# IETTI-223 – Advanced Electronics Theory (Semester 4 THEORY)

**NAME:** ____________________________  Last update 9 May 2022

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<th>Topic</th>
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<td>Intro to the Career</td>
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Essential information about this course:

- This is a theory course, but it is not lecture-based. At-home reading assignments replace lecture, while discussions about the text and problem-solving practice occupy class time.
- Full preparation for and participation in every theory session is a basic expectation. Lack of preparation will result in point deductions, as will lack of participation and/or late arrival.
- Half of your course grade comes from “oral presentations” where you solve problems in full view of classmates and instructor just like during a technical job interview.
- Half of your course grade comes from written “mastery exams” where every question must be correctly answered to pass. Multiple re-tries are allowed on different exam versions, but only the first exam’s score counts toward your course grade.
- You should budget a minimum of 12 hours per week for this course, approximately 4 hours in-class and 8 hours out-of-class preparation.
- Successful students (1) prioritize their study time, (2) test themselves on upcoming oral presentation and written exam topics, (3) and master principles before memorizing procedures.
Values

This educational program exists for one purpose: to empower you with a comprehensive set of knowledge, skills, and habits to unlock opportunities in your chosen profession. The following values articulate personal attitudes guaranteed to fulfill this purpose, and the principles upon which this program is designed. They embody what I like to call a *strong learning ethic*, similar to a strong work ethic but applied to the learning process rather than a job.

**Ownership** – you are the sole proprietor of your education, of your career, and to a great extent your quality of life. No one can force you to learn, make you have a great career, or grant you a fulfilling life – these accomplishments are possible only when you accept responsibility for them.

**Responsibility** – *ensuring* the desired outcome, not just *attempting* to achieve the outcome. Responsibility is how we secure rights and privileges.

**Initiative** – independently recognizing needs and taking responsibility to meet them.

**Integrity** – living in a consistently principled manner, communicating clearly and honestly, applying your best effort, and never trying to advance at the expense of others. Integrity is the key to trust, and trust is the glue that binds all relationships personal, professional, and societal.

**Perspective** – prioritizing your attention and actions to the things we will all care about for years to come. Never letting short-term concerns eclipse the long-term.

**Humility** – no one is perfect, and there is always something new to learn. Making mistakes is a symptom of living, and for this reason we need to be gracious to ourselves and to others.

**Safety** – assessing hazards and avoiding unnecessary risk to yourself and to others.

**Competence** – your ability to consistently and independently apply knowledge and skill to the solution of practical problems. Competence includes the ability to verify the appropriateness of your solutions and the ability to communicate so that others understand how and why your solutions work.

**Diligence** – exercising self-discipline and persistence in learning, accepting the fact there is no easy way to absorb complex knowledge, master new skills, or overcome limiting habits. Diligence in work means the job is not done until it is done *correctly*: all objectives achieved, all documentation complete, and all root-causes of problems identified and corrected.

**Community** – your actions impact other peoples’ lives, for good or for ill. Conduct yourself not just for your own interests, but also for the best interests of those whose lives you affect.

**Respect** is the acknowledgment of others’ intrinsic capabilities, responsibilities, and worth. Everyone has something valuable to contribute, and everyone deserves to fully *own* their lives.

file eet_values
(1) **COMMUNICATION and TEAMWORK** – Accurately communicate ideas across a variety of media (oral, written, graphical) to both technical and non-technical audiences; Function effectively as a member of a technical team.

(2) **SELF-MANAGEMENT** – Arrive on time and prepared; Work diligently until the job is done; Budget resources appropriately to achieve objectives.

(3) **SAFE WORK HABITS** – Comply with relevant national, state, local, and college safety regulations when designing, prototyping, building, and testing systems.

(4) **ANALYSIS and DIAGNOSIS** – Select and apply appropriate principles and techniques for both qualitative and quantitative circuit analysis; Devise and execute appropriate tests to evaluate electronic system performance; Identify root causes of electronic system malfunctions.

(5) **PROBLEM-SOLVING** – Devise and implement solutions for technical problems appropriate to the discipline.

(6) **DOCUMENTATION** – Interpret and create technical documents (e.g. electronic schematic diagrams, block diagrams, graphs, reports) relevant to the discipline.

(7) **INDEPENDENT LEARNING** – Select and research information sources to learn new principles, technologies, and/or techniques.
Course description

This course introduces microprocessor systems – including computer programming in both assembly language and C – and also explores serial data communication, advanced RF topics (e.g. modulation, mixers, Smith charts, VNAs), industrial signal conditioning, and industrial control systems. Mastery-style written exams guarantee attainment of conceptual learning outcomes, while oral presentations and Socratic dialogue demonstrate communicative learning outcomes.

Course learning outcomes

- Predict the performance of programmable circuits, serial data networks, complex RF circuits, analog signal conditioning circuits, and feedback control systems given schematic diagrams, component values, and other circuit parameters. (Addresses Program Learning Outcomes 4, 6)
- Write simple code to instruct a microprocessor or microcontroller to perform stated tasks. (Addresses Program Learning Outcomes 4, 6)
- Design and sketch simple digital memory circuits, serial data communication circuits, radio circuits, signal-conditioning circuits, and control system circuits to meet stated functional requirements. (Addresses Program Learning Outcomes 4, 5, 6)
- Articulate and apply technical principles related to microprocessors, data communication, RF modulation, signal conditioning, and feedback control systems as requested by a critical audience. (Addresses Program Learning Outcomes 1, 2, 4, 6, 7)
- Identify probable faults in microprocessor or microcontroller peripheral circuits, data communication circuits, radio circuits, signal processing circuits, and control systems given schematic diagrams and reported symptoms. (Addresses Program Learning Outcomes 5, 6)
Required Tools, Supplies, and Software

Listed by IETTI course number and course type (Thy = theory, Exp = Experiments, Prj = Projects).

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<th>Course Numbers</th>
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<td>$10 alligator-clip jumper wires (package of at least ten)</td>
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<td>$15 batteries: 6 Volt and 9 Volt</td>
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<td>$25-$100 soldering iron (pencil-tip), 30 Watts or less</td>
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<td>$0 software: schematic editor</td>
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<td>$0 software: Notepad++ text editor</td>
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<td>$0 software: NGSPICE circuit sim.</td>
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<td>$0 software: tshoot fault sim.</td>
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<td>$200 PLC and software</td>
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<td>$0 software: PCB layout editor</td>
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<td>$0 software: packet-sniffing software</td>
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**Required Tools, Supplies, and Software**

**Scientific calculator** – at minimum your calculator must perform trigonometric functions (sine, cosine, tangent, etc.), offer multiple memory registers, and display values in both scientific and “engineering” notations. I recommend the Texas Instruments model TI-36X Pro because it easily performs complex-number arithmetic necessary for AC circuit analysis and is inexpensive.

**Personal computer** – all course materials are available in electronic format and are free (most are also open-source), making a portable computer extremely useful. The school provides personal computers for on-campus use, but having your own will enable you to work outside of school. Any operating system, any size hard drive, any amount of RAM memory, and any screen size is appropriate, but your computer needs to have a keyboard and mouse (i.e. no tablets). Useful features worth higher cost include an RJ-45 Ethernet port and an EIA/TIA-232 (9-pin) serial port.

**Multimeter** – this is your first and most important electronic test instrument. At minimum it must measure DC and AC voltage, DC and AC current (milliAmpere range), resistance, and “diode check” voltage drop. Useful features worth higher cost include microAmpere current measurement, true-RMS AC measurement (for second-semester courses and above), frequency measurement, capacitance measurement, and minimum/maximum value capture. Cost is a strong function of accuracy, frequency range, and safety (“Category” ratings for over-voltage exposure). The Fluke model 87-V is an excellent professional-grade choice for digital multimeters, and the Simpson 260 is an excellent professional-grade choice for analog multimeters. Note that Fluke offers a 25% educational discount for students.

**Oscilloscope** – once too expensive for student purchase, entry-level USB-based oscilloscopes now cost less than a textbook. Pico Technology is an excellent brand, and their model 2204A comes with high-quality probes as well. Plugged into your personal computer using a USB cable, the Picoscope turns your computer’s monitor into a high-resolution oscilloscope display. Features include two measurement channels, 10 MHz bandwidth, built-in arbitrary waveform generator (AWG), ± 100 Volt over-voltage protection, digital “cursors” for precise interpretation of amplitude and frequency, meter-style measurement capability, Fast Fourier Transform algorithm for frequency-domain measurement, export ability to several graphic image formats as well as comma-separated variable (.csv) files, and serial communications signal decoding. Together with your multimeter, solderless breadboard and Development Board (which you will construct in the IETTI-102 Project course and is yours to keep) this forms a complete electronics laboratory for doing experiments and projects outside of school.

**Soldering** – the equipment you purchase for soldering need not be expensive, if you purchase the right solder. For electronics work you must use rosin-core solder. Kester is an excellent brand, and you should avoid cheap imported solders. For lead-based solder, a 63% tin and 37% lead alloy (Sn63/Pb37) works very well. A one-pound roll is likely more solder than you will need in these courses, so I recommend buying just a small tube or small roll. I recommend a fine-tipped soldering iron (15 Watts continuous power, although some with adjustable temperature controls may have higher power ratings to get up to soldering temperature more quickly) and a solder diameter 0.031 inches or smaller for doing fine printed-circuit board work. Also, keep the tip of your soldering iron clean by wiping it against a damp sponge or paper towel when hot, and not leaving it hot any longer than necessary. Hakko, X-tronic, and Lonove are all recommended brands.

**Microcontroller** – these courses are not brand- or model-specific, but the Texas Instruments MSP430 series is highly recommended for their powerful features, modern design, and programmability in multiple languages (assembly, C, C++, and Sketch). I particularly recommend the model MSP-EXP430G2ET “LaunchPad” development board (MSP430G2553IN20 microcontroller chip) with Code Composer Studio for the IDE software. A hobbyist-grade microcontroller such as the popular Arduino and Parallax BASIC Stamp are permissible only in first-year courses, but not in second-year courses.
Required Tools, Supplies, and Software

All software required for these courses is free, and some of it is open-source.

Schematic editor – this is used to draft schematic diagrams for circuits. A good one is TinyCAD, but there are also web-based CAD tools such as circuitlab.com that are very effective and easy to use.

Text editor – this is used to create plain-text files, kind of like a word processor but lacking formatting features such as typeface, font size, etc. It is absolutely necessary for writing code of any kind. Notepad++ is a very good editor, but others work well too.

NGSPICE – this is a modern adaptation of the venerable SPICE circuit simulator which uses a text-coded “netlist” rather than a visual schematic diagram to describe circuits. Very powerful, and with decades of netlist examples from earlier versions of SPICE to use as references. The installer lacks sophistication, being nothing more than a compressed (zip) file that you unpack. Once installed, you should instruct your computer’s operating system to automatically associate any files ending in the extension .cir with the NGSPICE executable file ngspice.exe so that all of your netlist files will appear with the NGSPICE icon and will automatically load into NGSPICE when double-clicked.

WSL – Windows Subsystem for Linux is a “virtual machine” Linux operating system that runs within the Windows operating system, giving you a command-line user environment mimicking that of a Unix operating system. It is a free application from Microsoft, with instructions available from Microsoft on how to install. I recommend installing the “Debian” distribution of WSL. Once installed, you will issue these commands in the following order to install all the necessary programming tools:

- `sudo apt update`
- `sudo apt install build-essential`
- `sudo apt install indent`
- `sudo apt install python3`

```bash
tshoot
```
- this is a specialized circuit-simulator program that inserts faults into circuits and tests your ability to locate them. The download consists of a single “tar” archive file which you must unpack and compile using the following two commands within a Unix-type operating system or within WSL. The fourth command listed below starts and runs the application:

```bash
- mkdir tshoot ; mv -v *.tar tshoot ; cd tshoot
- tar xvf *.tar
- make
- ./tshoot
```

IDE software – an “Integrated Development Environment” is a software package used to write code, and for our purposes this would be code meant to run in a microcontroller. For the Texas Instruments MSP430 series, the main IDE is called Code Composer Studio, and it supports programming in assembly language, C, and C++. A third-party add-on to Code Composer Studio called Energia supports programming in the Sketch language, identical to that used by the popular Arduino microcontroller series.

PCB layout editor – this is specialized drafting software intended for creating graphic files to be sent to printed circuit board (PCB) manufacturers so you can order your own custom PCBs. PCB Artist is free and exceptionally easy to use, but only exports files to the manufacturer Advanced Circuits. Free PCB layout editors capable of exporting “Gerber” format files which are universally accepted by PCB manufacturers include EasyEDA, KiCAD (very powerful but hard to learn), and pcb. Of these I recommend EasyEDA for beginners, or PCB Artist if you don’t mind being locked into one manufacturing option.

Packet-sniffing software – this is specialized software for monitoring network communications. An excellent (and free) option is Wireshark.
Grading standards for Theory courses

Your grade for this course is based on percentage scores (in every calculation rounded down to whole-numbered values), with each category weighted as follows:

- Oral presentation scores = 50%
- Written exam scores = 50% (Note: all exams are mastery-based, which means they must be eventually completed at 100% competence in order to pass the course)
- Unpreparedness for theory sessions = −1% per session
- Non-participation for theory sessions = −1% per session

All theory sessions are based on an “inverted” model of instruction rather than lecture. Instead of quietly listening to the instructor explain new concepts to you, you will independently explore those new concepts outside of class and then spend the class time discussing what you learned, what didn’t make sense, and solving problems. This instructional model has proven far more effective than lecture, principally for the reason that student engagement is mandatory and not optional. It also makes far more efficient use of students’ time, greatly minimizing the amount of necessary classroom hours to achieve the same learning.

Scoring for theory sessions is based on your preparation for and participation within each theory session. These scores are subtractive rather than additive; that is to say, arriving fully prepared and participating fully in each group discussion contributes nothing toward the course grade, but unpreparedness and/or non-participation detracts from the course grade. Showing up on time, fully prepared, and genuinely contributing to every activity is the minimum expectation for any professional career, and so this is the standard maintained in this course. Failure to arrive on time to a theory session, or arriving with incomplete preparatory work for that session results in a −1% deduction per session to your course grade. Satisfactory preparation is defined as a good-faith effort to complete all pre-work specified in the theory session plan. Note that this does not mean mastery of that session’s concepts, but simply a presentation of your best work. Failure to positively and proactively contribute to the discussion during a theory session similarly results in a −1% deduction per session. Half-point deductions are awarded for being mostly but not fully prepared/engaged.

If you must be late or absent for a theory session, submitting your work in electronic form (e.g. email attachment) prior to the scheduled time is acceptable for full credit. The standards are just as high for electronic submissions as for face-to-face demonstrations:

- For theory session preparation, submission of all assigned work (e.g. reading outline and reflections, answers and work for all assigned questions) before the scheduled start time of that theory session will count as full credit.
- For theory session participation, answering all “Challenges” for assigned questions will substitute for dialogue and problem-solving with classmates and instructor.

Absence during a scheduled oral presentation or a scheduled written exam will result in a 0% score for that assessment, except in the case of a documented emergency. In such emergency cases, written exams may be taken at some later time for full credit, and oral presentations may also be completed at a later date for full credit. During any assessment you are free to ask the instructor for clarification, but the instructor will not help you solve any problem nor will confirm if an answer is correct prior to its submission for scoring.

A failing (F) grade will be earned for the entire course if any written exam not completed with 100% accuracy on or before the deadline date, or for any of the following behaviors: false testimony (lying), cheating on any assignment or assessment, plagiarism (presenting another’s work as your own), willful violation of a safety policy, theft, harassment, sabotage, destruction of property, or intoxication. These behaviors are grounds for immediate termination in this career, and as such will not be tolerated here.
Complete the following **prior to** the scheduled session with your instructor:

- Read, outline, and reflect on the “Growing Your Career” chapter of the *Career Guide* document
- Read, outline, and reflect on the “Managing Finances” chapter of the *Career Guide* document
- Research open positions on job search engines (e.g., Indeed.com) searching for job titles listed in the “What is Electronics” chapter, focusing on those jobs listing a two-year (Associate’s) degree in electrical or electronics technology for education

Complete the following **during** the scheduled session:

- Discuss what you read in the *Career Guide*
- Discuss what you found in your job search:
  - What technical skills are common to these jobs?
  - What non-technical skills are common to these jobs?
- Calculate **time commitment** (3 hrs/week per semester-credit) for this semester’s courses
  - Full load = 12 credits = 36 hours/week total time commitment + General Education courses!
- Emphasize importance of **daily contact** with instructor, even in the event of an absence
- Emphasize importance of **personal effort** to solve problems prior to asking for help
- [Optional] – sign FERPA release forms

**Forms provided by the instructor for today’s session:**

- FERPA release form
- IETTI-223 Theory course document (printed from cover page through Theory Session 2)
- IETTI-225 Experiments course document
- IETTI-106 Projects course document

**Important resources:**

- [http://ibiblio.org/kuphaldt/socratic/model](http://ibiblio.org/kuphaldt/socratic/model), the Modular Electronics Learning Project web page containing all course documents, tutorials, and problem sets you will need in these courses
  - [http://ibiblio.org/kuphaldt/socratic/model/index#courses](http://ibiblio.org/kuphaldt/socratic/model/index#courses), links to all IETTI course documents
- [http://ibiblio.org/kuphaldt/socratic/model/calendar.html](http://ibiblio.org/kuphaldt/socratic/model/calendar.html), our semester calendar showing dates for theory sessions, special events, and all-lab project sessions
- [http://ibiblio.org/kuphaldt/socratic/model/daily_schedule.pdf](http://ibiblio.org/kuphaldt/socratic/model/daily_schedule.pdf), showing Monday-Friday class schedule
- “Required Tools, Supplies, and Software” page (in this document)
- “Grading standards for Theory courses” page (in this document)
- EETREF – a collection of digital documents often referenced in homework assignments, stored as a folder on the Desktop of every computer in the lab file wt_1004
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial (pages 15 through 26):
  - Other Layers
  - Design for Manufacturing
- Identify where the following foundational concepts appear in the assigned reading, and explain their significance to this topic:
  - Design Rule Checking (DRC)
  - Parasitic effect
  - Solder mask
  - Transmission line
  - Power plane
  - Fiducial mark
  - Silkscreen
  - Sinusoidal decomposition (i.e. Fourier analysis, harmonics)
  - Rat’s nest
  - Digital file format
- Identify the most common material used to manufacture printed circuit boards.
- Identify different methods of soldering components to PCBs.
- Explain the rationale behind the author’s suggested rules for high-frequency PCB design listed on page 21.
- Explain why it is a common design practice to place a capacitor in parallel with the DC power rails of every integrated circuit on a PCB, ideally as close to the IC as possible.
- Explain how certain aspects of PCB design can influence the quality of the final board’s soldered connections.
- Identify a PCB manufacturer online and the discount(s) they offer to students.

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following section of the Tutorial chapter:
  - Bitwise operators
- Complete “Driving microcontroller output bits” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Bitwise operation practice” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Bit-rotate program” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Read, outline, and reflect on the Simple four-bit ALU section of the Derivations and Technical References chapter.
- Read, outline, and reflect on the Binary adder circuits section of the Derivations and Technical References chapter.
- Complete “74181 ALU” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Signed binary addition” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Rotary encoder” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Doubling data width” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Doubling address width” in the Quantitative Reasoning section of the Questions chapter.
- Locate the first edition of *The Semiconductor Memory Book* published by Texas Instruments in 1975, read the datasheet for the model TMS 4033 JL/NL static RAM chip, and answer the following questions:
  - Identify the memory capacity and organization (address width, data width) for this memory IC
  - Explain the elements shown in the functional block diagram on page 50 of the book
  - Comment on the timing diagrams shown on page 52 – what do they signify?
  - On which terminal(s) is data written to this memory IC, and on which terminal(s) is data read from it?

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

**Additional resources:**

- Sections of the Case Tutorials chapter contain circuit examples showing both data expansion and address expansion using multiple memory ICs. I strongly recommend you examine these circuit diagrams if the concept of address expansion and data expansion is less than clear after reading the Tutorial.
- Animation of 16 × 8 ROM section of the Animations chapter.

(file wt_0057)
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Generating repeated values” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Prime sequence counter” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of failed data lines” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Digital building-blocks
  → Putting it all together – the processor
- Complete “Intel 8080 architecture” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Intel 8080 processor cycles” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Early microprocessor timing diagram” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Theory session 08

Source text – *Introduction to Microprocessors* learning module


Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - A simple computer example

- Complete “Minimal Z80 computer” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Memory map determination” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Machine code and assembly language
  → Interrupts
- Read, outline, and reflect on the Introduction to assembly language programming section of the Derivations and Technical References chapter.
- Complete “6502 turning on LEDs” in the Quantitative Reasoning section of the Questions chapter.
- Complete “PIC 16F18346 subroutines” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Random input states” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Theory session 10

Source text – Introduction to C Language Programming learning module


Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Pointers
  → Arrays
- Complete “Using C arrays to analyze a resistor circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Sine look-up table” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Array-reversal program” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
**Oral Presentations**

Today’s class session will consist of oral presentations made to the entire group. Each presentation will last approximately 15 minutes, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

*Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.*

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

You will be randomly assigned to analyze and explain one section of a single-board Intel 8080-based computer’s schematic diagram, the schematic diagram found as a PDF file in the [EETREF](#) collection ([EETREF/Projects/SingleBoardComputers/SingleBoardComputer_8080_schematic.pdf]). No student will know which function is theirs to explain until it is their turn to present, which means all students should be prepared to explain the entirety of the system. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. digital numeration, logic states, CPU instruction cycles, datasheet specifications, etc.).

Note: there are a few ICs in this schematic unique to this particular single-board computer. The GAL16V8B is a *programmable logic array*, used to mimic complex combinational logic. The designer of this board employed a PAL chip to save space rather than have several other ICs (e.g. the 8212 and 8214 peripheral ICs commonly used with the 8080 microprocessor don’t exist in this computer’s design). Also, an entire microcontroller is also included (AT89C2051) for the sole purpose of generating a low-frequency pulse signal called a *tick*. Two ICs specifically designed by Intel to be used with the 8080 microprocessor are the 8224 and the 8228, both present in this computer’s design.

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).

*One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem!* Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Section #1 – CPU clock source

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine how the clock signal source functions in this computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

- [20%] Identify what establishes the clock frequency for this computer
- [20%] Explain the significance of the two clock pulse signals needed by the 8080 CPU
- [20%] Identify which of these two clock pulse signals has a greater duty cycle
- [20%] Explain the significance of the SYNC signal
- [20%] Explain the significance of the STSTB signal

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Section #2 – System memory

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine how the RAM and ROM memory works in this computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

[20%] Identify the total address space (i.e. maximum number of possible address locations for the 8080 microprocessor)
[20%] Sketch a memory map showing the RAM and ROM memories as they exist in the microprocessor’s addressing range
[20%] Identify the electrical connections responsible for the microprocessor being able to select RAM versus ROM at any given moment in time
[20%] Identify the electrical connections responsible for the microprocessor being able to read from versus write to any memory location
[20%] Explain what a “monitor” program does that would be stored in the ROM

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Section #3 – General-Purpose I/O (GPIO)

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine how the General-Purpose I/O functions in this computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

○ [20%] Identify the specific purpose of the GPIO in this computer’s design
○ [20%] Identify whether the GPIO in this computer is capable of input (I) only, output (O) only, or both (I/O)
○ [20%] Explain where the GPIO data bits originate from
○ [20%] Explain how the GPIO is selected to access the computer’s bus(es)
○ [20%] Explain what would be necessary to equip this computer with a greater number of GPIO bits

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Section #4 – Port 0

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine how Port 1 functions in this computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

- [20%] Identify whether Port 0 in this computer is capable of input (I) only, output (O) only, or both (I/O)
- [20%] Explain how Port 0 is selected to access the computer’s bus(es)
- [20%] Identify the specific purpose of Port 0 in this computer’s design
- [20%] Explain how this specific purpose for Port 0 happens to rely on Port 1
- [20%] Propose (in general terms) what code would need to be executed in the 8080 microprocessor to utilize Port 0 for its intended purpose

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Section #5 – Ports 1 and 2

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine how Port 2 functions in this computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

○ [20%] Identify whether Ports 1 and 2 in this computer are capable of input (I) only, output (O) only, or both (I/O)
○ [20%] Explain how Port 1 is selected to access the computer’s bus(es)
○ [20%] Explain how Port 2 is selected to access the computer’s bus(es)
○ [20%] Identify the specific purpose of Ports 1 and 2 in this computer’s design
○ [20%] Propose (in general terms) what code would need to be executed in the 8080 microprocessor to utilize Ports 1 and 2 for their intended purpose

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Section #6 – Power conditioning

Examine the schematic diagram and any relevant technical sources on the 8080 microprocessor to determine the power requirements of the various ICs and how electrical power is conditioned in this particular computer. Plan on showing the relevant portion(s) of this computer’s schematic diagram to your audience as you present on this topic.

Grading

- [20%] Identify where power enters this computer, and what type of electrical power it is (AC versus DC, approximate voltage, etc.)
- [20%] Identify the different DC voltage levels necessary for powering all the ICs in this computer
- [20%] Explain how the first of these voltage levels is conditioned
- [20%] Explain how the second of these voltage levels is conditioned
- [20%] Explain how the third of these voltage levels is conditioned

Note: full credit given only for answers that are correct and logically supported by trusted principles and sources.
Theory session 12

The written exam will consist of the following types of questions and their related principles:

- (Question #1) Calculate voltages, currents, resistances, and/or power dissipations in a series-parallel resistor circuit. Properties of series and parallel networks, effects of opens vs. shorts, behavior of sources and loads, reduction of series-parallel networks into equivalent networks

- (Question #2) Calculate voltages, currents, and/or power dissipations in a circuit containing multiple sources. Properties of series and parallel networks, behaviors of sources and loads, Ohm’s Law, Joule’s Law, Kirchhoff’s Laws

- (Question #3) Sketch wires to form a memory array from multiple RAM or ROM ICs (i.e. address or data bus expansion). Digital memory IC addressing, digital memory IC enabling, decoder circuits

- (Question #4) Predict the outcome of a simple assembly-language computer program. Basic microprocessor function, basic microcontroller function, assembly language programming concepts, binary arithmetic, bitwise logical operations, hex dump memory displays

- (Question #5) Modify a given assembly-language program to make it fulfill a specified function. Basic microprocessor function, basic microcontroller function, assembly language programming concepts, binary arithmetic, bitwise logical operations, hex dump memory displays

- (Question #6) Calculate voltages, currents, resistances, and/or powers in a circuit where a microcontroller interfaces with input and/or output devices. Properties of series and parallel networks, behaviors of sources and loads, Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, basic microcontroller function, logic levels in TTL and CMOS circuits, pull-up and pull-down resistor function, BJT function, MOSFET function, binary-hex conversion

- (Question #7) Determine possible faults in a microcontroller I/O circuit. Basic microcontroller function, logic function truth tables, logic levels in TTL and CMOS circuits, BJT function, MOSFET function, effects of opens vs. shorts, Kirchhoff’s Laws, Ohm’s Law, behaviors of sources and loads
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Serial communication principles
  → Physical encoding of bits
  → Communication speed
  → Data frames
  → Parity
  → Frame check sequences

- Complete “Manchester encoding of a digital word” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Serial data stream decoding” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Ambiguous Manchester data stream” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Theory session 14

Source text – *Serial Data Communication* learning module


Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Flow control
  - Channel arbitration
  - The OSI Reference Model

- Complete “EIA/TIA-232 data frames of ASCII characters” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Manchester data frame with a specified bit rate” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

file wt_0110
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “TDR cable fault testing” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Echo time calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted digital network” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

Additional resources:

- Animation of an open transmission line section of the Animations chapter.
- Animation of a shorted transmission line section of the Animations chapter.
- Animation of a terminated transmission line section of the Animations chapter.

file wt_0037
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Minimalist EIA/TIA-232 system” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Terminating and bias resistors” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Networked DAQ modules” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the SPI bus (Serial Peripheral Interface) section of this document, and answer the following questions:
  - What are the various lines in an SPI network named, and what is each of their functions?
  - How are specific “slave” devices selected by the “master” device in an SPI network?
  - What is the “critical edge” in an SPI system, and how do the four different SPI modes help define it?
  - How are data frames started and ended in an SPI network?
  - One of the advantages of SPI is that the hardware is very simple, each device containing a simple shift register for SPI data transfer. Explain how shift registers are used within an SPI network to facilitate data transfer.

- Read, outline, and reflect on the I^2^C bus (Inter-Integrated Circuit) section of this document, and answer the following questions:
  - How does I^2^C differ from SPI?
  - What are the various lines in an I^2^C network named, and what is each of their functions?
  - How are specific “slave” devices selected by the “master” device in an I^2^C network?
  - How are data frames started and ended in an I^2^C network?
  - How is a successful I^2^C data transaction acknowledged by the receiving device?
  - What factors dictate the sizing of pull-up resistors in an I^2^C network?

- Locate the M24128 serial EEPROM datasheet (document DocID16892 revised September 2017, found in the Datasheets/memory directory of your EETREF document collection) and answer the following questions:
  - Explain the bit sequences necessary to write one byte of data to a particular address in this memory IC.
  - Explain the bit sequences necessary to write data to a “page” of addresses in this memory IC.
  - Explain the bit sequences necessary to read one byte of data from a particular address in this memory IC.
  - Explain the bit sequences necessary to read data from a sequence of addresses in this memory IC.

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Arbitration methods” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Power over Ethernet” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Preamble time and distance” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Use Wireshark “packet-sniffing” software to monitor network traffic on your personal computer, and then identify encapsulation of TCP segments within IP packets, and IP packets within Ethernet frames for some of the captured data.
- Complete “Tracing message routes” in the Diagnostic Reasoning section of the Questions chapter.
- Complete “Possible faults in a network” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Writing a simple HTML file” in the Conceptual Reasoning section of the Questions chapter.
- Complete “HTML color codes” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulty C++ program” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Interpreting an ASCII message frame” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Modbus ASCII message exchange” in the Quantitative Reasoning section of the Questions chapter.
- Complete “SCADA system fault” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Fiber optic data communication
  - Fiber optic cable construction
  - Multi-mode and single-mode optical fibers
  - Fiber optic connectors and routing
  - Fiber optic safety
- Complete “Transconductance and transimpedance amplifiers” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Power concentration” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Light direction testing” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and reason clearly.

file wt 0168
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

file wt_0002
The written exam will consist of the following types of questions and their related principles:

- (Question #1) ???.
- (Question #2) ???.
- (Question #3) ???.
- (Question #4) ???.
- (Question #5) ???.
- (Question #6) ???.
- (Question #7) ???.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Characteristics of RF
  - Skin effect
  - Balanced versus unbalanced signals
  - RF cabling
  - RF connectors
  - PCB layout
  - Near-field testing
  - RF safety

- Examine and reflect on the Example: near-field probing inside a PC section of the Case Tutorial chapter, and answer the following questions:
  - What useful information may we discern from these near-field probing examples?
  - Why does the H-field probe provide such different results when positioned differently over the PCB?

- Locate the datasheet for the Texas Instruments model TRF37A73 RF amplifier (document SLASE39, dated May 2014) and answer the following questions based on information within the document:
  - Is the RF input to this amplifier balanced or unbalanced?
  - Is the RF output from this amplifier balanced or unbalanced?
  - Why does it matter that both the amplifier’s input and output are “matched” to a value of 50 Ohms?
  - Explain the rationale for the PCB layout guidelines specified in this document.

- Locate the datasheet for the Texas Instruments model CC2591 RF front end (document SWRS070B, revised September 2014) and answer the following questions based on information within the document:
  - Is the antenna signal connection to this amplifier balanced or unbalanced?
  - How much receiver gain does this IC provide?
  - How much transmitter output power does this IC provide?
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Phasor analysis review
  - Reactive filtering
  - Bode plots
  - LC resonant filters
  - Roll-off
  - Mechanical-electrical filters
  - Summary of filter types
  - Filtering complex signals

- Complete “Identifying (even more) filter types” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Designing filters using IEC standard component values” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Using C to analyze a filter network” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Phasor diagram review
  - The basic Smith Chart
  - Frequency sweeps
  - Fine-resolution Smith Charts
- Complete “Network frequency-sweep tests” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Plotting component impedances on a Smith Chart” in the Quantitative Reasoning section of the Questions chapter.
- Determine which of the calculated results listed in “Practice: complex number calculations” of the Quantitative Reasoning section of the Questions chapter could be most easily plotted on a Smith Chart. 
  Hint: feel free to alter the “standard” 50 Ohm value of the Smith Chart if this helps with some of the examples!

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial in its entirety and answer the following questions:
  
  → What differentiates a VNA from test equipment such as a signal generator, an oscilloscope, or a spectrum analyzer?

  → Identify the components within the “RF Front-End” block diagram (figure 4), and explain how a VNA could be useful in testing each of those components.

  → What are S-parameters in general? Specifically, what do $S_{11}$, $S_{21}$, $S_{22}$, and $S_{12}$ mean?

  → Calibration is an important topic for VNAs, and is something you (the user) must do each and every time before using a VNA to test something. Explain why “user calibration” is necessary and how this differs from “factory calibration”.

  → What do “open”, “short”, and “load” refer to in the context of user calibration?

  → What is a swept frequency test, and where might we apply such a test?

  → What is a swept power test, and where might we apply such a test?

- Sketch a diagram showing how a VNA could be used to test the performance of a low-pass filter network.

- Sketch a diagram showing how a VNA could be used to measure the inductance of a custom inductor you wind.

- Hands-on experimentation with a real VNA (e.g. NanoVNA):
  
  → User calibration

  → Resistor, capacitor, inductor testing

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Impedance and admittance Smith Charts
  - Series-parallel analysis using Smith Charts
  - Matching network design using Smith Charts

- Complete “Impedance-matching networks” in the Quantitative Reasoning section of the Questions chapter.

- Locate the “CC1020 Low-Power RF Transceiver for Narrowband Systems” datasheet (document SWRS046I revised Sep 2018, found in the Datasheets/RF directory of your EETREF document collection) and answer the following questions:
  - Identify the range of input impedance values for this transceiver’s LNA (Low-Noise Amplifier) as shown on a Smith Chart
  - Identify the range of optimum load impedance values for this transceiver’s PA (Power Amplifier) as shown on a Smith Chart
  - Propose a reasonable explanation for the “loops” seen in some of these Smith Chart frequency sweep tests

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Theory session 30

Source text – Introduction to Modulation learning module


Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Introduction to modulation
  - Amplitude modulation
  - Frequency modulation
  - Phase modulation
  - Pulse modulation
  - Frequency-shifting

- Read, outline, and reflect on the Heterodyne radio reception section of the Historical References chapter.

- Complete “Reginald Fessenden’s invention” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Bat sonar detector” in the Conceptual Reasoning section of the Questions chapter.

- Complete “High-side versus low-side injection” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Identifying modulation types” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

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Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - I-Q modulators
  - Quadrature amplitude modulation
- Complete “???” in the Conceptual Reasoning section of the Questions chapter.
- Complete “???” in the Quantitative Reasoning section of the Questions chapter.
- Complete “???” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Frequency adjustment” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Output frequency predictions” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faults in a simple diode mixer” in the Diagnostic Reasoning section of the Questions chapter.
- Complete “The image problem” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Fourier’s Theorem
  - Fourier series
  - Filter-based Fourier analysis
  - Mixer-based Fourier analysis
  - Fourier analysis of a square wave
  - A digital Fourier transform algorithm

- Complete “Multi-harmonic analyzer” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Fourier analysis of a triangle wave” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Today’s class session will consist of oral presentations made to the entire group. Each presentation will last approximately 15 minutes, be graded on technical accuracy, and be followed by constructive criticism from the audience. You are allowed to bring notes for reference, but not allowed to read them to your audience. When you are chosen to present, you will have a brief period of time to gather your thoughts and set up for your presentation.

Your instructor will not provide answers to you prior to or during the presentation; you are solely responsible for any research, experimentation, and other actions necessary to adequately prepare for your presentation. If you inquire for help, the instructor may clarify what you will need to present on, and/or point you toward specific resources (e.g. “Try setting up a SPICE simulation”, “Try building a test circuit on your breadboard”, “Find and read the datasheet(s)”, “Research application notes written on this topic”, etc.), but do not expect them to give you answers or check your work because by this point in time you will have studied the necessary concepts to verify results for yourself, or at least to know where to go to find verification.

During your presentation the instructor and audience members are free to pose questions relevant to the graded objectives for your assigned problem. This may be done for the simple purpose of clarifying an unclear answer, or to probe for misconceptions.

The benefits of this exercise include honing your independent research skills, reinforcing your foundational knowledge of electronics, gaining confidence speaking to groups, and preparation for job interviews where being able to articulate your knowledge and solve realistic problems before a critical audience sets you apart from lesser-qualified candidates.

A problem will be randomly assigned to you from the options listed on the next several pages. No student will know which problem will be assigned to them until it is their turn to present, which means all students should be prepared to present on every problem shown. Furthermore, problems may contain unspecified parameters which will also be randomized at presentation time. Full credit will be given only for answers that are correct and logically supported by trusted principles and sources (e.g. Conservation of Energy, Ohm’s Law, datasheets, etc.).

You are to regard your audience as technically adept (i.e. assuming everyone in attendance is familiar with the technical concepts and language; “skilled in the art”).

One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
Evaluate this signal generator circuit:

Grading
- [20%] Identify the function provided by each of the operational amplifiers
- [20%] Identify what portion of the circuit generates the oscillations
- [20%] Explain how one type of wave-shape gets converted into another type of wave-shape
- [20%] Explain how frequency is controlled in this oscillator circuit
- [20%] Explain how PWM duty cycle is controlled in this oscillator circuit

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #2
(Component values randomly chosen by instructor):

Grading

- [20%] Current magnitude and direction through resistor $R_2$ ($I_{R2}$)
- [20%] Current magnitude and direction through node 5 ($I_5$)
- [20%] All current magnitudes and directions entering and exiting node 3
- [20%] Voltage magnitude and polarity between nodes 3 and 1 ($V_{3-1}$)
- [20%] Voltage magnitude and polarity of $V_{out}$

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #3
(Component values randomly chosen by instructor):

Grading

- [20%] Current magnitude and direction through resistor $R_1$ ($I_{R1}$)
- [20%] Current magnitude and direction through node 2 ($I_2$)
- [20%] All current magnitudes and directions entering and exiting node 6
- [20%] Voltage magnitude and polarity between nodes 5 and 8 ($V_{5-8}$)
- [20%] Voltage magnitude and polarity of $V_{\text{out}}$

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #4

Demonstrate the measurement of signals in both the time and frequency domains. You may elect to do a live demonstration where you use real test equipment, or you may demonstrate this using a live computer simulation (e.g. Picoscope software in “demo” mode).

Grading

- [20%] Predict and then demonstrate how an (increase/decrease) in signal amplitude will affect both time- and frequency-domain views of a signal.
- [20%] Predict and then demonstrate how an (increase/decrease) in fundamental signal frequency will affect both time- and frequency-domain views of a signal.
- [20%] Demonstrate signal wave-shapes that contain both even and odd harmonics.
- [20%] Demonstrate signal wave-shapes that contain only odd harmonics.
- [20%] Predict harmonic frequency values for a _____ wave with a fundamental frequency of _____ Hz.

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5

Sketch a sensor network capable of sensing (*temperature/strain/light/speed*) that will output an (*increasing/decreasing*) voltage signal as the sensed variable increases. Include an operational amplifier in your circuit to provide a specified voltage gain of _____.

Grading

- [20%] Explain the operating principle of the sensor chosen for your circuit
- [20%] Identify the effects of the sensor failing (*open/shorted*)
- [20%] Identify how to (*increase/decrease*) voltage gain in the circuit
- [20%] Re-design the circuit to have the opposite direction of response as originally specified
- [20%] Explain whether your circuit will be able to function using a “single” DC power supply, or if a “split” DC power supply will be required

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #6

Determine how to interface a voltmeter (with a 0 to 100 milliVolt range) to serve as an analog indicator for (field current/armature current/total current/total voltage/armature voltage/field voltage) in this DC motor circuit. Component values will be randomly chosen by instructor (including armature and winding resistance values), as well as maximum field and armature current values. Feel free to add components as necessary into the circuit:

![DC motor circuit diagram](image)

Grading

- [20%] Voltmeter polarity is proper for the application
- [20%] Voltmeter will not be over-ranged for maximum expected measurement value
- [20%] Voltmeter will indicate at least 50% of full-scale for maximum expected measurement value
- [20%] Any additions/edits to the circuit will not compromise its ability to achieve full-voltage or full-current operation
- [20%] Voltage magnitude and polarity between nodes 0 and 2 ($V_{0-2}$)

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Theory session 36

The written exam will consist of the following types of questions and their related principles:

- (Question #1) ???.
- (Question #2) ???.
- (Question #3) ???.
- (Question #4) ???.
- (Question #5) ???.
- (Question #6) ???.
- (Question #7) ???.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following section of the Tutorial chapter, especially focusing on the “Unity fractions” subsection:
  → Unit conversions and physical constants

- Complete “Analog-digital converter signals” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Pressure unit conversions” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Flow rate conversion” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter. Feel free to skip all subsections dealing with chemical sensors:
  - Potentiometric sensors
  - Amperometric sensors
  - Resistive sensors
- Complete “Thermistor bridge circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Balancing a resistive bridge” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a Wheatstone bridge (circuit _005) using tshoot software, and show the final results.
  - Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read the Tutorial chapter as necessary to refresh your memory on this subject.
- Examine and reflect on the ??? section of the Case Tutorial chapter, and answer the following questions:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

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Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - ADCs and DACs
  - Resolution
  - ADC sampling and aliasing
- Complete “Scaling and overvoltage protection for ADC” in the Conceptual Reasoning section of the Questions chapter.
- Complete “ADC0804 signal values” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Over/under-flowing ADC” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

Additional resources:

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “ADC measurements in a voltage divider” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Resistor sizing” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Damaged data acquisition system” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Connecting strain gauges to a DAQ” in the Conceptual Reasoning section of the Questions chapter.
- Complete “DC circuit monitor” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Measuring speed with a DAQ” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “CD4046B phase-locked loop applications” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Tone-controlled switching system” in the Conceptual Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
The written exam will consist of the following types of questions and their related principles:

- (Question #1) ???.

- (Question #2) ???.

- (Question #3) ???.

- (Question #4) ???.

- (Question #5) ???.

- (Question #6) ???.

- (Question #7) ???.
Complete the following prior to the scheduled session with your instructor:

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

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Theory session 51

Source text – ??? learning module


Complete the following prior to the scheduled session with your instructor:

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.

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Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

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Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Industrial digital security
  - Design-based fortifications
- Complete “Personal computer security” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Password strength” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Power grid vulnerabilities” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g. an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Stuxnet section of the Historical References chapter.
- Complete “Microcontroller security fuse” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Vulnerability databases” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Fortifying a natural gas SCADA system” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Complete the following prior to the scheduled session with your instructor:

**Theory Session Expectations:**

The instructor will assess your preparatory work for good-faith effort (e.g., an honest attempt to understand all tutorials and answer all questions) and your contributions to the dialogue (e.g., attentiveness, thoughtful solutions, good questions). Short quizzes may substitute for either.

Expect to have your reasoning exposed and challenged! Even correct answers will be met by questions from the instructor. Always refer back to the laws, properties, and other foundational principles learned in earlier sessions when explaining your answers. The instructor’s job is to challenge you to pay attention to detail and to reason clearly.
Theory session 60

The written exam will consist of the following types of questions and their related principles:

- (Question #1) ???.
- (Question #2) ???.
- (Question #3) ???.
- (Question #4) ???.
- (Question #5) ???.
- (Question #6) ???.
- (Question #7) ???.

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