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This is a theory course based on an “inverted” model of instruction: instead of lecture where an instructor orally transmits information to students and then students later apply that learning to homework done outside of class, the traditional format is “flipped” so that each student studies new information outside of class time prior to the session and then spends the session with their instructor articulating and applying what they learned. The advantages an “inverted” learning are many: (1) students’ reading skills improve, (2) students pace the speed of their learning to suit their own abilities, (3) students learn to confidently articulate their thoughts, (4) the instructor more clearly sees each student’s strengths and weaknesses, (5) the same amount of learning takes place with much less scheduled class time.

Theory session scores reflect the baseline expectations of preparation (i.e. good-faith effort to complete all the preparatory homework) and participation (i.e. contributing positively to the dialogue and correctly answering challenge questions). Late arrival is equivalent to unpreparedness and absence is equivalent to non-participation.

Oral presentations focus on circuit analysis and are graded on technical accuracy. They serve as review sessions on topics previously taught, as well as helping to build confidence and prepare students for job interviews.

All exams are mastery-based which means 100% accuracy is necessary to pass. Multiple opportunities exist to re-take mastery exams (with a different exam version given each time) but only the score earned on the first version counts toward the course grade. Mastery exams work very well to ensure every student passes a course with no significant “gaps” in their competence.
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 has been designed.

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. Recognizing that objective facts exist independent of, and sometimes in spite of, our subjective desires.

Humility – no one is perfect, and there is always something new to learn. Making mistakes is a symptom of life, 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 – applying knowledge and skill to the effective 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 impact.

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

file eet_values
EET Program Learning Outcomes

(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.
课描述

本课程介绍微处理器理论，包括汇编语言和C语言编程，以及信号和电源条件理论、调制和解调理论、串行数据通信理论和无线电通信理论。掌握式笔试保证了概念性学习目标的实现，而口头报告和苏格拉底对话则展示了沟通性学习目标的实现。

课程学习目标

- 预测微处理器外设电路、模拟传感器和信号调理电路、电源转换电路、调制电路和无线电电路的信号值，根据示意图、组件值和其他电路参数。 (Addresses Program Learning Outcomes 4, 6)
- 为执行指定任务编写简单代码。 (Addresses Program Learning Outcomes 4, 6)
- 设计和草图简单的数字逻辑电路、信号调理电路、调制电路和无线电电路以满足指定功能要求。 (Addresses Program Learning Outcomes 4, 5, 6)
- 以面向专业观众的要求表达和应用与微处理器和模拟传感、信号调理、电源调理、数据通信和无线电相关的技术原理。 (Addresses Program Learning Outcomes 1, 2, 4, 6, 7)
- 根据示意图和报告的症状识别微处理器外设电路、信号处理电路、电源转换电路、数据通信电路和无线电电路可能出现的故障。 (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).

Semester 1 = IETTI-101 (Theory), 103 (Experiments), and 102 (Projects)  
Semester 2 = IETTI-104 (Theory), 112 (Experiments), and 105 (Projects)  
Semester 3 = IETTI-222 (Theory), 221 (Experiments), and 220 (Projects)  
Semester 4 = IETTI-223 (Theory), 225 (Experiments), and 106 (Projects)

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<td>$0 software: PCB layout editor</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. 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.

**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.
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 python3`

**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 third command listed below starts and runs the application:

- `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.
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.

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
- [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 Tutorial chapter in its entirety.
- Read, outline, and reflect on the Ancient digital text code section of the Historical References chapter.
- Complete “ASCII-coded message” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Binary and Gray rotary encoders” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Failed ASCII bit” in the Diagnostic Reasoning section of the Questions chapter.
- Complete “Failed encoder photodetector” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

- Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.
- Questions welcome – please describe what doesn’t make sense to you!
- Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.
- Expect challenges – your instructor’s primary job is to challenge each student to think clearly.
- Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

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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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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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.
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:**

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

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`file wt_0128`
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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

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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:
  → 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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

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Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

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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:
  - 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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think 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:
  - Microcontrollers versus microprocessors
  - MSP430G2553 pin functions
  - MSP430G2553 architecture

- Examine and reflect on the Assembly example: adding two numbers section of the Case Tutorial chapter, and answer the following questions:
  - Identify the values of the two numbers being added together
  - Calculate the sum of these two numbers and express in both decimal and hexadecimal formats
  - Step through this program line-by-line as though the microcontroller were executing it *very slowly*

- Complete “Poor interface design” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

**Preparation and Participation checks** – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

**Questions welcome** – please describe what doesn’t make sense to you!

**Thinking exposed** – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

**Expect challenges** – your instructor’s primary job is to challenge each student to think clearly.

**Responsibility** – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are *minimum expectations*. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.

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**Source text** – *Texas Instruments MSP430 Microcontrollers* learning module

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

- Examine and reflect on the Assembly example: alternating LED blink section of the Case Tutorial chapter, and explain how this program functions.
- Complete “Interrupt capabilities” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Setting up Port 1 I/O” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Improving a debug session” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

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Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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”).

file wt_0116
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 circuits.
  
  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

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires all questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.
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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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.

- Complete “Testing determinism” in the Diagnostic Reasoning section of the Questions chapter.

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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.

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**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.
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.

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file wt_0136
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.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Industrial SCADA system” in the Conceptual Reasoning section of the Questions chapter.
- 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.

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file wt_0138
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:

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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:

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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:
  - 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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

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file wt_0142
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 “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:**

**Preparation and Participation checks** – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

**Questions welcome** – please describe what doesn’t make sense to you!

**Thinking exposed** – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

**Expect challenges** – your instructor’s primary job is to challenge each student to think clearly.

**Responsibility** – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are *minimum expectations*. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.

file wt_0143
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”).

file wt_0117

38
Problem #1 – RS-232 serial communication

Demonstrate the essential elements of RS-232 serial data communication. You may elect to do a live demonstration where you actually show this happening in real time, or you may demonstrate RS-232 data communication in recorded form (e.g. screenshots taken from a computer), or make your presentation a hybrid of real-time and previously-recorded data.

Grading

- [20%] Explain how to decode an RS-232 data frame (i.e. making sense of all the bits in the order they are transmitted over time)
- [20%] Identify the electrical connections necessary on your computer to both transmit and receive RS-232 data
- [20%] Demonstrate how to configure the software application needed to transmit or receive RS-232 data
- [20%] Explain how handshaking works in the RS-232 standard
- [20%] Identify the type of electrical signals used in RS-232 standard

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2 – RS-485 serial communication

Demonstrate the essential elements of RS-485 serial data communication. You may elect to do a live demonstration where you actually show this happening in real time, or you may demonstrate RS-485 data communication in recorded form (e.g. screenshots taken from a computer), or make your presentation a hybrid of real-time and previously-recorded data.

Grading

- [20%] Identify the similarities and differences between RS-232 and RS-485 data communication standards
- [20%] Compare the important performance metrics of RS-232 versus RS-485
- [20%] Identify the electrical connections necessary on your computer to both transmit and receive RS-485 data
- [20%] Explain how you would configure and connect an oscilloscope to capture an RS-485 data frame
- [20%] Identify the type of electrical signals used in RS-485 standard

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #3 – IEEE 802.3 Ethernet

Demonstrate the essential elements of 10BaseT or 100BaseT Ethernet data communication. You may elect to do a live demonstration where you actually show this happening in real time, or you may demonstrate Ethernet data communication in recorded form (e.g. screenshots taken from a computer), or make your presentation a hybrid of real-time and previously-recorded data.

Grading

- [20%] Explain how to decode an Ethernet data frame (i.e. making sense of all the bits in the order they are transmitted over time)
- [20%] Identify the electrical connections necessary on your computer to both transmit and receive Ethernet data
- [20%] Explain how different Ethernet devices are distinguished from one another on a common network
- [20%] Identify modern hardware components used to connect Ethernet devices together to form a single network
- [20%] Identify the type of electrical signals used in the twisted-pair (“BaseT”) Ethernet standard

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

Demonstrate certain aspects of digital data security as it applies to modern industrial data systems. You may elect to do a live demonstration where you actually show this happening in real time, or you may demonstrate Ethernet data communication in recorded form (e.g. screenshots taken from a computer), or make your presentation a hybrid of real-time and previously-recorded data.

Grading

- [20%] Demonstrate “packet-sniffing” software (e.g. WireShark, Snort) useful for detecting network intrusions
- [20%] Demonstrate common firewall settings on a personal computer
- [20%] Demonstrate how to create and retain strong passwords
- [20%] Identify some best practices for maintaining good security in an industrial data network
- [20%] Identify some common mistakes made by people maintaining or using a data network (these cannot be just the opposite of the “best practices” identified above, but must represent different aspects of security)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5 – Command-line diagnostic utilities

Demonstrate the use of standard command-line network diagnostic utilities on a personal computer. You may elect to do a live demonstration where you actually show this happening in real time, or you may demonstrate these tools’ use in recorded form (e.g. screenshots taken from a computer), or make your presentation a hybrid of real-time and previously-recorded data.

Grading

- [20%] Demonstrate how to use ping and explain what it is useful for
- [20%] Demonstrate how to use netstat and explain what it is useful for
- [20%] Demonstrate how to use traceroute and explain what it is useful for
- [20%] Demonstrate how to use ipconfig or ifconfig and explain what they are useful for
- [20%] Demonstrate how to use arp and explain what it is useful for

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

Present on the subject of transmission lines, with particular emphasis on how the related concepts apply to digital data networks.

Grading

- [20%] Explain what characteristic impedance is for a transmission line
- [20%] Identify all the factors influencing the amount of characteristic impedance that any transmission line exhibits
- [20%] Explain how to empirically measure the characteristic impedance of a transmission line
- [20%] Explain what causes signal reflections to occur in a transmission line, and how to eliminate them
- [20%] Explain why reflected signals may cause problems in a data communication network

Note: full credit given only for answers that are correct and logically supported by trusted principles.
The written exam will consist of the following types of questions and their related principles:

- (Question #1) Convert between different forms of digital numeration (e.g. binary, octal, hexadecimal, decimal).
  *Signed binary integers, unsigned binary integers, octal notation, hexadecimal notation*

- (Question #2) Interpret the data contained within an RS-232 data frame and check it for proper parity.
  *Serial data transmission, RS-232 networks, bit rate, parity checks, RS-232 data frames*

- (Question #3) Sketch wire connections necessary to complete a serial data communication network.
  *Serial data transmission, RS-232 networks, hardware handshaking, RS-422/485 networks, multipoint networks, simplex versus half- and full-duplex communication, typical RS-232 connector pin assignments, typical RS-422/485 terminal labels, transmission line termination*

- (Question #4) Identify effects of various faults within a digital communication network.
  *Serial data transmission, RS-232 networks, RS-422/485 networks, Ethernet networks, IP, TCP/UDP, arbitration methods, transmission line termination*

- (Question #5) Calculate the number of possible passwords given a character set and number of characters in the password.
  *Exponential functions*

- (Question #6) Identify vulnerabilities in a digital data network given a network diagram.
  *Firewall principles, DMZ principles, serial data transmission, password strength, basic hacking techniques*

- (Question #7) Determine possible faults within a serial data communication network.
  *Serial data transmission, RS-232 networks, RS-422/485 networks, Ethernet networks, transmission line termination, bit rate, parity checks, RS-232 data frames, use of “ping” utility*

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires all questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Simplified Tutorial chapter in its entirety.
- Complete “Amplifier test” in the Conceptual Reasoning section of the Questions chapter.
- Complete “AC line harmonic analyzer” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Discerning even/odd harmonics from the time domain” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Examine and reflect on the Example: capacitive coupling within cable section of the Case Tutorial chapter, and answer the following questions:
  → Identify conditions that would maximize coupling between the aggressor and the victim
  → How would an open fault in the lamp affect the meter’s measurement, if at all?
- Examine and reflect on the Example: inductive coupling within cable section of the Case Tutorial chapter, and answer the following questions:
  → Identify conditions that would maximize coupling between the aggressor and the victim
  → How would an open fault in the lamp affect the meter’s measurement, if at all?
- Complete “Phantom voltage measurements” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Compressor system wiring” in the Diagnostic Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Examine and reflect on the Oscilloscope, cable, and signal generator section of the Case Tutorial chapter, and answer the following questions:
  - Identify all waveform imperfections captured in the oscillographs
  - Comment on the effects wrought by each cabling alteration
- Complete “Two crosstalk scenarios” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Evaluating set-up and hold times” in the Quantitative Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Texas Instruments *What Is a High-Speed Eye Diagram?* slideshow document in your EETREF collection, and answer the following questions:
  - What is an eye diagram useful for?
  - Identify some of the relevant properties of an eye diagram.
  - Explain why the transmitted and received signal eye diagrams do not look the same.

- Locate the Tektronix tutorial *Fundamentals of Signal Integrity* in your EETREF collection, read the sections “Signal Integrity Described” (page 3), “Rising Bandwidth Challenges Digital Design” (pages 3-4), and “Isolating Analog Deviations” (pages 6-8), and answer the following questions:
  - Explain what it means for a digital signal to have good integrity.
  - How does *edge speed* relate to signal harmonics?
  - Identify some common causes of poor signal integrity and how to identify them using test equipment.

- Complete “The Soul of a New Machine” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Simultaneous crosstalk” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Measuring jitter using an eye diagram” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Pulse waveform oscillographs” in the Diagnostic Reasoning section of the Questions chapter.

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*Questions welcome* – please describe what doesn’t make sense to you!

*Thinking exposed* – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

*Expect challenges* – your instructor’s primary job is to challenge each student to think clearly.

*Responsibility* – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

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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. 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.

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

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Negative feedback
  → Attenuated and offset feedback
  → Inverting and noninverting amplification

- Complete “Necessary resistor values for specified voltage gains” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Calculating input and output voltages” in the Quantitative Reasoning section of the Questions chapter.

- Complete “PCB measurements” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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Additional resources:

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
- The Gallery chapter of the SPICE Modeling of Amplifier Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Differential amplification
  - Summation
  - Precision current circuits
- Complete “Vocal eliminator circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Subtractor calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Summer circuit calculations” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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Additional resources:

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- The Gallery chapter of the SPICE Modeling of Amplifier Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the Operational amplifier imperfections section of the Derivations and Technical References chapter.
- Complete “Model 324 opamp qualitative analysis” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Current regulator limits” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults on a simple amplifier circuit” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

**Preparation and Participation checks** – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

**Questions welcome** – please describe what doesn’t make sense to you!

**Thinking exposed** – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

**Expect challenges** – your instructor’s primary job is to challenge each student to think clearly.

**Responsibility** – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

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**Additional resources:**

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
- The Gallery chapter of the SPICE Modeling of Amplifier Circuits learning module contains circuit examples complete with computer-generated analyses useful as practice problems. Using SPICE, you may modify these simulations for the purpose of generating your own practice problems and solutions!
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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.

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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:

**Preparation and Participation checks** – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

**Questions welcome** – please describe what doesn’t make sense to you!

**Thinking exposed** – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

**Expect challenges** – your instructor’s primary job is to challenge each student to think clearly.

**Responsibility** – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are *minimum expectations*. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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”).
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 $V_{out}$

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 \((\text{increase/decrease})\) in signal amplitude will affect both time- and frequency-domain views of a signal
- [20%] Predict and then demonstrate how an \((\text{increase/decrease})\) 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 \((\text{temperature/strain/light/speed})\) that will output an \((\text{increasing/decreasing})\) voltage signal as the sensed variable increases. Include an operational amplifier in your circuit to provide a specified voltage gain of _____.

Grading

- [20%] Identify the effects of the sensor failing \((\text{open/shorted})\)
- [20%] Identify how to \((\text{increase/decrease})\) 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:

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

- (Question #1) Calculate voltages, currents, and/or resistances in an analog sensor circuit.  
  *Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, bridge networks, rheometric sensing, potentiometric sensing, amperometric sensing.*

- (Question #2) Calculate voltages, currents, and/or resistances in an analog signal-conditioning circuit.  
  *Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, rheometric sensing, potentiometric sensing, amperometric sensing, negative feedback, operational amplifier circuits.*

- (Question #3) Design and sketch a signal-conditioning circuit for an ADC.  
  *Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, bridge networks, rheometric sensing, potentiometric sensing, amperometric sensing, negative feedback, operational amplifier circuits, voltage divider networks, elementary filter networks, behaviors of sources and loads, ADC behavior, differential voltage measurement, ground-referenced voltage measurement.*

- (Question #4) Sketch wire connections necessary to interface a DAQ unit to an analog sensor network.  
  *Properties of series and parallel networks, rheometric sensing, potentiometric sensing, amperometric sensing, behaviors of sources and loads, ADC behavior, differential voltage measurement, ground-referenced voltage measurement.*

- (Question #5) Evaluate digital timing diagrams for adequate signal integrity.  
  *Timing diagrams, AC quantities, switch bounce, oscilloscope display interpretation, eye diagram interpretation, resonance, propagation delay, set-up time, hold time, logic levels in TTL and CMOS circuits.*

- (Question #6) Identify ways to mitigate interference in signal cables.  
  *Differential voltage measurement, ground-referenced voltage measurement, transmission line termination, electric (capacitive) coupling, magnetic (inductive) coupling.*

- (Question #7) Identify possible/impossible faults in an analog function circuit.  
  *Ohm’s Law, Kirchhoff’s Laws, negative feedback, operational amplifier circuits, BJT behavior, MOSFET behavior, voltage divider networks, behaviors of sources and loads, effects of opens vs. shorts.*

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires all questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial (pages 4 through 15):
  - Introduction
  - Component Placement & Design

- Identify where the following foundational concepts appear in the assigned reading, and explain their significance to this topic:
  - Pads versus Vias
  - Garbage-in, Garbage-out (GIGO)
  - Routing or Tracking
  - Clearance
  - Design Rule Checking
  - Measurements in “thous” or “mils”
  - Signal separation
  - Track/space specification
  - Snap grid

- Identify some of the factors relevant to choosing the width of a track on a PCB.

- Why is it standard for some pads to be square while most are circular or oval?

- Why is it important to use the grid features of the PCB layout software?

- Explain the rationale for the following statement: For high currents, use multiple vias when going between layers.

- Compare the “good” versus “bad” track routing examples on page 13 and explain why they are so.

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Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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:**

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**Questions welcome** – please describe what doesn’t make sense to you!

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Standard pass regulator design” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Series regulator calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in an LDO regulator” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Satellite electronics” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Transistor without a heat sink” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find the mistake(s)” in the Diagnostic Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Comparator output waveform” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Duty cycle and power calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in a PWM circuit” in the Diagnostic Reasoning section of the Questions chapter.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “555-based inverter circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Converter efficiency” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Tracing fault current” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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file wt_0148
Theory session 43

Source text – *DC-AC Power Conversion* learning module


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

- Complete “Bright/Royer self-excited inverter circuits” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Early three-phase inverter design” in the Conceptual Reasoning section of the Questions chapter.

**Theory Session Expectations:**

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file wt_0149
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Matching source and load voltages
  - Capacitor and inductor review
  - Simple step-down converter
  - Buck converter
  - Boost converter

- Complete “Buck converter regulation” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Converter efficiency calculations” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Faults in a buck converter” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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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:
  - Inverting converter
  - Cuk converter
  - Flyback converter
  - Forward converter
- Complete “24 Volt spotlight” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Dying battery source” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faults in a boost converter” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Battery UPS circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Electronic fuse circuit calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Wire faults in a remote-sensing circuit” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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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”).
Problem #1

(Component values randomly chosen by instructor, including $\beta$ values for all transistors and resistance of the load):

Grading

- [20%] Current magnitude and direction through resistor $R_1$ ($I_{R1}$)
- [20%] Current magnitude and direction through node 3 ($I_3$)
- [20%] All current magnitudes and directions entering and exiting node 6
- [20%] Voltage magnitude and polarity between nodes 1 and 6 ($V_{1-6}$)
- [20%] Voltage magnitude and polarity across resistor $R_2$ ($V_{R2}$)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2
(Component values randomly chosen by instructor, including $\beta$ values for all transistors and resistance of the load):

Grading
- [20%] Current magnitude and direction through resistor $R_3$ ($I_{R3}$)
- [20%] Current magnitude and direction through node 6 ($I_6$)
- [20%] All current magnitudes and directions entering and exiting node 0
- [20%] Voltage magnitude and polarity between nodes 1 and 4 ($V_{1-4}$)
- [20%] Voltage magnitude and polarity across resistor $R_1$ ($V_{R1}$)

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

- [20%] All current directions when transistor is in the “on” state
- [20%] All voltage polarities when transistor is in the “on” state
- [20%] All current directions when transistor is in the “off” state
- [20%] All voltage polarities when transistor is in the “off” state
- [20%] Energy efficiency if $V_{source} = \underline{\phantom{0}}, I_{source} = \underline{\phantom{0}}, V_{load} = \underline{\phantom{0}},$ and $I_{load} = \underline{\phantom{0}}$

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

Grading

0. [20%] All current directions when transistor is in the "on" state
0. [20%] All voltage polarities when transistor is in the "on" state
0. [20%] All current directions when transistor is in the "off" state
0. [20%] All voltage polarities when transistor is in the "off" state
0. [20%] \( I_{\text{load}} \) if \( V_{\text{source}} = \_), \( I_{\text{source}} = \_), \( V_{\text{load}} = \_), \text{ and Efficiency} = \_

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

- [20%] All current directions when transistor is in the “on” state
- [20%] All voltage polarities when transistor is in the “on” state
- [20%] All current directions when transistor is in the “off” state
- [20%] All voltage polarities when transistor is in the “off” state
- [20%] Energy efficiency if $V_{source} = ____$, $I_{source} = ____$, $V_{load} = ____$, and $I_{load} = ____$

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #6
(Component values randomly chosen by instructor, assume $\beta$ is arbitrarily large):

Grading

- [20%] Time needed for load voltage to stabilize after switch closes
- [20%] Current magnitude and direction through capacitor $C_1$ ($I_{C1}$) at the exact moment the switch first closes
- [20%] Current magnitude and direction through diode $D_1$ ($I_{D1}$) after stabilization
- [20%] Voltage magnitude and polarity between nodes 2 and 4 ($V_{2-4}$) after stabilization
- [20%] Energy efficiency if $V_{source} =$ _____ and $V_{load} =$ _____

Note: full credit given only for answers that are correct and logically supported by trusted principles.
The written exam will consist of the following types of questions and their related principles:

- (Question #1) Calculate thermal parameters for a heat sink and semiconductor device.
  
  Joule’s Law, thermal resistance, thermal “Ohm’s Law”, heat versus temperature, semiconductor PN junction behavior, transistor power dissipation.

- (Question #2) Calculate parameters for a PWM-controlled load (e.g. voltage, current, average power, PWM duty cycle).
  
  Ohm’s Law, Joule’s Law, pulse width modulation.

- (Question #3) Select appropriate component values for a PWM power control circuit.
  
  Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, pulse width modulation, 555 timer circuits, capacitor behavior, inverse exponential calculations, transistor switching circuits, behaviors of sources and loads.

- (Question #4) Design and sketch an interface circuit between a microcontroller and a power conversion circuit.
  
  Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, sourcing versus sinking digital outputs, BJT behavior, MOSFET behavior, transistor switching circuits, pulse width modulation, commutating diodes.

- (Question #5) Identify the effect of faults in a DC-AC converter circuit.
  
  Effects of opens vs shorts, capacitor behavior, inductor behavior, transformer behavior, BJT behavior, MOSFET behavior, DC-DC conversion techniques.

- (Question #6) Identify the effect of faults in a DC-DC converter circuit.
  
  Effects of opens vs shorts, capacitor behavior, inductor behavior, transformer behavior, BJT behavior, MOSFET behavior, DC-DC conversion techniques.

- (Question #7) Identify possible/impossible faults in a power conversion circuit fault.
  
  Effects of opens vs shorts, capacitor behavior, inductor behavior, transformer behavior, BJT behavior, MOSFET behavior, linear regulator techniques, DC-DC conversion techniques, DC-AC conversion techniques.

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires all questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Quarter-wave antenna” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Frequencies and wavelengths” in the Quantitative Reasoning section of the Questions chapter.
- Complete “RF emissions from a computer PCB” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

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Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Parabolic dish feed” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Antenna dimensions” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Whip antenna orientations” in the Diagnostic Reasoning section of the Questions chapter.

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file wt_0161
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Simplified Tutorial chapter in its entirety.
- Complete “Ultimate Transmatch” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Transformer impedance ratios” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Matching section” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

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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:
  - Effective radiated power
  - Link budget fundamentals
  - Link budget graph
- Complete “Link budget graph” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Power and loss calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Waveguide power loss” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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file wt_0162
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Fresnel zones
- Complete “Fresnel zone interference” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Minimum transmitter power” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Possible faults in radio SCADA system” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

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file wt_0173
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Amplitude modulation
  - Frequency modulation
  - Phase modulation
  - Pulse modulation
- Complete “Carrier-less radio” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Oscillographs comparing sinusoids” 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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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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:
  - 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.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Solid-state PA component functions” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Tank circuit calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faults in a low-power CW transmitter” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

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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:
  - 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:

Preparation and Participation checks – the instructor assesses your preparatory work (e.g. good-faith effort) and your contributions to the dialogue (e.g. attentiveness, thoughtful solutions, good questions). Simple quizzes may substitute for either.

Questions welcome – please describe what doesn’t make sense to you!

Thinking exposed – you must defend your reasoning, not just your answers. Your instructor will do the same when offering help. All answers should ultimately stem from foundational principles.

Expect challenges – your instructor’s primary job is to challenge each student to think clearly.

Responsibility – if you cannot answer a question, at least propose some practical way to find a solution. Simply giving up is not an option!

Arriving prepared and contributing positively are minimum expectations. Unpreparedness and disengagement result in penalties to the course grade. Late arrival is equivalent to unpreparedness, and absence equivalent to non-participation. If you cannot attend in person, you may submit your work in advance of the session for full credit, with answers to “Challenge” questions as extra work substituting for participation.
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.

Each student will analyze various sections of a system documented in schematic form, the schematic diagrams of the system taken from US Patent 1,835,031 (“Concentric Conducting System” by Lloyd Espenscheid and Herman Affel, granted 8 December 1931), and the particular diagram being randomly chosen from the following list. The patent document itself may be found in the EETREF collection (EETREF/Patents/US_Patent_1835031_Affel_coaxial_cable.pdf), and contains much explanatory text in addition to these figures. No student will know which diagram 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.

Note: these circuits used in these communication systems were based on vacuum tubes rather than transistors. You will not be expected to explain the operation of these tubes in detail, but know that each one may be considered analogous to an N-channel FET.

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”).

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Problem #1 – Television/telephone system shown in Figure 14

Grading

☐ [20%] Purpose of the plugs and jacks shown in the diagram
☐ [20%] Purpose of the filter networks shown at either end of the system
☐ [20%] Purpose of the repeater
☐ [20%] Trace individual signal pathways from one video-phone to the other
☐ [20%] Advantages of coaxial ("concentric conductor") transmission line over competing technologies of the day

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

- [20%] Purpose and frequency range of the directional filters
- [20%] Explain necessity of modulation and demodulation in this system
- [20%] Explain how a “harmonic producer” circuit might function
- [20%] Purpose of the harmonic producer’s frequencies in this system
- [20%] Highest signal frequency likely to be seen on the coaxial transmission line

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #3 – Tandem modulation system shown in Figures 17 and 18

Grading

- [20%] Bandwidth of each telephone voice channel
- [20%] Purpose of “step-up” apparatus at each stage in Fig 17
- [20%] Purpose of “step-down” apparatus at each stage in Fig 18
- [20%] Purpose of filter networks at each stage
- [20%] Highest signal frequency likely to be seen on the coaxial transmission line, based on example system of Fig 18

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #4 – Repeater circuits shown in Figure 12

Grading

- [20%] Trace signal directions from terminal apparatus, through transmission line and repeaters
- [20%] Explain purpose of equalizer networks at each repeater
- [20%] Signal-coupling methods used within each repeater circuit
- [20%] Contrast the three different system designs shown in Fig 12
- [20%] Explain why all repeaters are to be enclosed in sheet-metal boxes

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #5 – Tandem modulating circuit shown in Figure 19

Grading

- [20%] Purpose of “HF” network
- [20%] Purpose of “LF” network
- [20%] Frequencies appearing at output of the first modulating tube circuit (MM), given signal and carrier frequencies of your choosing
- [20%] Frequencies appearing at output of the second modulating tube circuit (MM’), given the same signal and carrier frequencies
- [20%] Frequencies appearing at final output, given the same signal and carrier frequencies

*Note: full credit given only for answers that are correct and logically supported by trusted principles.*
Problem #6 – Tandem demodulating circuit shown in Figure 20

Grading

- [20%] Purpose of “HF” network
- [20%] Purpose of “LF” network
- [20%] Frequencies appearing at output of the first modulating tube circuit (MM), given signal and carrier frequencies of your choosing
- [20%] Frequencies appearing at output of the second modulating tube circuit (MM’), given the same signal and carrier frequencies
- [20%] Frequencies appearing at final output, given the same signal and carrier frequencies

Note: full credit given only for answers that are correct and logically supported by trusted principles.
The written exam will consist of the following types of questions and their related principles:

- (Question #1) Calculate parameters for RF circuits (frequency, L and C values).
  - Resonance, resonant oscillator circuits (e.g., Colpitts, Hartley, etc.), properties of series and parallel networks, phasor calculations, filter networks

- (Question #2) Compute power gains/losses in radio communication systems using decibels.
  - Decibels, power dissipation in RF cables, antenna gain, RF link budgets

- (Question #3) Identify RF signal modulation based on oscillograph or spectrum displays.
  - Modulation schemes, AC quantities, oscilloscope display interpretation, spectrum analyzer display interpretation, sinusoidal decomposition (Fourier analysis), sidebands

- (Question #4) Identify the effect of faults in a radio transmitter or receiver circuit.
  - Modulation and demodulation schemes, mixer circuits, effects of opens and shorts, oscilloscope display interpretation, spectrum analyzer display interpretation,

- (Question #5) Determine possible faults within a wireless serial data communication network.
  - Serial data transmission, RS-232 networks, RS-422/485 networks, transmission line termination, bit rate, parity checks, effects of opens and shorts, antennas, RF link budgets

The written exams are printed on paper, and will be handed to you at the beginning of the exam session. They are closed-book and closed-note. A scientific calculator is allowed, but no use of mobile phones or personal computers as calculators. Music played through earbuds is welcome. You may ask questions of the instructor, who will clarify questions but will not provide hints or any other form of help. Numerical answers must be within 1% of the correct (un-rounded) answer in order to be counted as correct.

The written exam is a mastery exam, which means passing the exam requires all questions be answered correctly, and that passing this exam is necessary to pass the course. If upon your first submission to the instructor any errors are found, the instructor will mark which sections of the exam have been passed (with “1” characters) and which sections have not (with “0” characters), and will return the exam to you for another attempt. If upon your second submission any errors remain (or new errors added), you must re-take a different version of the exam on a different day. Scoring is based on the number of attempts: the number of “1” marks divided by the total number of “0” and “1” marks. The score from the first version of the exam you take factors into your course grade. Re-take exams are not scored, but only checked for absence of all errors by the second submission. Exam re-takes occur during lab time, a maximum of one per day.