

INST 142 (PLC Programming)

NAME: _____

Session	Topic	Score
1	Introduction to PLCs	;
2	PLC contact and coil instructions	;
3	Digital numeration (binary)	;
4	Digital numeration (octal, hex)	;
5	PLC counter instructions	;
6	PLC counter applications	;
7	Open session	-----
8	<i>Exam 1</i> (written ; demonstration)	;
9	PLC timer instructions	;
10	PLC timer applications	;
11	Open session	-----
12	Open session	-----
13	<i>Exam 2</i> (written ; demonstration)	;

Due	Experiment	Score
8	PLC demonstration program (contact and coil instructions)	
8	PLC demonstration program (counter instructions)	
13	PLC implementation of an arbitrary truth table	
13	PLC demonstration program (timer instructions)	
13	PLC-controlled motor starter	

Due	Troubleshooting	Score
13	PLC-controlled AC motor starter circuit	

Due	Project	Score
13	PLC-controlled system	

Your grade for this course will be based on a percentage score, with each category weighted as follows:

- All mastery objectives complete by deadline dates = 40%
 - All written exams passed without error by the end of the next exam date (or end of quarter, whichever comes first)
 - All demonstration exam circuits correctly completed by the end of the next exam date (or end of quarter, whichever comes first)
 - All objectives of all experiments completed by their respective due date
 - All troubleshooting challenges completed by their respective due dates
 - All objectives of all projects completed by their respective due dates
- Written exam scores = 10%
- Demonstration exam scores = 10%
- Experiment scores = 20%
- Troubleshooting scores = 10%
- Project score(s) = 10%

Please note the importance of completing all mastery objectives by their deadline dates. Failure to complete *any* mastery objective in time deducts 40% from your total score. If this happens, it means the highest possible score you can earn for the course will be 60%, which is below the 70% threshold for a C-, the lowest passing grade. In other words, you *must* complete all mastery objectives by their due dates in order to pass the course, regardless of any other score.

Deductions to your course grade are based on your preparation for and participation within each theory session. 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. Failure to positively and proactively contribute to the discussion during a theory session also results in a -1% deduction per session. Showing up on time, fully prepared, and genuinely contributing to every theory session is the *minimum* expectation.

A failing (F) grade will be earned if any mastery objectives are past deadline, 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.

If for some reason you know you will be late or absent, 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 contribution, answering all "Challenges" for assigned questions will count as full credit.
- For experiments, video documentation of you completing all objectives in their proper order will count as full credit.
- For projects, video documentation of you completing the objective(s) will count as full credit.

Absence during a scheduled exam will result in a 0% score for that exam, except in the case of a *documented emergency*.

file mgrading

Sessions

Experiments

NAME: _____

DUE DATE: _____

Experiment source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

Independently prepare for and execute the “Experiment: contact and coil demonstration program” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1015

NAME: _____

DUE DATE: _____

Experiment source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

Independently prepare for and execute the “Experiment: counter demonstration program” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1016

NAME: _____

DUE DATE: _____

Experiment source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

Independently prepare for and execute the “Experiment: PLC implementation of an arbitrary truth table” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1020

NAME: _____

DUE DATE: _____

Experiment source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

Independently prepare for and execute the “Experiment: timer demonstration program” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1017

NAME: _____

DUE DATE: _____

Experiment source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

Independently prepare for and execute the “Experiment: PLC-controlled motor starter” outlined in the Projects and Experiments chapter.

Complete the following *before* running the experiment:

- Write an hypothesis (i.e. what *you* think will happen during the experiment). Your hypothesis must be *testable*, meaning a prediction that may be proven or disproven through measured data.
- Write the experimental procedure you intend to follow, describing the components and equipment you will use, and the steps you will take. Include diagrams and code listings.
- Write a list of possible risks (both personal and system-related), and related precautions.
- Present your paper copy of objective list (in the table below) for the instructor to mark.

After running the experiment and recording data, you will need to analyze the data to see whether or not it supports your hypothesis. If not, revise the hypothesis and/or the experiment, and re-run until both agree. Record all data, as well as any revisions made to the hypothesis and procedure.

Your instructor must observe your experiment running, and you are free to document this on video if the instructor cannot be present to observe. Be sure to identify yourself and also capture the time and date within your video.

Objective	Attempts	Completed
Written hypothesis		
Written experimental procedure (with diagrams)		
Written risk assessment and mitigation plan		
Safe and accurate demonstration of experiment		
Data presented and archived		
Written analysis: hypothesis supported?		
Written analysis: sources of error?		
Correctly answered challenge question		
Data and written analyses for all re-runs	-----	
Fractional score ; Percentage score	Score = 7 /	Score = %

The instructor will certify completion of each objective in order from top to bottom. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard, which may be stated quite simply: *has this been done to a level of detail, accuracy, and safety acceptable to a professional supervisor or client?* You may ask a question or request help from the instructor at any time without counting as an attempt. Note that re-runs of an experiment are an expected occurrence and will not be counted as additional attempts – the number of attempts only track your *first* run of the experiment.

A score is calculated by dividing the number of objectives (seven) by the total number of attempts to complete those objectives. Experiments are *mastery* activities, meaning every experimental objective must be properly completed by the due date in order to pass the course. A final score of zero will result if (1) the experiment is run without a proper hypothesis, procedure, *and* risk assessment/mitigation; or (2) any safety standard is violated (e.g. touching energized conductors) ; or (3) you copy anyone else’s work.

file m1021

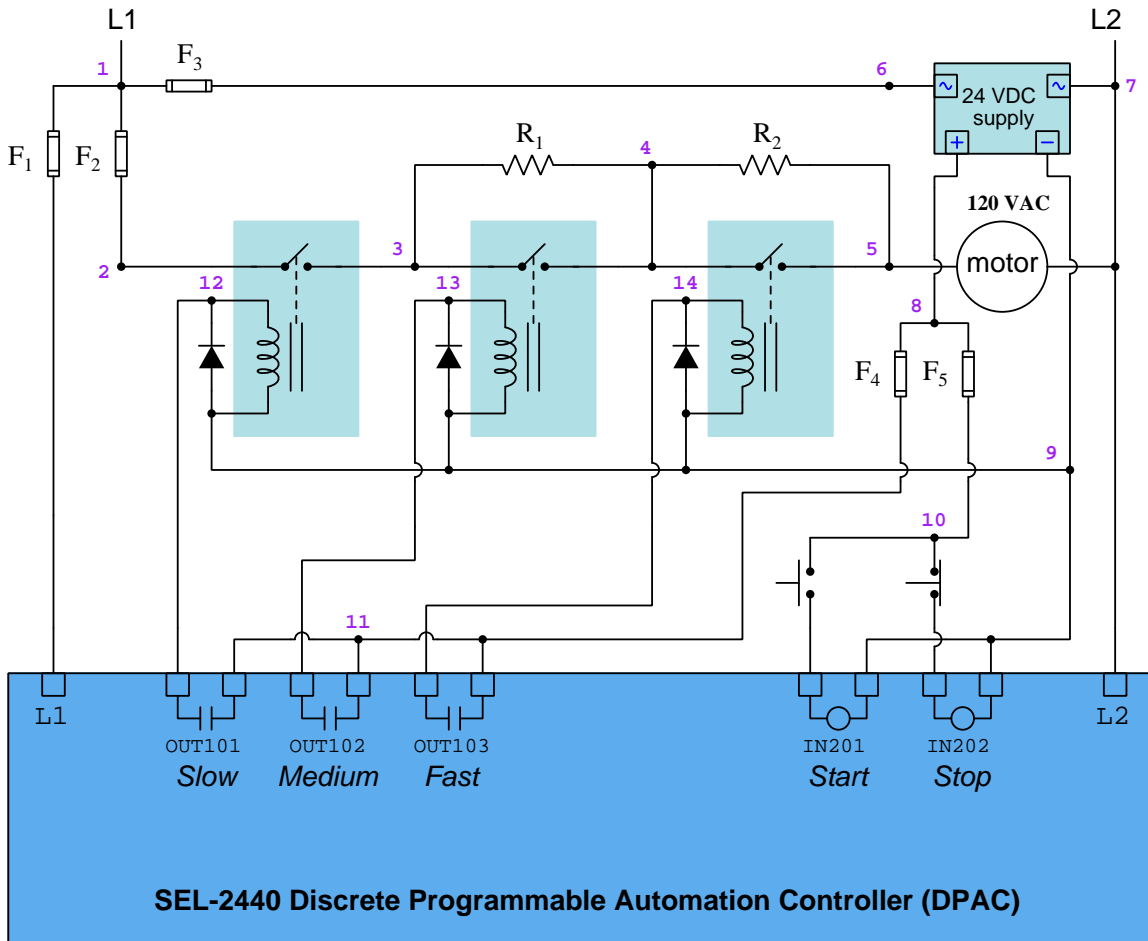
Troubleshooting

NAME: _____

DUE DATE: _____

Troubleshooting challenge	Attempts	Completed
PLC-controlled AC motor starter circuit		

For this troubleshooting challenge you will work with a pre-constructed AC inrush-limited motor starter circuit controlled by a PLC, where all system components are hidden from view and you will have access only to a terminal block with wires connecting to labeled test points within the circuit.



Troubleshooting is *mastery-based*, meaning every one must be competently completed by the due date in order to pass the course, and you will be given multiple opportunities to re-try if you do not pass on the first attempt. Re-tries will be performed on a randomized scenario. Scoring is based on the number of attempts necessary to successfully troubleshoot a circuit (e.g. 1 attempt = 100% ; 2 attempts = 80% ; 3 attempts = 60% ; 4 attempts = 40% ; 5 attempts = 20% ; 6 or more attempts = 0%). Troubleshooting assessments are closed-book and closed-note.

You may *practice* troubleshooting as often as you wish using the open-source computer-based simulation program TROUBLESHOOT. If the troubleshooting exercise is based on a circuit you construct, you may practice by having classmates introduce faults which you then attempt to diagnose. If the troubleshooting is based

on a shared system owned by the college, you may practice using the system unfaulted, but will not be permitted to practice with faults. The reason for this is that we have found when students practice inserting faults into a common system, they often leave that system for others in a state of disrepair. Therefore, only unfaulted practice is allowed on college-owned systems.

The SEL-2440 Discrete Programmable Automation Controller is a PLC, but unlike most it programs in a text-based language called *SELogic*, consisting of lines of equations whereby values are assigned and variables are linked. Like most text-based programming languages, the “equals” symbol (=) here represents *assignment*, the right-hand side representing the data source and the left-hand side representing the data destination. The statement `OUT101 = LT01`, for example, instructs this PLC to read the Boolean value of variable `LT01` and copy that value to variable `OUT101`. As you might guess, `INxxx` represents a discrete input to the PLC electrically driven by an external switch and `OUTxxx` represents a discrete contact output on the PLC driving an external load. Any text to the right of a pound symbol (#) is a *comment* added strictly as an aid to any person reading the code, and is ignored by the PLC.

SELogic code for across-the-line starting:

```
ELAT = 1 # Declares one S-R latch instruction
SET01 = IN201 # Start switch "sets" latch when active
RST01 = NOT IN202 # Stop switch "resets" latch when inactive
OUT101 = LT01 # Latch drives Slow relay
OUT102 = LT01 # Latch drives Medium relay
OUT103 = LT01 # Latch drives Fast relay
```

SELogic code for inrush-limited starting:

```
ELAT = 1 # Declares one S-R latch instruction
SET01 = IN201 # Start switch "sets" latch when active
RST01 = NOT IN202 # Stop switch "resets" latch when inactive
OUT101 = LT01 # Latch drives Slow relay
ESV = 2 # Declares two timer instructions
SV01 = OUT101 # Timer 1 activated by Slow output
SV01PU = 1.0 # Timer 1 on-delay time
SV01DO = 0.0 # Timer 1 zero off-delay time
OUT102 = SV01T # Timer 1 drives Medium relay
SV02 = OUT102 # Timer 2 activated by Medium output
SV02PU = 1.0 # Timer 2 on-delay time
SV02DO = 0.0 # Timer 2 zero off-delay time
OUT103 = SV02T # Timer 2 drives Fast relay
```

No access to or even understanding of the programming is strictly necessary for troubleshooting this system. All you need to do is pay attention to the LED I/O indicators on the PLC's front panel and of course take intelligent diagnostic tests at the numbered test points using your multimeter.

Projects

NAME: _____

DUE DATE: _____

Source text – *Introduction to PLCs* learning module

URL – http://ibiblio.org/kuphaldt/socratic/model/mod_plc.pdf

- Complete the following objectives within a team of no more than four people for the project documented as “Project: PLC-controlled system” in the Projects and Experiments chapter. This project description is purposefully vague, allowing for a wide range of project options. Any project idea that is safe, legal, and suitably challenging will be authorized. The instructor has final approval authority over the project choice and scope.

Pre-construction objective	Attempts	Completed
<i>(Team)</i> – Prototype diagram and project scope		
<i>(Team)</i> – Risk assessment/mitigation plan		
<i>(Team)</i> – Project timeline and action plan		

NOTE: All pre-construction objectives must be verified complete by the instructor before any project construction or live testing begins! Since projects usually include components and resources of substantial cost, it is important to have a solid plan before proceeding.

Objective	Attempts	Completed
<i>(Team)</i> – Demonstration of working system		
<i>(Individual)</i> – Project diagrams and coding		
<i>(Team)</i> – Bill of Materials		
<i>(Individual)</i> – Written summary of lessons learned		
Fractional score / Percentage score	Score = /	Raw score = %
Deductions for unprofessionalism	Instances =	Adj. score = %

The instructor will certify completion of each objective at your request. For each time you claim readiness, a mark will be added to the corresponding “Attempt” cell. Each “Completed” cell will be initialed by the instructor when that objective has met the standard. A full description of each objective and its corresponding standard begins on the next page of this document. You may ask a question or request help from the instructor at any time without counting as an attempt.

Scoring is based on the number of attempts necessary to fulfill all objectives: the number of objectives divided by the total number of attempts to complete all objectives, expressed as a percentage. Thus, a perfect score is possible only by completing all objectives on the first attempt. If one or more members of a team repeatedly compromise team performance, they may be removed from the team and required to complete the project alone. Every project is a *mastery* item for the course, meaning that every objective of every project must be completed by the due date in order to pass the course.

Deductions will be levied for any instance of unprofessional behavior, and affect the Adjusted score. This includes unsafe work practices (–20%), improper equipment usage (–10%), poor teamwork (–10%), etc. Expectations include maintaining an orderly work environment and returning all tools and test equipment by the end of every day, as well as following clear instructions (e.g. instructions given in equipment manuals, learning modules, verbally by the instructor), communicating with teammates, and productively managing time.

Objective descriptions and standards

Prototype diagram and project scope

Prior to any construction, the team must present diagrams of what they intend to build along with a description of what the project will do. Initial planning for a PLC project should be quite detailed, including:

- Prototype I/O wiring diagram based on PLC manufacturer's manual showing all component values, wiring connections, and terminal labels.
- Power wiring diagram complete with overcurrent protection and additional components such as AC/DC power supply units.
- A list showing all tagnames (i.e. sensible English names describing each and every input and output) and associated I/O channels to be used in the project. An example is shown below:

Hardware I/O terminal	I/O type	Tagname	Notes
Card 1, terminal IN0	24 VDC discrete input	START_PB	Black pushbutton, momentary NO contacts
Card 1, terminal IN1	24 VDC discrete input	STOP_PB	Red pushbutton, momentary NC contacts
Card 1, terminal IN2	24 VDC discrete input	E_STOP	Red pushbutton, latching NC contacts
Card 2, terminal IN0	4-20 mA analog input	MTR_TEMP	Current signal scaled 0 to 150 deg F
Card 3, terminal OUT0	120 VAC discrete output	CONTACTOR	To terminal A1

The project scope is a written description of what the completed project should actually do, and it should be as practical and reasonable as time will allow. It is recommended that your project implement some form of counting and timing functions in addition to basic combinational and/or latching logic.

Risk assessment/mitigation plan

The team must assess all risks associated with the project's construction and operation, both equipment-related and personal, along with practical steps to mitigate those risks. *This project will involve 120 VAC electrical power, and therefore there is a non-trivial risk of electrical shock and fire. To address this you will need overcurrent protection and wiring practices appropriate for 120 VAC line power.*

Project timeline and action plan

The team will present a simple timeline of expected construction and testing progress, culminating at the project deadline date. Deviations from this plan may occur, but it is still important to formulate a plan in order to budget time and resources. *You should reserve several days' worth of time to develop the program for your PLC, and plan on testing this code in stages as you build it up to its final form.*

Demonstration of working system

The team will demonstrate proper operation of the project, based on the original project scope.

Project diagrams and coding

Each individual team member will present their own copy of diagrams for the project using industry-standard formats and symbols. All PLC programming code must also be fully documented, complete with comments written within the text of the code.

Bill of Materials

The team will present a simple Bill of Materials listing all components and materials necessary to build the project, along with current cost estimates for each item and a total cost estimate for the project as a whole. Assembled devices given to students (e.g. Terminal Block Boards) need not have their internal

components itemized but may be listed as single line-items in the Bill of Materials. The total cost of a Terminal Block Board is about \$200.

Written summary of lessons learned

Each individual team member will present their own written summary describing key points they learned during the construction and testing of the project. It is strongly encouraged that everyone document their own mistakes, as they *will* inevitably occur, and it is important that they serve as learning opportunities. The scope of this summary may be as wide as you wish, reflecting on everything from technical lessons learned, to interpersonal lessons learned, to ways of improving time management, etc.