
ESET 3304/3104:01L, Programmable Logic Controller Lecture and Lab

Fall 2024, CRN: 12496, 12494

Course Syllabus

| | |
|--------------------------------|---|
| Instructor: | Wael Deabes, Ph.D. Office: 211K (STEC Building) E-Mail: wdeabes@tamusa.edu |
| | Student emails will receive a reply within one business day. |
| Class Modality: | Face to Face (F2F) |
| Credit Hours: | 3 Credits (Lecture) + 1 Credit (Lab) |
| Meeting Time and Place: | Lec.: Monday 8:00 AM - 10:45 PM, Lab: Wednesday 8:00 AM – 10:45 PM, Room: STEM 245 |
| Class Duration: | 01/20 – 05/04 |
| Course Website: | https://tamusa.blackboard.com/ultra/courses/_273611_1/outline |
| Office Hours: | Monday & Wednesday: 02:00 PM – 03:00 PM (In person) Email the professor for communication to zoom meeting (Mon – Fri) |

Catalog Course Description: Introduction to PLCs with hands-on instruction and industrial applications. PLC fundamentals such as components, memory organization, discrete I/O, logic gates, relay ladder logic, timers, counters, interrupts, word-level logic, and troubleshooting. Topics include data manipulation, sequences, program control, and real-world I/O device connectivity. Design and develop programming algorithms for motors, sensors, switches, networks, valves, relays, and hydraulic and pneumatic systems.

Corequisite: ESET 3104.

Course Contents: (*Subject to change based on relevance and time)

- Introduction to PLCs.
- PLC Hardware: PLC vs Relay, power supplies, CPUs, I/O modules, and connected devices.
- PLC Programming Basics: Ladder logic, Function Block Diagrams (FBD), Structured Text (ST), instructions, and operations.
- Ladder Logic Programming: inputs, outputs, timers, counters, and control tasks.
- Analog I/O and Data Processing.
- Sequential Control and State Machines.
- Advanced PLC Instructions: Arithmetic, comparison, and data movement instructions.
- Human-Machine Interface (HMI): Integration of HMI with PLCs.
- PLC Networking and Communication.
- Fault Detection and Troubleshooting.

Course Objectives:

The primary goal is to provide a comprehensive understanding of PLC systems, from physical installation to advanced logic programming.

- **Understanding PLC Hardware Architecture:** Identify the internal and external components of a PLC, including the CPU, I/O modules (analog and digital), and memory mapping.
- **Mastering Control Logic:** Teach the fundamentals of **Ladder Logic (LD)**,

- Function Block Diagrams (FBD), and Structured Text (ST).
- **System Integration:** Demonstrate how to interface PLCs with external sensors (proximity, photoelectric) and actuators (motors, solenoids, valves).
- **Troubleshooting and Maintenance:** Develop the skills to diagnose hardware faults and debug software errors in a live industrial environment.
- **Safety Standards:** Introduce industry-standard safety protocols, including emergency stops and fail-safe programming.

Course Outcomes

Upon successful completion of the course, a student should be able to:

1. **Technical Proficiency**
 - a) **Design and Develop:** Create functional Ladder Logic programs to control multi-stage industrial processes.
 - b) **Hardware Configuration:** Properly wire and configure a PLC rack, ensuring correct voltage levels and signal isolation.
 - c) **Program Implementation:** Upload, download, and monitor programs using industry-standard software (such as RSLogix, TIA Portal, or EcoStruxure).
2. **Analytical Skills**
 - a) **Translate Requirements:** Convert a written "Sequence of Operations" or a physical process flow into a logical control program.
 - b) **Optimizing Logic:** Use Timers, Counters, and Math functions to make industrial processes more efficient and precise.
3. **Problem Solving**
 - a) **Fault Detection:** Use software "Force" functions and status indicators to isolate mechanical failures versus programming bugs.
 - b) **Simulation:** Validate program integrity through simulation software before deploying to physical hardware.

Required Materials:

Textbook:

- [1] Max Rabiee, **"Programmable Logic Controllers: Hardware and Programming"**, 5th Edition, ISBN-13: 978-1649259875, Goodheart-Willcox, 2021.
- [2] Frank D. Petruzzella, **"Programmable Logic Controllers"**, 5th Edition, ISBN-13:978-0073373843, McGraw Hill, 2016.
- [3] Kamel, Khaled, and Eman Kamel. **"Programmable logic controllers: Industrial control"**. McGraw Hill Professional, ISBN 13: 978-0071810456, 2013.
- [4] Gary A. Dunning, **"Introduction to the ControlLogix Programmable Automation Controller"**, Cengage Learning, 2nd Edition, ISBN 13: 9781111539290.
- [5] Handbook, PLC. **"Practical Guide to Programmable Logic Controllers."** AutomationDirect.com.

Blackboard: Connect to <http://tamusa.blackboard.com>. You will have lecture notes, solutions to problems, multimedia materials, and other supplementary materials in Blackboard. All class communications will be through Blackboard, and students should monitor this several times a day.

Time Expectation for coursework: You are expected to spend 3-6 hours per week for the course. Based on the background, some student may require more time. Time spent may be longer when assignment/exams are due.

Course Grades and Policies:

- Final grades will be assigned using the weighted average of the following components.
- The instructor reserves the right to adjust the grading scale and/or weights based on the difficulty of work assigned throughout the semester.

- **Lecture Grading Policy**

- **Class works 30 %:** Quizzes 10%, Homework & Assignments 20%.
- **Final Project 20%:** (Details under Final Projects Tab)
- **Exams 50%:** (15%, 15%, 20%)

- **Lab Grading Policy**

- **Attendance 10%:** it is a must.
- **Lab works 50 %:** Run the experiments
- **Technical Reports 30%:** (Details under Appendix A)
- **Technical Discussion 10%**

Course grades are awarded as follows:

A: Over 90.0%; B: 80.0 ~ 89.99%; C: 70 ~ 79.99%; D: 60.0 ~ 69.99%; F: less than 59.99%.

- **Reading Assignment (RA):** Students are required to read specific sections in the textbook before each lecture, to enable a teaching style somewhat similar to a “flipped classroom”, i.e., concentrating on the intuitive understanding of the material, computational problems, etc., instead of derivations of equations.
 - *RA (not graded) should be completed 11:59 pm CST every Friday, + Questions from students need to be posted on Discussion Board by midnight every Saturday!*
- **HomeWorks** will be assigned, falling mainly into three categories
 - Computational exercises related to the specific chapters treated during the past instruction week.
 - Computational exercises requiring a “big picture” approach, using material from different lectures throughout the semester
 - Simulations to be written by the students to cover more realistic scenarios for which closed-form equations often do not exist.
- **Lab Report:** Due every Wednesday next week. See [Appendix A](#) below for Laboratory Report Format and Guidelines + General Rubrics.
- **Final Project:** To pass this class, students must prepare a report and present it during Finals Week. Students will work in teams (if possible, 1-2 students/team). Each team will identify (or use previous) a practical electronic engineering project (e.g., research, prototype, product, or design) and submit their project plan with a timeline at week 4 to the instructor for approval. Each team will have to submit a report that describes and analyzes the main findings (Week 14-15) and present the work in Class (during finals week). The Report should not exceed 10 pages double-spaced, 12 font sizes with 1-inch margins, and the Final presentation should not exceed 25 slides. The project should demonstrate the student's ability to transfer the knowledge and skills acquired in the course to real-world applications.
- **Exams:** There will be two (3) exams during the semester: all to be taken at the scheduled date, time, and location (in Class)/ no makeup allowed! Final exams cannot be rescheduled or missed.
 - **Schedule of Exam and content**

| Exam# (%) | Content | Time allowed | Format | Tentative Date |
|-------------|------------|--------------|-----------------------|--|
| Exam1 (15%) | Topics 1-5 | 90 minutes | Long Answer Questions | Week 6, Monday in Class from 11:05 am |
| Exam2 (15%) | Topics 6-9 | 90 minutes | Long Answer Questions | Week 12, Monday in Class from 11:05 am |
| Final (20%) | All topics | 120 minutes | Long Answer Questions | Week 15, Monday in Class from 11:05 am |

Examinations and assignments: There will be multiple assignments and exams during the semester. The assignments and exams will consist of conceptual multiple-choice, problem-solving, and short

essay questions. The assignments /exam materials will come from lecture notes, the text, and class discussions. Questions will emphasize understanding and applications of concepts and topics covered in class. Exams will be in person during class time.

Make up and Late Assignment/exam/quiz policy: As a general rule, make-ups or late submissions will **NOT** be offered or accepted for any missed assignments/exams/quizzes. Late submissions or makeups may be accepted/administered only in extraordinary circumstances such as an excused official university activity, a severe illness, or a dire emergency. However, you must provide comprehensive documentation either before or within a few days of the missed assignment/quiz/exam.

Class conducts and civility code: Everyone in class is expected to follow all rules in the student handbook, as well as common courtesy during classroom lectures and discussions in class and online, including the following:

1. Attendance may be taken at the beginning or the end of the class. A vital part of every student's education is regular attendance of class meetings.
2. It is the students' responsibility to obtain and be able to use the required materials and software for this class.
3. Students should regularly check the Course Calendar, Announcements, and Messages (e-mail) systems in Blackboard.
4. Students should be prepared to turn in their assignments' solutions and must be uploaded to BB by their due date and time. **No late assignments will be accepted, nor are make-ups allowed.**
5. If you cannot submit answers to any assignment online and are within the deadline. You can only get credit for your work by emailing the instructor your completed assignment. As possible, take pictures/snapshots of the Issue faced online so it can be addressed.
6. Student must retain copies of all assignments and graded work for verification purposes and provide it to the instructor, if necessary. Keep own copies of all computer files and e-mails till final grade is received.
7. Talking while the instructor is lecturing is extremely disruptive and discourteous to the instructor and other students.
8. Using computers or phones (except for a valid urgent need) during class for a purpose not related to class is disruptive. All cell phones and gadgets should be turned OFF and headphones removed.
9. For any questions about the exams and assignments, a student should contact the instructor, well in advance of the day they are due, so the instructor may have enough time to provide feedback.
10. All communications will be via e-mail communications to the Texas A&M University e-mail account, and students are expected to use their school provided email account. The instructor will reply to a student e-mail messages and voice messages within 2 business days (Monday-Friday).
11. For all classwork, exams, quizzes, etc., if a student is completing it off-campus, they are responsible for the availability of internet connectivity. Extensions will **not** be granted for lack of availability of internet connections.

Submission window may close or marked late, even if late by one second. Anyone violating these policies may be subject to disciplinary actions.

Broader Use of Generative AI Permitted Within Guidelines: Artificial intelligence (AI) tools, including ChatGPT, are permitted in this course for students who wish to use them. To adhere to our scholarly values, students must cite any AI-generated material that informed their work (this includes in-text citations and/or use of quotations and in your reference list). Using an AI tool to generate content without proper attribution qualifies as academic dishonesty and violates Texas A&M-San Antonio's standards of academic integrity.

Tentative Schedule

| Week | Topics / Daily Activities | Readings (from Image) | Labs & Homework |
|----------------|--|-----------------------|---|
| Week 1 | PLC Overview, Components, & Architecture | Chapters 1 & 2 | Lab: Hardware Identification; HW: PLC Selection Criteria |
| Week 2 | Number Systems, Codes, & I/O Devices | Chapters 3 & 4 | Lab: Wiring Digital Sensors; HW: BCD & Binary Conversions |
| Week 3 | From Relay Logic to PLC Programming | Chapters 5 & 6 | Lab: Converting Relay Schematics to Ladder |
| Week 4 | Programming Logic Gate Functions | Chapter 7 | Lab: AND/OR/XOR Logic Implementation; HW 1 |
| Week 5 | PLC Timer Instructions (TON, TOF, RTO) | Chapter 8 | Lab: Time-Delayed Motor Starting |
| Week 6 | Mid-Term Exam 1 (Chapters 1-8) | Review | HW 2: Timer Accumulation Calculations |
| Week 7 | PLC Counter Instructions (CTU, CTD) | Chapter 9 | Lab: Conveyor Part Counting System |
| Week 8 | Math & Comparison Instructions | Chapters 10 & 11 | Lab: High/Low Limit Alarm Logic; HW 3 |
| Week 9 | Program Control: Jumps & MCR | Chapter 11 | Lab: Implementing Master Control Relays |
| Week 10 | Subroutine Functions & Modular Code | Chapter 12 | Lab: Designing Reusable Logic Blocks; HW 4 |
| Week 11 | Logic, Bit Shift, & Data Handling | Chapters 13 & 14 | Lab: Tracking Parts on a Shift Register |
| Week 12 | Mid-Term Exam 2 (Chapters 9-14) | Review | — |
| Week 13 | Sequencer Instructions & Applications | Chapter 15 | Lab: Automated Machine Step-Sequencing |
| Week 14 | Troubleshooting & PLC Networking | Chapters 16 & 17 | Lab: Fault Finding & Network Setup; HW 5 |
| Week 15 | Advanced Programming (RSLogix 5000) | Chapter 18 | Final Project: Tag-Based Automation Design |
| Final | Comprehensive Final Exam | Chapters 1-18 | Final Project Demonstration |

IMPORTANT POLICIES AND RESOURCES

Academic Accommodations for Persons with Disabilities: Texas A&M University-San Antonio is committed to providing all students with reasonable access to learning opportunities and accommodations in accordance with The Americans with Disabilities Act, as amended, and Section 504 of the Rehabilitation Act. If you experience barriers to your education due to a disability or think you may have a disability, please contact Disability Support Services in the Central Academic Building, Suite 210, or at (210) 784-1335 or visit <https://www.tamusa.edu/index.html> or email us at dss@tamusa.edu. Disabilities may include, but are not limited to, attentional, learning, mental health, sensory, physical, or chronic health conditions. All students are encouraged to discuss their disability-related needs with Disability Support Services and their instructors as soon as possible.

Academic Learning Center: The Academic Learning Center provides free course-based tutoring to all currently enrolled students at Texas A&M University-San Antonio. Students wishing to work with a tutor can make appointments through the Brainfuse online tutoring platform. Brainfuse can be accessed in the *Tools* section of Blackboard. You can contact the Academic Learning Center by emailing tutoring@tamusa.edu, calling (210) 784-1307, or visiting the Central Academic Building, room 202.

Counseling/Mental Health Resources: As a college student, there may be times when personal stressors interfere with your academic performance and/or negatively impact your daily functioning. If you are experiencing emotional difficulties or mental health concerns, support is available to you through the Student Counseling Center (SCC). To schedule an appointment, call 210-784-1331 or visit Madla 120. All mental health services provided by the SCC are free and confidential (as the law allows). The Student Counseling Center provides brief individual and group therapy, crisis intervention, consultation, case management, and prevention services.

Crisis support is available 24/7 by calling the SCC at 210-784-1331 (after-hours select option '2'). For more information and self-help resources, please visit www.tamusa.edu/studentcounseling

Emergency Preparedness: JagE Alert is Texas A&M University-San Antonio's mass notification. In the event of an emergency, such as inclement weather, students, staff and faculty, who are registered, will have the option to receive a text message, email with instructions and updates. To register or update your information visit: <https://tamusa.bbportal.com/>. More information about Emergency Operations Plan and the Emergency Action Plan can be found here: <https://www.tamusa.edu/about-us/campus-information/safety/university-police-department/documents/emergency-operations-plan.pdf> and <https://www.tamusa.edu/about-us/campus-information/safety/university-police-department/documents/emergency-action-plan.pdf>. Download the SafeZone App for emergencies or call (210) 784-1911. Non-Emergency (210) 784-1900

Financial Aid and Verification of Attendance: According to the following federal regulation, 34 CFR 668.21: U.S. Department of Education (DoE) Title IV regulation, a student can only receive Title IV funds based on Title IV eligibility criteria which include class attendance. If Title IV funds are disbursed to ineligible students (including students who fail to begin attendance), the institution must return these funds to the U.S. DoE within 30 days of becoming aware that the student will not or has not begun attendance. Faculty will provide the Office of Financial Aid with an electronic notification if a student has not attended the first week of class. Any student receiving federal financial aid who does not attend the first week of class will have their aid terminated and returned to the DoE. Please note that any student who stops attending at any time during the semester may also need to return a portion of their federal aid.

Writing, Language, and Digital Composing Center: The Writing, Language, and Digital Composing Center supports graduate and undergraduate students in all three colleges as well as faculty and staff. Tutors work with students to develop reading skills, prepare oral presentations, and

plan, draft, and revise their written assignments. Our language tutors support students enrolled in Spanish courses and students composing in Spanish for any assignment. Our digital studio tutors support students working on digital projects such as eportfolios, class presentations, or other digital multimedia projects. Students can schedule appointments through JagWire under the Student Services tab. Click on “Writing, Language, and Digital Composing Center” to make your appointment. The Center offers face-to-face, synchronous online, and asynchronous digital appointments. More information about what services we offer, how to make an appointment, and how to access your appointment can be found on our website at <https://bit.ly/WLDCCenter>.

Meeting Basic Needs: Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live, and believes this may affect their performance in the course, is urged to contact the Dean of Students (DOS@tamus.edu) for support. Furthermore, please notify the professor if you are comfortable in doing so. This will enable them to provide any resources they may possess.

Military Affairs: Veterans and active-duty military personnel are welcomed and encouraged to communicate, in advance if possible, and special circumstances (e.g., upcoming deployment, drill requirements, disability accommodations). You are also encouraged to visit the Patriots’ Casa in-person room 202, or to contact the Office of Military Affairs with any questions at military.va@tamus.edu or (210)784-1397.

Religious Observances: Texas A&M University-San Antonio recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holidays according to their tradition. Under the policy, students are provided an opportunity to make up any examination, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second week of classes for regular session classes.

The Six-Drop Rule: Students are subject to the requirements of Senate Bill (SB) 1231 passed by the Texas Legislature in 2007. SB 1231 limits students to a maximum of six (6) non-punitive course drops (i.e., courses a student chooses to drop) during their undergraduate careers. A non-punitive drop does not affect the student’s GPA. However, course drops that exceed the maximum allowed by SB 1231 will be treated as “F” grades and will impact the student’s GPA.

Statement of Harassment and Discrimination: Texas A&M University-San Antonio is committed to the fundamental principles of academic freedom, equality of opportunity and human dignity. To fulfill its multiple missions as an institution of higher learning, A&M-San Antonio encourages a climate that values and nurtures collegiality and the uniqueness of the individual within our state, nation, and world. All decisions and actions involving students and employees should be based on applicable law and individual merit. Texas A&M University-San Antonio, in accordance with applicable federal and state law, prohibits discrimination, including harassment, on the basis of race, color, sex, religion, national origin, age, disability, genetic information, veteran status, sexual orientation, gender identity, gender expression, or pregnancy/parenting status. Individuals who believe they have experienced harassment or discrimination prohibited by this statement are encouraged to contact the appropriate offices within their respective units.

Texas A&M University-San Antonio faculty are committed to providing a safe learning environment for all students and for the university as a whole. If you have experienced any form of sex- or gender-based discrimination or harassment, including sexual assault, sexual harassment, domestic or dating violence, or stalking, know that help and support are available. A&M-San Antonio’s Title IX Coordinator can support those impacted by such conduct in navigating campus life, accessing health and counseling services, providing academic and housing accommodations, and more. The university strongly encourages all students to report any such incidents to the Title IX Coordinator. Please be aware that all A&M-San Antonio employees (other than those designated as confidential resources

such as counselors and trained victim advocates) are required to report information about such discrimination and harassment to the university. This means that if you tell a faculty member about a situation of sexual harassment or sexual violence, or other related misconduct, the faculty member must share that information with the university's Title IX Coordinator (titleix@tamusa.edu, 210-784-2061, CAB 439K). If you wish to speak to a confidential employee who does not have this reporting requirement, you can contact the Student Counseling Center at (210) 784-1331 or visit them in Madla 120.

Pregnant/Parenting Students: Texas A&M-San Antonio does not require a pregnant or parenting student, solely because of that status or issues related to that status, to (1) take a leave of absence or withdraw from their degree or certificate program; (2) limit the student's studies; (3) participate in an alternative program; (4) change the student's major, degree, or certificate program; or (5) refrain from joining or cease participating in any course, activity, or program at the University. The university will provide reasonable accommodations to pregnant students that would be provided to a student with a temporary medical condition and that are related to the health and safety of the student and the student's unborn child. These could include maintaining a safe distance from substances, areas, and activities known to be hazardous to pregnant individuals and their unborn child; excused absences because of illness or medical appointments; modified due dates for assignments; rescheduled tests/exams; taking a leave of absence; and being provided access to instructional materials and video recordings of lectures for excused absences, if these would be provided to any other student with an excused absence. Pregnant/parenting students are encouraged to contact the Title IX Coordinator with any questions or concerns related to their status (titleix@tamusa.edu; 210-784-2061; CAB 439K).

Texas A&M-San Antonio has also designated the Title IX Coordinator as the liaison officer for current or incoming students who are the parent or guardian of a child younger than 18 years of age. The Title IX Coordinator can provide students with information regarding support services and other resources.

Students' Rights and Responsibilities: The following statement of students' rights and responsibilities is intended to reflect the philosophical base upon which University Student Rules are built. This philosophy acknowledges the existence of both rights and responsibilities, which is inherent to an individual not only as a student at Texas A&M University-San Antonio but also as a citizen of this country.

Students' Rights

1. A student shall have the right to participate in a free exchange of ideas, and there shall be no university rule or procedure that in any way abridges the rights of freedom of speech, expression, petition, and peaceful assembly as set forth in the U.S. Constitution.
2. Each student shall have the right to participate in all areas and activities of the university, free from any form of discrimination, including harassment, on the basis of race, color, national or ethnic origin, religion, sex, disability, age, sexual orientation, gender identity, gender expression, genetic information, or veteran status in accordance with applicable federal and state laws.
3. A student has the right to personal privacy except as otherwise provided by law, and this will be observed by students and University authorities alike.
4. Each student subject to disciplinary action arising from violations of university student rules shall be assured a fundamentally fair process.

Students' Responsibilities

1. A student has the responsibility to respect the rights and property of others, including other students, the faculty and staff, and the administration.
2. A student has the responsibility to be fully acquainted and compliant with the University Student Rules found in the Student Handbook, Student Code of Conduct, on our website, and in the University Catalog.

3. A student has the responsibility to recognize that student actions reflect upon the individuals involved and upon the entire University community.

Students are expected to exhibit a high level of honesty and integrity in their pursuit of higher education. Students engaging in an act that violates the standards of academic integrity will find themselves facing academic and/or disciplinary sanctions. Academic misconduct is any act, or attempt, which gives an unfair advantage to the student. Additionally, any behavior specifically prohibited by a faculty member in the course syllabus or class discussion may be considered as academic misconduct. For more information on academic misconduct policies and procedures please review the [Student Code of Conduct](#).

Important Dates:

| | |
|------------|-------------------------|
| January 20 | First day of class |
| March 9-14 | Spring Break-No classes |
| April 3 | Study Day – No classes |
| May 4 | Last day of classes |
| May 5 | Study Day – No classes |
| May 6-12 | Final exams |

The complete academic calendar is available online:

<https://www.tamusa.edu/academics/academic-calendar/index.html>

APPENDIX A

Laboratory Report Format and Guidelines

It is essential that students be able to express their ideas and defend their arguments with clarity, detail and subtlety. Similarly, it is important that they can read and critique the ideas and arguments of others in like manner. The creation of lab reports assists in this endeavor.

Unless otherwise specified, all lab exercises require a write-up. All reports should be neat and legible. Standard technical writing style is expected along with proper grammar and spelling. This means that active voice, first person, personal pronouns, and the like should be avoided. For example, don't write "I set the power supply to 6 volts". Instead use "The power supply was set to 6 volts". Reports are an individual endeavor. Although it is perfectly fine to discuss your data and experimental results with your lab partner, the creation of the Report itself is an individual exercise. Plagiarism will not be tolerated. A report should conform to the following outline, in the order given:

- 1) **Objective / Hypothesis.** These are statements regarding the items, relationships, characteristics, etc. that you are investigating in this particular exercise. This is the first part that you write. Indeed, it can be written before you even step foot into the lab. A hypothesis tends to be narrow and focused, but not so focused that it only applies to this particular exercise. Examples might be "The speed of sound in air increases as the air temperature rises" or "The voltage across a given resistance is directly proportional to the current through it". This section tends to be fairly short.
- 2) **Conclusion.** Address the hypothesis was it verified? These are concise statements of fact regarding the circuit action(s) under investigation. Make sure that you have moved from the specific lab situation to the general case. If all works well, these should match nicely with your Objective/Hypothesis section. Under no circumstances should you reach a conclusion that is not supported by your data, even if that conclusion is stated in the text or in lecture. What matters here is what you did and your analysis of it. If there is a discrepancy between your results and theory, state the discrepancy and don't ignore your results. The Conclusion is the final section that you write. It addresses the Objective and is supported by the Discussion. Think of it as an Executive Summary.
- 3) **Discussion (AKA Analysis).** Reduce and analyze your data. Explain circuit action or concepts under investigation. Relate theoretical results to the lab results. Don't just state what happened, but comment on why and its implications. Derive your conclusions from this section. The Discussion is not a rewording of the procedure, however, any deviations from the procedure as given by the lab manual must be noted in this section. Otherwise, the procedure used is assumed to be the same as in the lab manual. The Discussion is the penultimate part that you write and tends to be the longest section. When performing your analysis, always keep in mind that you should be trying to affirm the null hypothesis. The null hypothesis is, in essence, the inverse of the stated hypothesis. You can think of it as the default situation. Using the first example hypothesis above, the null would be "The speed of sound in air is not dependent on-air temperature". In your data tables, you'd be looking to see if the null is true, i.e., that there is no relationship between speed and temperature. In this case, if your data were correct, they would indicate an increase in speed as temperature rose, so the null is not true, and therefore your hypothesis is a valid candidate for describing reality. Having this mindset helps you to avoid cherry picking the data, that is, only seeing the things that confirm what you want and ignoring the rest. Cherry picking is a form of observer bias, is intellectually dishonest, and any good investigation needs to avoid it.
- 4) **Final Data Sheet.** Include all derived and calculated data. Make sure that you include percent deviations for each theory/measurement pair. Use $\text{Percent Deviation} = (\text{Measured-Theory})/\text{Theory} * 100$, and include the sign. Include the model and serial numbers of all test equipment. Along with the graphs, this is the second part of the Report that you write. Until this section is completed, it is not possible to complete an analysis and write the Discussion

section.

- 5) **Graphs**, Answers to questions at the end of the exercise, Other. All graphs must be properly titled, created using appropriate scales, and identified with labels. It is suggested that graphs be created with a plotting program or a spreadsheet. Alternately, graphs may be created manually but must be drawn using either a straight edge or a French curve (depending on the type of graph) on appropriate graph paper.
 - a. You can get details on graphing under Blackboard Tab (LabGraph Sample)
 - b. You can see an example lab report under Blackboard Tab (LabReport Sample).

Make sure that you leave sufficient space in the margins and between sections for my comments. 1.5 line spacing is fine. Multi-page reports should print single-sided and must be stapled in the upper left corner. Paper clips, fold-overs, bits of hook-up wire, etc. are not acceptable. Reports are due no later than the start of the next lab period following the date performed. Late reports are reduced by one letter grade for the first half week late and two letter grades for the second half week. Reports are not acceptable beyond one week late. Below is the grading standard.

Grade of A: *The Report meets or exceeds the assignment particulars. The Report is neat and professional in appearance, including proper spelling and syntax. The analysis is at the appropriate level and of sufficient detail. Data tables and graphical data are presented in a clear and concise manner. Problem solutions are sufficiently detailed and correct. Diagrams have a professional appearance.*

Grade of B: *The Report is close to the ideal although it suffers from some minor drawbacks which may include some spelling or grammatical errors, analyses which may lack sufficient detail, minor omissions in tabular or graphical data, and the like. In general, the Report is solid but could use refinement or tightening.*

Grade of C: *The Report is serviceable and conveys the major ideas although it may be vague in spots. Spelling and grammatical errors may be more numerous than those found in a grade A or B report. Some gaps in data or omissions in explanations may be seen.*

Grade of D: *Besides typical spelling and grammatical errors, the Report suffers from logical errors such as conclusions which are not supported by laboratory data. Analyses tend to be vague and possibly misleading. Graphs and diagrams are drawn in an unclear manner.*

Grade of F: *The Report exhibits many of the following deficiencies: Excessive spelling and grammatical errors, missing sections such as graphs, tables, and analyses, blatantly incorrect analyses, wayward or incomprehensible data, problem solutions tend to be incorrect or missing, and graphical data or diagrams are presented in a shoddy manner.*