volt level. Ray continues to insist that Jack use the tic-tracer despite Jack’s protests, and invites himself along to the work site with Jack carrying the tic-tracer. Jack retrieves the approved high-voltage voltmeter from the shop’s tool room and proceeds to the MCC building.

Once Jack and Ray arrive at the MCC, Jack performs all the steps previously described, including using the approved voltmeter to do a final safety check on the busbars. After this, Ray extends the probe of the tic-tracer toward one of the de-energized busbars. Paradoxically, it *tics* once. Jack re-tests with the high-voltage voltmeter to ensure the busbar is indeed energized, and it still registers 0 Volts. Ray tries the tic-tracer again and finds it gives a “false positive” tic once every few times he approaches the busbar.

“Good thing we brought a *real* voltmeter” says Jack.

²In high-power electrical systems, solid copper metal bars called *busses* are used to conduct electricity rather than wires. These metal bars are held away from any other electrically conductive components by *insulators*. Both the busbars and the insulators should be inspected at regular intervals for dust and debris and for any signs of distress (discoloration from heat, evidence of arcing, etc.).

³The act of *racking out* a medium-voltage circuit breaker involves unplugging it from its cubicle in the MCC assembly so that the load bus will remain de-energized even if the breaker contacts happen to close. If tripping the circuit breaker is analogous to flipping the toggle switch of an appliance to the “off” position, racking out the circuit breaker is analogous to unplugging the power cord from the wall receptacle.

⁴A *tic-tracer* is an inexpensive voltage-sensing device which senses the presence of ground-referenced AC voltage via electrical capacitance, generating audible “tic” pulses to signal voltage. The device has a plastic-covered probe which only needs to be *close* to the conductor to sense voltage – direct contact with the conductor is not required.

⁵At elevated voltage levels, avoiding direct contact with the power conductor is insufficient to maintain safety. One must remain a certain minimum distance from an energized conductor to avoid *flashover*: a phenomenon where the air within the gap separating you from the conductor ionizes from the high potential and becomes electrically conductive, causing an arc to jump between you and the conductor. According to the 2015 version of the NFPA 70e Standard for Electrical Safety in the Workplace, the limited approach boundary for such a medium-voltage busbar is just over 2 feet. The approved voltmeter Jack wants to use has a three foot long probe. The tic-tracer’s probe is 6 inches long.

A good lesson to take away from this incident is to stand your ground when someone suggests a less-safe method of doing a job, no matter who that person might be. You may find yourself in a similar situation, especially when working alongside someone who learned their trade before the days of NFPA 70e and comparable industrial safety standards. Remember that the law is on your side as far as workplace safety is concerned!

It pays to educate yourself on all applicable safety standards. One thing Jack could have done here was to cite the NFPA 70e standard on safe approach distances for 4160 Volt circuits, but he didn't. All he knew was that the tic tracer wasn't physically long enough to ensure a safe air gap between himself and the busbar, but the approved voltmeter was. Citing a national safety standard is a sure way to settle a safety argument.

10.2.2 How to get yourself black-listed

Wendy is working as an electronics technician for a contractor, mostly doing installations of security and alarm systems in newly-constructed commercial buildings. Like all contracting jobs, the work comes and goes, but Wendy has learned to budget wisely which allows her to enjoy months at a time without work because when she is working the income is very good.

During one of her breaks from work, Wendy is doing maintenance on her home. Cleaning the gutters on her home one day, she slips and falls from the ladder. The landing was hard, and although no bones were broken she did receive a large bruise from the fall and as a result is left limping for days afterward.

Wendy's brother Ralph has been disabled for years with a severe spine injury. His doctor regularly prescribes Vicodin for pain relief which means Ralph always has an ample supply, and one day while visiting Wendy he offers some of that medication to her. She gladly accepts it, knowing it will help ease her pain and general stress.

One week later Wendy receives a telephone call from her contract employer announcing a new construction job. This job will require a drug screening as usual. Wendy fails the drug screening because it detected the Vicodin she took – medication for which she has no doctor's prescription.

She tries to explain to her employer that it was her brother's Vicodin, and that she only took it because of the pain she was in after falling from her ladder at home. The employer not only is unsympathetic, but black-lists Wendy and never calls her again.

All it took was one lapse of judgment on Wendy's part to derail her lucrative career.

Chapter 11

Epilogue

Over the decades I have been teaching electronics I have seen hundreds of people complete their education for this field and enter the workforce successfully. Those that have been most successful seem to be those who are the most *interested* in it for its own sake. A number of people choose this career path because it is lucrative, but at the end of the day money just isn't enough to keep you inspired to do good work and grow professionally. You probably know of people in your own life who are competent at their good-paying jobs, but *hate going to work*.

Don't let this be your fate. You *do* have a choice of employment in a free market, and if there is any wisdom I can pass along to you in this regard, it would be to choose a career that engages you on multiple levels. If that career is working as a technician, then hopefully this guide will give you some useful information. If that career is something else entirely, then maybe this Epilogue will be the most useful part. Whatever the case, *don't waste away your working life at a job you hate*.

This doesn't mean that the "right" career choice will always make you happy. Life is never that simple. *Everyone* dislikes their job from time to time. However, on the whole your work life should feel rewarding on more than just one level.

Appendix A

Tools used

I am indebted to the developers of many open-source software applications in the creation of these learning modules. The following is a list of these applications with some commentary on each.

You will notice a theme common to many of these applications: a bias toward *code*. Although I am by no means an expert programmer in any computer language, I understand and appreciate the flexibility offered by code-based applications where the user (you) enters commands into a plain ASCII text file, which the software then reads and processes to create the final output. Code-based computer applications are by their very nature *extensible*, while WYSIWYG (What You See Is What You Get) applications are generally limited to whatever user interface the developer makes for you.

The GNU/Linux computer operating system

There is so much to be said about Linus Torvalds' `Linux` and Richard Stallman's `GNU` project. First, to credit just these two individuals is to fail to do justice to the *mob* of passionate volunteers who contributed to make this amazing software a reality. I first learned of `Linux` back in 1996, and have been using this operating system on my personal computers almost exclusively since then. It is *free*, it is completely *configurable*, and it permits the continued use of highly efficient `Unix` applications and scripting languages (e.g. shell scripts, Makefiles, `sed`, `awk`) developed over many decades. `Linux` not only provided me with a powerful computing platform, but its open design served to inspire my life's work of creating open-source educational resources.

Bram Moolenaar's Vim text editor

Writing code for any code-based computer application requires a *text editor*, which may be thought of as a word processor strictly limited to outputting plain-ASCII text files. Many good text editors exist, and one's choice of text editor seems to be a deeply personal matter within the programming world. I prefer `Vim` because it operates very similarly to `vi` which is ubiquitous on `Unix/Linux` operating systems, and because it may be entirely operated via keyboard (i.e. no mouse required) which makes it fast to use.

Donald Knuth's \TeX typesetting system

Developed in the late 1970's and early 1980's by computer scientist extraordinaire Donald Knuth to typeset his multi-volume magnum opus *The Art of Computer Programming*, this software allows the production of formatted text for screen-viewing or paper printing, all by writing plain-text code to describe how the formatted text is supposed to appear. \TeX is not just a markup language for documents, but it is also a Turing-complete programming language in and of itself, allowing useful algorithms to be created to control the production of documents. Simply put, *\TeX is a programmer's approach to word processing*. Since \TeX is controlled by code written in a plain-text file, this means anyone may read that plain-text file to see exactly how the document was created. This openness afforded by the code-based nature of \TeX makes it relatively easy to learn how other people have created their own \TeX documents. By contrast, examining a beautiful document created in a conventional WYSIWYG word processor such as Microsoft **Word** suggests nothing to the reader about *how* that document was created, or what the user might do to create something similar. As Mr. Knuth himself once quipped, conventional word processing applications should be called WYSIAYG (What You See Is *All* You Get).

Leslie Lamport's \LaTeX extensions to \TeX

Like all true programming languages, \TeX is inherently extensible. So, years after the release of \TeX to the public, Leslie Lamport decided to create a massive extension allowing easier compilation of book-length documents. The result was \LaTeX , which is the markup language used to create all ModEL module documents. You could say that \TeX is to \LaTeX as **C** is to **C++**. This means it is permissible to use any and all \TeX commands within \LaTeX source code, and it all still works. Some of the features offered by \LaTeX that would be challenging to implement in \TeX include automatic index and table-of-content creation.

Tim Edwards' **Xcircuit** drafting program

This wonderful program is what I use to create all the schematic diagrams and illustrations (but not photographic images or mathematical plots) throughout the ModEL project. It natively outputs PostScript format which is a true vector graphic format (this is why the images do not pixellate when you zoom in for a closer view), and it is so simple to use that I have never had to read the manual! Object libraries are easy to create for **Xcircuit**, being plain-text files using PostScript programming conventions. Over the years I have collected a large set of object libraries useful for drawing electrical and electronic schematics, pictorial diagrams, and other technical illustrations.

Gimp graphic image manipulation program

Essentially an open-source clone of Adobe's `PhotoShop`, I use `Gimp` to resize, crop, and convert file formats for all of the photographic images appearing in the `MODEL` modules. Although `Gimp` does offer its own scripting language (called `Script-Fu`), I have never had occasion to use it. Thus, my utilization of `Gimp` to merely crop, resize, and convert graphic images is akin to using a sword to slice bread.

SPICE circuit simulation program

`SPICE` is to circuit analysis as `TEX` is to document creation: it is a form of markup language designed to describe a certain object to be processed in plain-ASCII text. When the plain-text "source file" is compiled by the software, it outputs the final result. More modern circuit analysis tools certainly exist, but I prefer `SPICE` for the following reasons: it is *free*, it is *fast*, it is *reliable*, and it is a fantastic tool for *teaching* students of electricity and electronics how to write simple code. I happen to use rather old versions of `SPICE`, version 2g6 being my "go to" application when I only require text-based output. `NGSPICE` (version 26), which is based on Berkeley `SPICE` version 3f5, is used when I require graphical output for such things as time-domain waveforms and Bode plots. In all `SPICE` example netlists I strive to use coding conventions compatible with all `SPICE` versions.

Andrew D. Hwang's ePiX mathematical visualization programming library

This amazing project is a `C++` library you may link to any `C/C++` code for the purpose of generating PostScript graphic images of mathematical functions. As a completely free and open-source project, it does all the plotting I would otherwise use a Computer Algebra System (CAS) such as `Mathematica` or `Maple` to do. It should be said that `ePiX` is *not* a Computer Algebra System like `Mathematica` or `Maple`, but merely a mathematical *visualization* tool. In other words, it won't determine integrals for you (you'll have to implement that in your own `C/C++` code!), but it can graph the results, and it does so beautifully. What I really admire about `ePiX` is that it is a `C++` programming library, which means it builds on the existing power and toolset available with that programming language. Mr. Hwang could have probably developed his own stand-alone application for mathematical plotting, but by creating a `C++` library to do the same thing he accomplished something much greater.

gnuplot mathematical visualization software

Another open-source tool for mathematical visualization is `gnuplot`. Interestingly, this tool is *not* part of Richard Stallman’s GNU project, its name being a coincidence. For this reason the authors prefer “gnu” *not* be capitalized at all to avoid confusion. This is a much “lighter-weight” alternative to a spreadsheet for plotting tabular data, and the fact that it easily outputs directly to an X11 console or a file in a number of different graphical formats (including PostScript) is very helpful. I typically set my `gnuplot` output format to default (X11 on my Linux PC) for quick viewing while I’m developing a visualization, then switch to PostScript file export once the visual is ready to include in the document(s) I’m writing. As with my use of `Gimp` to do rudimentary image editing, my use of `gnuplot` only scratches the surface of its capabilities, but the important points are that it’s *free* and that it *works well*.

Python programming language

Both Python and C++ find extensive use in these modules as instructional aids and exercises, but I’m listing Python here as a *tool* for myself because I use it almost daily as a *calculator*. If you open a Python interpreter console and type `from math import *` you can type mathematical expressions and have it return results just as you would on a hand calculator. Complex-number (i.e. *phasor*) arithmetic is similarly supported if you include the complex-math library (`from cmath import *`). Examples of this are shown in the Programming References chapter (if included) in each module. Of course, being a fully-featured programming language, Python also supports conditionals, loops, and other structures useful for calculation of quantities. Also, running in a console environment where all entries and returned values show as text in a chronologically-ordered list makes it easy to copy-and-paste those calculations to document exactly how they were performed.

Appendix B

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Appendix C

References

“Commuter Rail Safety Study”, US Department of Transportation, Federal Transit Administration, Office of Safety and Security, November 2006.

Appendix D

Version history

This is a list showing all significant additions, corrections, and other edits made to this tutorial. Each entry is referenced by calendar date in reverse chronological order (newest version first), which appears on the front cover of the tutorial for easy reference. Any contributors to this open-source document are listed here as well.

4 March 2025 – added a photograph of a VOR navigation transmitter to the “Aerospace and Avionics” subsection of the “Jobs and Industry Sectors” section of the “What is Electronics?” chapter.

7 September 2024 – re-named the subsection “Electronics manufacturing” to Electronics manufacturing/R&D”. Also re-named the subsection “Aerospace” to “Aerospace and avionics”.

15 January 2024 – added social media as another source of information employers may consult when conducting background checks.

5 January 2024 – added an Introduction chapter with sections containing questions related to each of the other chapters.

1 January 2024 – elaborated on the importance of expressing why it is you wish to work for a company (within a cover letter) in the “Resumes and Cover Letters” chapter, and also corrected some minor typographical errors throughout.

25 April 2023 – minor edits to the “What makes you marketable” chapter.

12 April 2023 – added and modified some job titles.

7 November 2022 – corrected a typographical error courtesy of Jessica Rigney.

28 October 2022 – added another job title to the list, Modbus Technician.

14 May 2022 – corrected a wrong image in the “Jobs and industry sectors” section of the “What is Electronics?” chapter, regarding vehicle testing by the Pacific Northwest Laboratories. Ended up

replacing this image with one from Argonne National Laboratory with a less ambiguous declaration of public-domain status.

19-23 April 2022 – added more process equipment photographs to the “Jobs and industry sectors” section of the “What is Electronics?” chapter.

18 April 2022 – added an entry on CNC machine tools to the “Jobs and industry sectors” section of the “What is Electronics?” chapter.

14 April 2022 – added a photograph of an impedance analyzer to the new section within chapter 2 called “Industry equipment” along with an LCR meter.

21-25 March 2022 – began a new section within chapter 2 called “Industry equipment” showing photos of test equipment and other hardware commonly encountered by electronics technicians on the job.

2 August 2021 – substituted a better photograph of a natural gas metering station for the one originally shown (image_5266).

9 July 2021 – replaced some TeX-style italicizing markup with LaTeX-style.

8 June 2021 – added reference to autonomous ships in the “Marine transportation” subsection.

3 June 2021 – added reference to autonomous vehicles in the “Public roads and railway systems” subsection.

10 May 2021 – added quote from successful graduate about the merits of pursuing a career that isn’t exactly what you went to school for, but is exactly what you want.

7 May 2021 – added photos on building automation.

4-5 May 2021 – made minor edits to the “What Is Electronics?” chapter (“Jobs and Industry Sectors” section), including adding comments to the “Marine transportation” subsection regarding the NMEA, and commenting out the subsection on “Precision Agriculture” until further notice.

19 January 2021 – minor typographical corrections.

15 November 2020 – added career information for telecommunications and also for transportation.

16 August 2020 – minor edits to the “What Makes an Employee Valuable?” chapter, including a change of the title to “What Makes You Marketable?”.

15 January 2020 – added comment in the résumé and cover letter chapter about their importance compared to grades.

10 January 2020 – added more good cover-letter ideas, courtesy of Scott Hodge.

24 December 2019 – corrected some typographical errors identified by Michael Cochrane of SEL.

22 December 2019 – added photographs showing electronics technician jobs, and expanded greatly on the “Jobs and industry sectors” section of the *What is Electronics?* chapter.

21 December 2019 – expanded on career options for Electronics Technicians, and also revised sample job descriptions. Made numerous edits throughout the document.

20 December 2019 – continued modifying text from “So You Want To Be An Instrument Technician?” to fit the new scope of Electronics work (instead of Instrumentation).

19 December 2019 – document first created, largely based on “So You Want To Be An Instrument Technician?” written a couple of years prior.

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