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<td>Intro to the Career</td>
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<td>Session 02</td>
<td>C coding – basics</td>
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<td>Oscillators</td>
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Essential information about this course:

- Learning to independently digest technical information and solve novel problems is even more important than learning electrical and electronic theory. To develop these skills we will read extensively to gain new knowledge, then tackle unfamiliar problems using that knowledge.

- This is a theory course, but it is not lecture-based. At-home reading assignments replace lecture, while discussions about the text and problem-solving practice occupy class time.

- Full preparation for and participation in every theory session is a basic expectation. Lack of preparation will result in point deductions, as will lack of participation and/or late arrival.

- Half of your course grade comes from “oral presentations” where you solve problems in full view of classmates and instructor just like during a technical job interview.

- Half of your course grade comes from written “mastery exams” where every question must be correctly answered to pass. Multiple re-tries are allowed on different exam versions, but only the first exam’s score counts toward your course grade.

- You should budget a minimum of 12 hours per week for this course, approximately 4 hours in-class and 8 hours out-of-class preparation.

- Successful students (1) prioritize their study time, (2) test themselves on upcoming oral presentation and written exam topics, (3) and master principles before memorizing procedures.
Values

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

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

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

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

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

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

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

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

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

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

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

Respect is the acknowledgment of others’ intrinsic capabilities, responsibilities, and worth. Everyone has something valuable to contribute, and everyone deserves to fully own their lives.
(1) **COMMUNICATION and TEAMWORK** – Accurately communicate ideas across a variety of media (oral, written, graphical) to both technical and non-technical audiences; Function effectively as a member of a technical team.

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

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

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

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

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

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

This course reviews DC and AC circuit theory while introducing principles of C-language computer programming, then builds on that foundation to explore analog amplifier circuits (both discrete-transistor and operational amplifier), principles of RF and radio systems, operational amplifier circuits, AC motor controls, and protective relaying. Mastery-style written exams guarantee attainment of conceptual learning outcomes, while oral presentations and Socratic dialogue demonstrate communicative learning outcomes.

Course learning outcomes

- Predict the performance of resistor networks, time-delay networks, AC reactive networks, transistor amplifiers, simple RF circuits, operational amplifier circuits, and AC power control circuits given schematic diagrams, component values, and other circuit parameters. (Addresses Program Learning Outcomes 4, 6)

- Compute component values necessary to achieve stated performance goals in resistor networks, transistor amplifier circuits, RF communication circuits, operational amplifier circuits, and AC power control circuits. (Addresses Program Learning Outcomes 4, 6)

- Design and sketch simple filter networks, transistor amplifier circuits, operational amplifier circuits, and AC power control circuits to meet stated functional requirements. (Addresses Program Learning Outcomes 4, 5, 6)

- Articulate and apply technical principles related to fundamental DC/AC circuit theory, analog electronics, RF systems, and AC power circuits as requested by a critical audience. (Addresses Program Learning Outcomes 1, 2, 4, 6, 7)

- Identify probable faults in resistor networks, transistor amplifier circuits, radio transceiver systems, operational amplifier circuits, and AC power control circuits given schematic diagrams and reported symptoms. (Addresses Program Learning Outcomes 5, 6)
### Required Tools, Supplies, and Software

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

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 236 (Projects)

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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. Most operating systems, size of hard drive, amount of RAM memory, and screen size is appropriate, but your computer must have a keyboard and mouse (i.e. no tablets). Avoid ChromeBooks. Useful features worth higher cost include an RJ-45 Ethernet port and an EIA/TIA-232 (9-pin) serial port.

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

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

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

**PLC** – these courses are not brand- or model-specific, but the Koyo “CLICK” series of Programmable Logic Controller sold by Automation Direct is highly recommended for low cost and ease of use.

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

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

**Schematic editor** – this is used to draft schematic diagrams for circuits. A good one is TinyCAD, but there are also web-based CAD tools such as diagrams.net that are very effective and easy to use. KiCad offers an excellent schematic editor as well as other tools for translating schematic diagrams into printed circuit board (PCB) layouts, useful in later courses.

**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`

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

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

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

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

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

file eet_tools
Grading standards for Theory courses

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

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

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

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

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

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

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

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

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

• Read, outline, and reflect on the “Interviews and the Screening Process” 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*
  → Share your answers for selected “Sample Technical Questions”
  → Share your answers for selected “Sample Behavioral Questions”

• Discuss what you found in your job search:
  → What technical skills are common to these jobs?
  → What non-technical skills are common to these jobs?

• Calculate time commitment (3 hrs/week per semester-credit) for this semester’s courses
  → Full load = 12 credits = 36 hours/week total time commitment + General Education courses!

• Emphasize importance of daily contact with instructor, even in the event of an absence

• Emphasize importance of personal effort to solve problems prior to asking for help

• [Optional] – sign FERPA release forms

Forms provided by the instructor for today’s session:

• FERPA release form
• IETTI-222 Theory course document (printed from cover page through Theory Session 2)
• IETTI-221 Experiments course document (only if you are enrolled in this course as well)
• IETTI-220 Projects course document (only if you are enrolled in this course as well)

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_1003
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - What is a programming language?
  - Creating and running a simple C program
  - C program fundamentals
  - Writing neat code
  - Comments

- Complete “Writing your first C program” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Re-writing a ‘Hello world!’ program” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Find mistakes in a very simple program” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Formatted output using printf
  → Data types
  → Basic mathematical functions
  → Using the C math library

- Explain the following foundational concepts for DC circuits:
  → Ohm’s and Joule’s Laws
  → Kirchhoff’s Voltage and Current Laws
  → Properties of series networks
  → Properties of parallel networks
  → The distinction between an electrical source and an electrical load

- Complete “Using C to analyze a series resistor circuit” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Using C to analyze a parallel resistor circuit” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Using C to analyze a series-parallel resistor circuit” in the Quantitative Reasoning section of the Questions chapter.

- Identify specific modules in the Modular Electronics Learning Project collection with tutorials and practice problems to refresh your knowledge of the DC circuit concepts you find most challenging.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following section of the Tutorial chapter:
  - Formatted input using `scanf`
- Complete “Writing a power calculation program” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Find mistakes in a millimeter conversion program” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Explain the following foundational concepts for AC circuits:
  - Peak versus RMS quantities
  - Resistance versus reactance versus impedance
  - Phasor diagram
  - Power factor
  - Polyphase AC power

- Complete “Using C to analyze a series AC RLC circuit” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Using C to analyze a parallel AC RLC circuit” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Case-sensitivity in variable names” in the Diagnostic Reasoning section of the Questions chapter.

- Identify specific modules in the Modular Electronics Learning Project collection with tutorials and practice problems to refresh your knowledge of the AC circuit concepts you find most challenging.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Conditionals
  - Loops
- Complete “Resonant frequency calculator program” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Using C to plot a sine wave” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Geometric sequence counting program” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Complete “RC time-constant calculator program” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Using C to analyze an RC charging-discharging circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Writing an LR time-delay analysis program” in the Quantitative Reasoning section of the Questions chapter.
- Identify specific modules in the Modular Electronics Learning Project collection with tutorials and practice problems to refresh your knowledge of capacitor and inductor time-delay circuits.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Complete “Using C to analyze a series AC resistor-capacitor circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Writing a cutoff frequency calculator program” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Writing a low-pass filter simulation program” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → MSP430G2553 pin functions
  → Elementary output and input
- Complete “Integer conversion table” in the Quantitative Reasoning section of the Questions chapter.
- Compare and contrast three different Case Tutorial sections on programs that add two numbers together (one written in Assembly, one written in C, and one written in Sketch). Then, answer the following questions:
  → Identify the value of the calculated sum, in each example
  → Which two out of these three programming languages appears most similar to each other?
  → How are comments shown in each of the three languages?

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - CCS assembly-language programming
  - CCS C-language programming
  - Energia programming

- Complete “Terminal assignments and limits” in the Quantitative Reasoning section of the Questions chapter.

- Compare and contrast three different Case Tutorial sections on programs that alternately blink LEDs (one written in Assembly, one written in C, and one written in Sketch). Then, answer the following questions:
  - Identify how each of the two LEDs’ states are controlled by the code
  - Explain how a time delay is implemented in each programming language
  - What advantages and disadvantages do you see to each programming language as used in the MSP430 microcontroller?

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Oral Presentations

Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, 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_0227*
Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>( R ) vs. ( X ) vs. ( Z )</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td></td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td></td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields and inductance</td>
<td></td>
</tr>
<tr>
<td>Inverse-exponential growth/decay</td>
<td></td>
</tr>
</tbody>
</table>

*One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem!* Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1
(Component values randomly chosen by instructor):

Note: the instructor will choose component values simple enough that you will not need an electronic calculator to obtain exact solutions. For this reason, you will not be permitted to use any calculating device when analyzing this circuit! This prohibition of calculating devices is typical during technical interviews for electronics technician jobs.

Grading

- [20%] Current magnitude and direction through resistor $R_3$ ($I_{R3}$)
- [20%] Current magnitude and direction through node 4 ($I_4$)
- [20%] All current magnitudes and directions at node 1
- [20%] Voltage magnitude and polarity between nodes 1 and 3 ($V_{1-3}$)
- [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):

Note: the instructor will choose component values simple enough that you will not need an electronic calculator to obtain exact solutions. For this reason, you will not be permitted to use any calculating device when analyzing this circuit! This prohibition of calculating devices is typical during technical interviews for electronics technician jobs.

Grading

- [20%] Current magnitude and direction through resistor $R_2$ ($I_{R2}$)
- [20%] Current magnitude and direction through node 2 ($I_2$)
- [20%] All current magnitudes and directions entering and exiting node 3
- [20%] Voltage magnitude and polarity between nodes 3 and 4 ($V_{3-4}$)
- [20%] Voltage magnitude and polarity across resistor $R_3$ ($V_{R3}$)

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

Assume the switch has been in the \((open/closed)\) state long enough for the capacitor’s voltage to stabilize, and is suddenly toggled to the opposite state at time \(t = 0\). All component values will be randomly chosen by instructor, as well as the point in time \((t = ____)\) at which all values will be calculated:

Grading

- [20%] Current magnitude and direction through resistor \(R_2\) \((I_{R2})\)
- [20%] Current magnitude and direction through node 2 \((I_2)\)
- [20%] Current magnitude and direction through capacitor \(C_1\) \((I_{C1})\)
- [20%] Voltage magnitude and polarity across capacitor \(C_1\) \((V_{C1})\)
- [20%] Voltage magnitude and polarity across resistor \(R_1\) \((V_{R1})\)

\textit{Note: full credit given only for answers that are correct and logically supported by trusted principles.}
Problem #4
Assume the switch has been in the (open/closed) state long enough for the inductor's current to stabilize, and is suddenly toggled to the opposite state at time \( t = 0 \). All component values will be randomly chosen by instructor, as well as the point in time \( t = \) _____ at which all values will be calculated:

Grading

- [20%] Current magnitude and direction through resistor \( R_2 \) \( (I_{R2}) \)
- [20%] Current magnitude and direction through node 2 \( (I_2) \)
- [20%] Current magnitude and direction through inductor \( L_1 \) \( (I_{L1}) \)
- [20%] Voltage magnitude and polarity across inductor \( L_1 \) \( (V_{L1}) \)
- [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.
Problem #5

(Component values randomly chosen by instructor):

Grading

- [20%] Voltage magnitude and phase angle across resistor $R_1$ ($V_{R1}$)
- [20%] Voltage magnitude and phase angle across capacitor $C_1$ ($V_{C1}$)
- [20%] Voltage magnitude and phase angle across inductor $L_1$ ($V_{L1}$)
- [20%] Total (source) current magnitude and phase angle ($I_{total}$)
- [20%] Power factor

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6
Design a passive filter network meeting performance characteristics randomly chosen by instructor:

- Type of filter = (low-pass/high-pass)
- $f_{\text{cut-off}} = \underline{\text{Hertz}}$
- Using (inductor/capacitor)
- Minimum input impedance = $\underline{\text{Ohms}}$ @ cut-off

Grading
- [20%] Proper pass characteristic (either low- or high-pass)
- [20%] Correct $f_{\text{cut-off}}$ with component values chosen
- [20%] Predict effect(s) of resistor failing open
- [20%] Predict effect(s) of reactive component ($L$ or $C$) failing open
- [20%] Calculate $Z_{\text{in}}$ at $f_{\text{cut-off}}$

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 voltage, current, resistance, and/or power in a series DC resistor circuit.  
  *Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of series networks*

- (Question #2) Calculate voltage, current, resistance, and/or power in a parallel DC resistor circuit.  
  *Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of parallel networks*

- (Question #3) Calculate voltages, currents, resistances, and/or power dissipations in a series-parallel DC 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 #4) Calculate voltages, currents, and/or times for a resistor-capacitor circuit.  
  *Properties of series and parallel networks, behaviors of sources and loads, capacitor behavior, inverse exponential calculations*

- (Question #5) Calculate voltages, currents, and/or times for a resistor-inductor circuit.  
  *Properties of series and parallel networks, behaviors of sources and loads, inductor behavior, inverse exponential calculations*

- (Question #6) Design and sketch a passive filter circuit with a specified cutoff frequency and characteristic.  
  *Filter circuit behavior, capacitive reactance, inductive reactance, resonance*

- (Question #7) Calculate voltage, current, and/or impedance in a series or parallel AC network.  
  *Capacitive reactance, inductive reactance, impedance, complex-number arithmetic, properties of series networks, properties of parallel networks, Ohm’s Law, Kirchhoff’s Laws*

- (Question #8) Convert between different forms of digital numeration (e.g. binary, octal, hexadecimal, decimal).  
  *Signed binary integers, unsigned binary integers, octal notation, hexadecimal notation*

- (Question #9) Determine logic states within a combinational logic circuit.  
  *Logic function truth tables, logic levels in TTL and CMOS circuits, effects of opens vs. shorts*
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.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Transistor summary” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Proper BJT types” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Explaining the meaning of calculations” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Reliable and unreliable lamp control circuits” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Theory session 15

Source text – Transistor Biasing learning module

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

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Another BJT with slow-changing DC input” in the Conceptual Reasoning section of the Questions chapter.
- Complete “BJT amplifier biasing strategies” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Quiescent base current” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

file wt_0039
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Common-collector amplifier
  - Common-emitter amplifier

- Complete “Altering common-emitter resistor values” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Common-emitter calculations” in the Quantitative Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

**Additional resources:**

- 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!
Theory session 17

Source text – Thévenin’s and Norton’s Theorems learning module


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 following sections of the Case Tutorial chapter, identifying which foundational concepts (e.g. Ohm’s Law, Kirchhoff’s Laws, etc.) were applied to calculate the values shown:
  - Example: Thévenizing a multi-source network
  - Example: Nortonizing a multi-source network
- Complete “Thévenizing a loaded voltage divider” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Fault current of a battery bank” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems.
- Animation of Thévenin’s Theorem section of the Animations chapter.

file wt_0230
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Common-base amplifier
  - Amplifier gain comparisons
  - Input and output impedances

- Complete “Achieving a specified voltage gain” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Gain and quiescent values for common-emitter amplifier” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Faulty audio amplifier design” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- 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:
  - Paired transistors
  - Cascaded stages
  - Push-pull amplifiers
- Complete “Audio amplifier evaluation” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Approximating voltage gain” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Amplifier signal clipping” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- Animation of class-B crossover distortion section of the Animations chapter.
  file wt_0074
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Differential pairs
  - Current mirrors
  - Active loading

- Complete “Model 324 differential amplifier qualitative analysis” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Audio amplifier quiescent values” in the Quantitative Reasoning section of the Questions chapter.

- Complete “Current mirror calculations” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- Animation of class-B crossover distortion section of the Animations chapter.

file wt_0231
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Impulse testing” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Gain ratios into decibels” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Decibels into gain ratios” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Audio amplifier design improvement” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Neon lamp relaxation oscillator” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Colpitts oscillator frequency” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Effects of faults in a strobe light circuit” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- William Hewlett’s Oscillator section of the Historical References chapter.
- LC Resonance section of the Derivations and Technical References chapter.
Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, 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”).

**Note:** all schematic diagrams for these problems are annotated with node numbers. These will be helpful when describing locations in the circuit for your audience, but they also serve as a cue on how to practice. Simply write a SPICE netlist using these node numbers, inserting component values of your choice, and then use SPICE to verify the results you calculate. Using SPICE, you may make as many versions of these circuits for practice as you would like! For example, the circuit of problem #1 may be converted into the following SPICE netlist (assuming all resistors are 1 kΩ in size, the voltage source is 12 Volts, and the switch is closed):

```plaintext
* Netlist
v1 0 3 dc 12
r1 2 4 1000
rswitch 3 4 1e-3
rload 1 3 1000
q1 1 2 0 bjt
.model bjt pnp bf=100
.op
.end

file wt_0232
```
Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>R vs. X vs. Z</td>
</tr>
<tr>
<td>Ohm's Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule's Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Properties of wye networks</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Properties of delta networks</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td>Heat transfer</td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td>Pulse-width modulation</td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields and inductance</td>
<td></td>
</tr>
<tr>
<td>Inverse-exponential growth/decay</td>
<td></td>
</tr>
<tr>
<td>Conduction in semiconductors</td>
<td></td>
</tr>
<tr>
<td>Behavior of PN junctions</td>
<td></td>
</tr>
<tr>
<td>Behavior of BJTs</td>
<td></td>
</tr>
<tr>
<td>Behavior of FETs</td>
<td></td>
</tr>
<tr>
<td>Sinking vs. sourcing current</td>
<td></td>
</tr>
</tbody>
</table>

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

$V_1$ and $R_{load}$ component values randomly chosen by instructor. Assume $R_1$ size chosen to ensure transistor saturation when “on”:

![Diagram]

$\beta = 100$

Grading

- [20%] Current magnitude and direction through load resistor ($I_{load}$) when switch closed
- [20%] Voltage magnitude and polarity between collector and emitter ($V_{CE}$) when switch closed
- [20%] Voltage magnitude and polarity between collector and emitter ($V_{CE}$) when switch open
- [20%] Power dissipated by transistor $Q_1$ when switch closed
- [20%] Resistance value for resistor $R_1$ that would ensure saturation

*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

〇 [20%] Voltage gain \((A_V)\) as a ratio and as a decibel value
〇 [20%] Input impedance \((Z_{in})\)
〇 [20%] Output impedance \((Z_{out})\)
〇 [20%] Assuming your choice of bias resistor values, specify a DC quiescent voltage \(V_B\) suitable for Class-A operation
〇 [20%] Largest value of \(V_{in}\) without clipping, assuming Class-A operation

Note: full credit given only for answers that are correct and logically supported by trusted principles. Note that approximations are permissible, since exact computations can be overwhelmingly complex in discrete-transistor amplifier networks.
Problem #3

(Component values randomly chosen by instructor):

Grading

- [20%] Voltage gain ($A_V$) as a ratio and as a decibel value
- [20%] Input impedance ($Z_{in}$)
- [20%] Output impedance ($Z_{out}$)
- [20%] Assuming your choice of bias resistor values, specify a DC quiescent voltage $V_B$ suitable for Class-A operation
- [20%] Largest value of $V_{in}$ without clipping, assuming Class-A operation

Note: full credit given only for answers that are correct and logically supported by trusted principles. Note that approximations are permissible, since exact computations can be overwhelmingly complex in discrete-transistor amplifier networks.
Problem #4
Thévenize this circuit, assuming resistor ____ is the load:

Grading

- [20%] Thévenin equivalent voltage ($V_{Th}$)
- [20%] Thévenin equivalent resistance ($R_{Th}$)
- [20%] Load current magnitude ($I_{load}$)
- [20%] Load resistance value necessary for maximum load power ($P_{load}$)
- [20%] Sketch diagram of Thévenin equivalent circuit powering the load

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5
(Component values randomly chosen by instructor):

Grading

- [20%] Voltage gain ($A_V$) as a ratio and as a decibel value
- [20%] Output frequency ($f_{out}$)
- [20%] Reactance of $C_2$ at operating frequency
- [20%] Assuming your choice of bias resistor values, specify a DC quiescent voltage $V_B$ suitable for Class-A operation
- [20%] Largest value of $V_{in}$ without clipping, assuming Class-A operation

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6
Predict the effects of resistor \( \text{failing (open/shorted)} \), assuming the circuit is amplifying an AC signal in class-A operation when the fault occurs:

Grading

- [20%] AC signal voltage (increases/decreases/remains the same) between nodes ? and ? \((V_{?-?})\)
- [20%] AC signal voltage (increases/decreases/remains the same) between nodes ? and ? \((V_{?-?})\)
- [20%] DC quiescent voltage (increases/decreases/remains the same) between nodes ? and ? \((V_{?-?})\)
- [20%] DC quiescent voltage (increases/decreases/ remains the same) across resistor \( R_7 \) \((V_{R7})\)
- [20%] DC quiescent voltage (increases/decreases/ remains the same) across capacitor \( C_7 \) \((V_{C7})\)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Theory session 24

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

- (Question #1) Design and sketch a circuit using either a BJT or an FET to switch DC power to a load. BJT behavior, FET behavior, behavior of sources and loads, Kirchhoff’s Laws, properties of series and parallel networks

- (Question #2) Calculate voltages and currents in a series-parallel AC circuit. Capacitive reactance, inductive reactance, impedance, complex-number arithmetic, properties of series networks, properties of parallel networks, Ohm’s Law, Kirchhoff’s Laws

- (Question #3) Sketch a Thévenin equivalent network for a series-parallel DC resistor circuit. Ohm’s Law, Kirchhoff’s Laws, ideal versus real sources, properties of series and parallel networks, Thévenin’s Theorem, Norton’s Theorem

- (Question #4) Calculate the approximate gain for a multi-stage BJT amplifier circuit based on component values or signal measurements, expressed as both a ratio and a decibel figure. Ohm’s Law, BJT behavior, BJT amplifier behavior, gain calculations, decibels

- (Question #5) Calculate voltages, currents, and/or power dissipations in a BJT or FET switching circuit. Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of series and parallel networks, BJT behavior, FET behavior

- (Question #6) Select appropriate components to set the frequency of an oscillator. Ohm’s Law, properties of series and parallel networks, resonance, tank circuits, Wein bridge networks

- (Question #7) Determine possible faults in a discrete-transistor amplifier circuit. Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, effects of opens vs. shorts, amplifier behavior

- (Question #8 – REVIEW) Interpret amplitude values (peak, peak-peak, RMS), period values, phase shifts, and/or frequency values from an oscillograph display. Oscilloscope operation, AC measurements, RMS vs peak ratios for sine and square and triangle/ramp waveforms

- (Question #9 – REVIEW) Design and sketch an unloaded voltage divider network given required voltage and/or current values. Ohm’s Law, Joule’s Law, Kirchhoff’s Laws, properties of series networks

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

- Read, outline, and reflect on the following section of the Tutorial chapter:
  → Functions

- Complete “Decibel calculator program” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Sine calculator program” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Find mistake in a function-calling program” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Composition of light
  - Fourier’s Theorem
  - Time vs. frequency in circuits
  - Time-frequency relationships
  - Applications for frequency-domain analysis
- Complete “LR circuit energized by a square-wave source” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Resistor powered by a square-wave source” 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:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

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

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

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 “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.
- Locate the FCC’s Office of Engineering and Technology (OET) Bulletin number 63 on low-power non-licensed transmitters (found in the Datasheets/Regulatory directory of your EETREF document collection), read the relevant section(s), and answer the following questions:
  → In what ways are experimental (i.e. home-made) devices restricted by the FCC?
  → What are the penalties for non-compliance with an experimental transmitter?
  → Suppose you are building a prototype transmitter with intent to eventually market it – how do the requirements differ from those of a purely experimental or hobbyist transmitter?
  → How may we estimate the power output of a transmitter (in Watts) based on measured electric field strength (in Volts/meter) and distance from transmitting antenna (in meters)?

**Theory Session Expectations:**

Summary the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort. Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Source text – Radio Antennas learning module


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.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the 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:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Decibels section of the Derivations and Technical References chapter.  
  → A helpful tip when learning any math-heavy concept from text is to perform all the mathematical examples yourself, checking to see that you get the same results!

- Read, outline, and reflect on the following sections of the Tutorial chapter:  
  → Effective radiated power

- Complete “Cable loss and frequency” in the Conceptual Reasoning section of the Questions chapter.

- Complete “Power ratio and dB conversions” in the Quantitative 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:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following *prior to* the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the *Tutorial* chapter:
  - Link budget fundamentals
  - Link budget graph
  - Fresnel zones
- Complete “Link budget graph” in the *Conceptual Reasoning* section of the *Questions* chapter.
- Complete “Using C to calculate receiver power” 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.

*NOTE: there are many calculations required to perform a full link budget calculation, and therefore many places one can make mistakes. Here are some proven strategies for success:*

- Make a formula note page listing every new formula you encounter, the necessary units of measurement, and a description of what it means.
- Work through each representative example problem shown in the text, on your own, until your answers match the text’s. Avoid consulting the text for assistance unless absolutely necessary. *Unless and until you can do the problem(s) on your own, you have not yet learned the concept!*
- Carefully organize all your numerical results in link budget calculations, using either a table and/or a link budget graph!

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- 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:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Locate the Texas Instruments CC1190 datasheet for their 850-950 MHz “RF front end” IC (document SWRS089A revised February 2010, found in the Datasheets/RF directory of your EETREF document collection) and answer the following questions:
  - Examine the block diagram for this device and identify the function of each block within it, as well as the functions of all externally-connected components
  - Identify the functions of the three digital control pins (PA_EN, LNA_EN, and HGM) on this IC
  - Identify the maximum RF power output of this device’s power amplifier (PA) as well as its efficiency in percent
  - Identify whether this “front end” IC is designed for balanced or unbalanced RF signals
- 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:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, 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”).
## Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>$R$ vs. $X$ vs. $Z$</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Transmission lines</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Heat transfer</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td>Modulation types</td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td></td>
</tr>
<tr>
<td>Electric fields and capacitance</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields and inductance</td>
<td></td>
</tr>
<tr>
<td>Conduction in semiconductors</td>
<td></td>
</tr>
<tr>
<td>Behavior of PN junctions</td>
<td></td>
</tr>
<tr>
<td>Behavior of BJTs</td>
<td></td>
</tr>
<tr>
<td>Behavior of FETs</td>
<td></td>
</tr>
</tbody>
</table>

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

Calculate parameters associated with the link budget for a radio transmitter/receiver network. The following parameters will be randomly chosen by the instructor:

- Distance between transmitting and receiving antennae (in either miles or kilometers)
- Frequency of RF signal (in Hertz)
- Sensitivity of receiver (in dBm)
- RF power output of transmitter (either in Watts or dBm/dBW/etc.)

Assume no losses between the transmitter and its antenna, or between the receiver and its antenna.

Grading

- [20%] RF signal loss over space between antennae, assuming perfect conditions (in dB)
- [20%] Wavelength of RF signal ($\lambda$) in meters and also in feet
- [20%] Minimum antenna height for first Fresnel zone to clear ground (assuming perfect conditions)
- [20%] DC power necessary to run the transmitter, assuming _____% RF power amplifier efficiency
- [20%] Methods to improve reception without modifying transmitter or receiver electronics

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2

Calculate parameters associated with a coaxial cable used to connect the output of a radio transmitter to its antenna, assuming perfect impedance matching throughout the system. The following parameters will be randomly chosen by the instructor:

- Cable velocity factor
- Cable length
- Cable loss (dB per foot or meter)

The instructor will also choose random power values to fill in the “blank” spaces below. The unit of measurement for each power will also be random (e.g. Watts, milliWatts, dBm, dBW, etc.).

Grading

- [20%] Power received by antenna at ____ transmitter output power
- [20%] Power dissipated by cable at ____ transmitter output power
- [20%] Necessary transmitter output power to deliver ____ of power to antenna
- [20%] Transmitter output power when cable dissipates ____ of heat
- [20%] Signal propagation time from one end of cable to the other

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

Sketch three different types of radio antennas (all specified by instructor) and comment on their characteristics:

- [10%] Identify radiation pattern of first antenna
- [10%] Identify whether the feed line for the first antenna will be balanced or unbalanced
- [10%] Identify radiation pattern of second antenna
- [10%] Identify whether the feed line for the second antenna will be balanced or unbalanced
- [10%] Identify radiation pattern of third antenna
- [10%] Identify whether the feed line for the third antenna will be balanced or unbalanced
- [10%] Identify which antenna is the most directional
- [10%] Identify which antenna exhibits the least gain
- [20%] EIRP of a ____ Watt transmitter connected to a ____ dBi gain antenna

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

Grading

- [20%] Identify what would have to be altered to (increase/decrease) its frequency
- [20%] Identify the effect(s) of ___ failing (open/shorted)
- [20%] Identify ways to increase the physical range of this radio circuit
- [20%] Explain how you could test this circuit for proper operation with its antenna disconnected
- [20%] Explain how you could send a message to someone using this transmitter

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5
Analyze the following instrument, designed to provide an approximate measurement of RF power from a transmitter to its antenna:

Grading
○ [20%] How is the DC meter able to operate from the AC power on the transmission line?
○ [20%] Explain how you could use this instrument to indicate when an antenna “tuner” had been properly adjusted
○ [20%] Identify one cause for sub-optimal power transfer in a real antenna system
○ [20%] Identify another cause for sub-optimal power transfer in a real antenna system
○ [20%] Identify the effect(s) of ___ failing (open/shorted)

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

Sketch a schematic diagram showing a radio transmitter with 50 Ohm output impedance (unbalanced) connected to a 50 Ohm coaxial cable transmission line, impedance-matched to a monopole antenna having an impedance of ____ Ohms. Assume an operating frequency of ____ Hertz.

Grading

〇 [20%] Sketch a matching network based on a transformer
〇 [20%] Propose primary and secondary turns values for this transformer
〇 [20%] Sketch a matching network based on a matching section
〇 [20%] Propose impedance and length for the matching section
〇 [20%] Explain in detail why a matching network is beneficial to this application

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)** Determine the appropriate dimensions for a radio antenna given signal frequency, or vice-versa.
  Wavelength calculations, speed of light, antenna types and configurations (e.g. monopole, dipole, Yagi, loop), conversions between metric and imperial units of length

- **(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 the length of a transmission line given reflectometry data, or vice-versa.
  Velocity factor, speed of light, oscillograph display interpretation, conversions between metric and imperial units of length

- **(Question #6)** Identify the purposes of individual components within an RF amplifier circuit, given a schematic diagram.
  Transistor amplifier configurations (e.g. common-base, etc.), RF chokes, bypass capacitors, coupling, amplifier biasing

- **(Question #7)** Determine necessary circuit parameters and/or configurations to properly match feedlines with other components (e.g. transceiver, antenna) in an RF system.
  Transmission lines, standing wave ratio (SWR), transformer impedance ratios, quarter-wave matching sections, balun transformers, Maximum Power Transfer Theorem, Thévenin's/Norton's Theorems, velocity factor, speed of light

- **(Question #8 – REVIEW)** Calculate voltages, currents, and/or powers in a transformer circuit
  Transformer behavior, Ohm’s Law, Joule’s Law

- **(Question #9 – REVIEW)** Apply right-triangle trigonometry to the solution of practical distance problems.
  Law of sines, Pythagorean Theorem, sine function, cosine function, tangent function
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Tutorial chapter in its entirety.
- Complete “Determining output polarities” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Solar panel tracker” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Hysteretic comparator with rail-to-rail output” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faults in thermostat circuit” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

**Additional resources:**

- The “Example: comparator response to various inputs” section of the Case Tutorials chapter gives insightful examples of a comparator responding to different input conditions.
- Differential pair amplifiers section of the Derivations and Technical References chapter.
- Comparator generating PWM waveform 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 “Miscalibrated speedometer” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Mathematical functions in feedback path” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Loss of servo feedback” 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 following sections of the Tutorial chapter:
  - Negative feedback
  - Regulation
  - Servos and control systems
  - Attenuated and offset feedback
- Complete “Fooling a voltage regulator” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Load current path” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Internal faults in a TL082” in the Diagnostic Reasoning section of the Questions chapter.

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Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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:
  → Inverting and noninverting amplification
- Read, outline, and reflect on the Split DC power supplies section of the Derivations and Technical References chapter.
- Complete “Calculating output voltages and gains” in the Quantitative Reasoning section of the Questions chapter.
- 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 “Effects of faults on a simple amplifier circuit” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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 following sections of the Tutorial chapter:
  - Differential amplification
  - Summation
- 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.
- Demonstrate how to make your own practice problem for learning about this topic, complete with a reliable means of checking the correctness of your work.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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!
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Source text – Operational Amplifiers learning module

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

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Precision current circuits
  - Boosted output
- Read, outline, and reflect on the Operational amplifier imperfections section of the Derivations and Technical References chapter.
- Complete “Unusual current-regulating circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Current regulator limits” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Troubleshooting a microphone amplifier” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

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:
  → Precision rectification
- Complete “Opamp power rectifier?” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Precision rectifier analysis” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Incorrect full-wave rectifier analysis” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

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

- Read, outline, and reflect on the following section of the Tutorial chapter: Integrators and differentiators
- Complete “Rogowski coil power meter” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Integrator calculations” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Pushbutton-adjustable voltage” in the Diagnostic Reasoning section of the Questions chapter.

Theoretical Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

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 section of the Tutorial chapter:
  → Oscillator circuits
- Complete “Adjustable oscillator” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Limiting network” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Effects of faults in a relaxation oscillator” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.

Additional resources:

- Sections of the Case Tutorials chapter contain circuit examples which may serve as practice problems. In particular, the section showing the design of a triangle/square/PWM oscillator is particularly relevant to this theory session’s topic.
- 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 the following circuit examples and answer the associated questions:
  - Adjusted reference voltage circuit – determine all circuit voltages and currents at $\alpha = 0\%$, $\alpha = 50\%$, and $\alpha = 100\%$
  - High-side current-sensing circuit design – determine $V_o$ at a current of 0.25 Amperes
  - Single-ended input to differential output circuit – determine $V_{o-}$ and $V_{o+}$ at an input signal voltage of 1.5 Volts
  - Relaxation oscillator circuit – reduce the $R_2/R_3$ voltage divider reference network to an equivalent Thévenin source, and then explain how this produces a sawtooth waveform centered around 2.5 Volts

**Theory Session Expectations:**

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Oral Presentations

Today’s class session will consist of oral presentations made to the entire group. Each presentation will be time-limited, 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_0119

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Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

<table>
<thead>
<tr>
<th>Conservation of Energy</th>
<th>Amplitude, period, frequency</th>
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</thead>
<tbody>
<tr>
<td>Behavior of sources vs. loads</td>
<td>R vs. X vs. Z</td>
</tr>
<tr>
<td>Ohm’s Law</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Joule’s Law</td>
<td>Power factor</td>
</tr>
<tr>
<td>Effects of opens vs. shorts</td>
<td>Resonance</td>
</tr>
<tr>
<td>Properties of series networks</td>
<td>Fourier analysis</td>
</tr>
<tr>
<td>Properties of parallel networks</td>
<td>Properties of filters</td>
</tr>
<tr>
<td>Kirchhoff’s Voltage Law</td>
<td>Behavior of transformers</td>
</tr>
<tr>
<td>Kirchhoff’s Current Law</td>
<td>Properties of wye networks</td>
</tr>
<tr>
<td>Maximum Power Transfer Theorem</td>
<td>Properties of delta networks</td>
</tr>
<tr>
<td>Superposition Theorem</td>
<td>Heat transfer</td>
</tr>
<tr>
<td>Thévenin’s and Norton’s Theorems</td>
<td>Pulse-width modulation</td>
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<td>Electric fields and capacitance</td>
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<tr>
<td>Magnetic fields and inductance</td>
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<tr>
<td>Inverse-exponential growth/decay</td>
<td></td>
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<tr>
<td>Conduction in semiconductors</td>
<td></td>
</tr>
<tr>
<td>Behavior of PN junctions</td>
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<td>Behavior of BJTs</td>
<td></td>
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<tr>
<td>Behavior of FETs</td>
<td></td>
</tr>
<tr>
<td>Sinking vs. sourcing current</td>
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</table>

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

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

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

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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 \( V_{\text{out}} \)

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

(Instrumentation amplifier circuit – 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
(Component values randomly chosen by instructor):

Grading

- [20%] Current magnitude and direction through resistor $R_1$ ($I_{R1}$)
- [20%] Current magnitude and direction through load ($I_{R_{load}}$)
- [20%] Voltage magnitude and polarity between nodes F and G ($V_{FG}$)
- [20%] AC voltage magnitude between nodes A and B ($V_{AB}$)
- [20%] Power dissipation of voltage-reference diode ($P_{D5}$)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5
(Frequency randomly chosen by instructor):

Wein-bridge oscillator

\[\begin{align*}
C_2 & \quad C_1 \\
R_1 & \quad R_2 \\
R_3 & \quad R_4
\end{align*}\]

Grading

- [20\%] Appropriate values for resistors \(R_1\) and \(R_2\), between 1 k\(\Omega\) and 100 k\(\Omega\) each
- [20\%] Appropriate values for resistors \(R_3\) and \(R_4\), between 1 k\(\Omega\) and 100 k\(\Omega\) each
- [20\%] Appropriate values for capacitors \(C_1\) and \(C_2\), between 0.001 \(\mu\)F and 1 \(\mu\)F each
- [20\%] Effect on output signal if \(\ldots\) fails (open or shorted)
- [20\%] Effect on output signal if \(\ldots\) fails (open or shorted)

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

Analyze this opamp circuit with random components inserted into it (component values randomly chosen by instructor):

Grading

- [20%] $V_{out}$ when $V_{in} =$
- [20%] Opamp output terminal current when $V_{out} =$
- [20%] $V_A$ when $V_{in} =$
- [20%] $V_B$ when $V_{in} =$
- [20%] Consequence of ____ failing (open or shorted)

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)** Determine input parameters (e.g., voltage, current, resistance) necessary to drive a comparator-based circuit into a given output state. 
  Comparator behavior, Ohm’s Law, Kirchhoff’s Voltage Law, voltage dividers, Wheatstone bridge networks, shunt resistors for current measurement, AND/OR/NAND/NOR/XOR/NOT logic gate behavior

- **(Question #2)** Design and sketch an operational amplifier circuit with a specified voltage gain. 
  Ohm’s Law, amplifier behavior, negative feedback, opamp behavior, inverting versus non-inverting opamp circuits

- **(Question #3)** Calculate voltages and/or currents in a conventional summer or subtractor operational amplifier circuit. 
  Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, negative feedback, opamp summer circuits, opamp differential amplifier circuits

- **(Question #4)** Calculate voltage and current values within an arbitrary operational amplifier circuit given component values and some given voltage and/or current values. 
  Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, BJT behavior, BJT amplifier behavior, negative feedback, opamp behavior, comparator behavior

- **(Question #5)** Calculate voltages and/or currents in an operational amplifier circuit conditioning a signal from a sensor or sensor network. 
  Wheatstone bridge networks, voltage dividers, Ohm’s Law, Kirchhoff’s Laws, properties of series and parallel networks, voltage and current for a capacitor, negative feedback, opamp behavior, comparator behavior, integrator and differentiator behavior, shunt resistors

- **(Question #6)** Determine possible faults in a discrete-transistor or operational amplifier circuit. 
  Ohm’s Law, Kirchhoff’s Laws, Properties of series and parallel networks, effects of opens vs. shorts, amplifier behavior, negative feedback, opamp behavior

- **(Question #7 – REVIEW)** Identify a passive filter circuit characteristic from its schematic diagram, and predict the effects of a component fault on that characteristic. 
  Properties of series networks, properties of parallel networks, effects of opens vs. shorts, filter circuit behavior, capacitive reactance, inductive reactance

- **(Question #8 – REVIEW)** Sketch a Thévenin equivalent network for a series-parallel DC resistor circuit. 
  Ohm’s Law, Kirchhoff’s Laws, ideal versus real sources, properties of series and parallel networks, Thévenin’s Theorem, Norton’s Theorem

- **(Question #9 – REVIEW)** Qualitatively predict voltage, current, and power changes in a series or parallel resistor circuit resulting from one component change. 
  Properties of series and parallel networks, effects of opens vs. shorts, behavior of sources and loads, properties of voltage sources, properties of current sources
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Elementary motor starters
  - Latching motor starters
- Complete “Start/Jog control” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Three-motor starter circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Motor current calculations” in the Quantitative Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  → Automatic motor starting
  → Inrush current
  → Inrush-limited starting
- Complete “Sketching connections for a three-phase starter” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Wye motor fed by Delta source” in the Quantitative Reasoning section of the Questions chapter.
- Run at least one simulation of a relay-controlled motor (Circuit 008) using tshoot software, and show the final results.
  → Base each of your diagnostic tests on the application of some foundational concept of electric circuits (e.g. properties of series/parallel networks, Kirchhoff’s Laws, etc.)

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the following sections of the Tutorial chapter:
  - Basic VFD function
  - AC motor braking
- Complete “Start-stop-speed-direction control” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Currents within a VFD circuit” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Grinding machine braking” in the Conceptual Reasoning section of the Questions chapter.
- Locate technical literature for a VFD with dynamic braking capability and identify the following information within the document(s):
  - Wiring diagram showing input AC power, connections to the motor, and where the braking resistor would connect
  - Ratings for motor drive power (voltage, current, and/or power in Watts)
  - Ratings for dynamic braking power (voltage, current, and/or power in Watts)

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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:
  - Important VFD parameters
  - Line reactors
- Complete “VFD/pump configuration” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Line reactor harmonic impedance” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Predicting effects of VFD component faults” in the Diagnostic Reasoning section of the Questions chapter.

**Theory Session Expectations:**

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Expect the instructor to question your reasoning and challenge your answers, even when correct! Base your answers on the laws, properties, and other foundational principles learned previously. The instructor will challenge you to pay attention to detail, examine assumptions, and apply sound reasoning.
Complete the following prior to the scheduled session with your instructor:

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Faults in a power system” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Pole-mounted transformers” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted and unfaulted phasor diagrams” 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 Full Tutorial chapter:
  → Low-voltage circuit breakers
  → Medium-voltage circuit breakers
  → High-voltage circuit breakers
- Complete “Low-pressure lockout” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Trip time from oscillograph” in the Quantitative Reasoning section of the Questions chapter.
- Locate technical literature from a manufacturer of high-voltage circuit breakers (e.g. Siemens) and identify the following information within those documents:
  → Voltage and current ratings for at least one live-tank circuit breaker model
  → Voltage and current ratings for at least one dead-tank circuit breaker model
  → Type(s) of stored-energy mechanism(s) for tripping/closing

Theory Session Expectations:

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Theory session 55

Source text – *Principles of Protective Relaying* learning module


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

- Read, outline, and reflect on the Full Tutorial chapter in its entirety.
- Complete “Proper breakers to trip” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Identifying which relays will pick up” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Fuse curve” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Fault oscillographs” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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:
  - Potential transformers
  - Current transformers
  - Instrument transformer safety
  - Instrument transformer test switches
- Complete “Multi-ratio CT wiring” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Transformer-isolated voltage calculations” 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:**

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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 “Motor protection” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Three-phase 50/51 protection circuit” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted 50/51 system” 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 “87 line protection” in the Conceptual Reasoning section of the Questions chapter.
- Complete “Faulted generator” in the Quantitative Reasoning section of the Questions chapter.
- Complete “Faulted 87 system” in the Diagnostic Reasoning section of the Questions chapter.

Theory Session Expectations:

Summarize the assigned text(s) in your own words, including descriptions of mathematical analyses, thought experiments, analogies, and other devices employed by the author. Contribute positively to the dialogue, and if you are confused at any point the minimum expectation is to ask thoughtful questions. The instructor will assess your preparatory work and contributions for good-faith effort.

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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_0212
Foundational Concepts

The following list shows foundational concepts related to prior topics of study. If you find yourself unable to solve any circuit-related problem, this list is a helpful means of reminding you which concepts might apply:

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<td>Behavior of thyristors</td>
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<td>Switch/gate circuits and Boolean</td>
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<td>Switch/gate circuits and truth tables</td>
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<td>Logic voltage levels</td>
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<td>DeMorgan’s Theorem</td>
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One of the most important skills for success in these assessments is knowing how to check your work as you progress through each problem! Applying mental math and estimations along the way for each calculated result is vital for avoiding the pitfall of a wrong result compromising future answers.
Problem #1

(Instructor will randomly choose motor base parameters (line voltage, line current, frequency, shaft speed, horsepower), motor efficiency, and time-delay relay TD1 time duration. Assume an autotransformer tap ratio of 50%):

Grading

- [20%] Current through L2 terminal at full motor load ($I_{L1}$) after TD1 has timed out
- [20%] Voltage between terminals _____ and _____ at time _____ seconds after pressing “Start”
- [20%] Status of contact _____ at time _____ seconds after pressing “Start”
- [20%] Consequence of _____ failing (open/shorted)
- [20%] Consequence of _____ failing (open/shorted)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #2
(Instructor will randomly choose motor base parameters (line voltage, line current, frequency, shaft speed, horsepower), line reactor inductance, motor efficiency, and VFD efficiency. Assume a 480 Volt three-phase source frequency of 60 Hz):

Grading

- [20%] Current through L1 terminal at full motor speed and load \(I_{L1}\)
- [20%] Current through T3 terminal at full motor speed and load \(I_{T3}\)
- [20%] VFD output frequency at ____ RPM motor shaft speed
- [20%] Reactance of L2 line reactor for the fundamental frequency \(X_L\)
- [20%] Reactance of L1 line reactor for the fifth harmonic frequency \(X_L\)

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

(Instructor will randomly choose two of the following – $I_{\text{line}}$, $I_{\text{phase}}$ (source or load), $V_{\text{line}}$, $V_{\text{phase}}$ (source or load), $R_{\text{phase}}$ (load), $P_{\text{total}}$):

Grading

○ [20% each] Calculate five of the unspecified parameters (student’s choice)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #4
(Instructor will randomly choose two of the following – $I_{\text{line}}$, $I_{\text{phase}}$ (source or load), $V_{\text{line}}$, $V_{\text{phase}}$ (source or load), $R_{\text{phase}}$ (load), $P_{\text{total}}$):

Grading

- [20% each] Calculate five of the unspecified parameters (student’s choice)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #5
(Instructor will randomly choose CT ratios, line voltage, maximum rated load power, and coil burdens):

Power diagram

Control diagram

Grading

○ [20%] Current magnitude through coil ____ at full load
○ [20%] Voltage magnitude across coil ____ at full load
○ [20%] Instantaneous pick-up current value for relay to trip at $I_{line(fault)} = \underline{\hspace{2cm}}$ Amperes
○ [20%] Time-overcurrent pick-up current value for relay = ____ Amperes
○ [20%] Consequence of ____ failing (open/shorted)

Note: full credit given only for answers that are correct and logically supported by trusted principles.
Problem #6
(Instructor will randomly choose CT ratios, line voltage, maximum rated generator power, and coil burdens):

Grading
- [20%] Current magnitude through coil ___ at full load (no fault)
- [20%] Voltage magnitude across coil ___ at full load
- [20%] Current magnitude through coil ___ at $I_{A1} = ___$ Amperes and $I_{A2} = ___$ Amperes
- [20%] Consequence of ___ failing (open/shorted)
- [20%] Consequence of ___ failing (open/shorted)

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

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Theory session 60

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

- (Question #1) Sketch proper wire connections to form a working motor starter circuit. *Contactor behavior, ladder logic diagrams, three-phase motor control, industrial pushbutton switch function*

- (Question #2) Calculate voltage, current, resistance, and/or power in a balanced three-phase AC circuit. *Properties of wye-connected networks, properties of delta-connected networks*

- (Question #3) Calculate voltages and/or currents within a three-phase protective relay circuit. *Properties of wye-connected networks, properties of delta-connected networks, complex numbers, phasor arithmetic, Ohm’s Law, KVL, KVL, instrument transformers, 50/51 overcurrent relays, inverse-time trip functions, 87 differential current relays*

- (Question #4) Determine possible faults in a protective relay circuit. *Effects of opens vs. shorts, properties of wye-connected networks, properties of delta-connected networks, overcurrent protection, differential current protection, instrument transformer properties*

- (Question #5) Determine possible faults in a motor starter circuit. *Effects of opens vs. shorts, three-phase AC induction motors, ladder logic diagrams, BJT behavior*