

# ACTivATE Exercise Documentation

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## Course in which the Exercise is Embedded

Mechatronics 10

### Instructor

Steven Gillette

### Course Title

Fundamental of Electronics

## Applied Critical Thinking Exercise Overview

### Exercise Title

Troubleshooting Mechatronics Systems

### Description

This report documents one of a series of lessons that covers the troubleshooting of electronic circuits typical of Mechatronics systems. The purpose is to provide students with a structured framework for the troubleshooting of complex Mechatronics systems and to specifically associate critical thinking skills with the troubleshooting process.

### Discipline(s)/Subject Area

Mechatronics, electronics, physics, engineering

### Grade or Course Level

Community College

### Time Needed

One 2-hour laboratory exercise

## Foundation

### College Course Outcome(s) for the Selected Exercise (from WEB CMS)

1. Build and test various electronic circuits, identify proper circuit function, compare that function to actual circuit function. (MECH 10)
2. Diagnose errors in the operation of a Mechatronics system and hypothesize root causes. Modify the equipment and assess the resultant behavior. (MECH 04)
3. Describe the function and application of common electrical devices and circuits used in Mechatronics systems. (MECH 04)
4. Build and test the student project. Troubleshoot any problem areas. (MECH 14)
5. Construct the complete Mechatronics system then analyze, diagnose and modify the behavior to meet product requirements. (MECH 44)
6. Analyze, assemble and evaluate pneumatic, hydraulic, closed loop Mechatronics systems. (MECH 54)
7. Design, build, test, and troubleshoot various output device interfaces. (MECH 90)

8. Design, build, test, and troubleshoot various input device interfaces. (MECH 90)
9. Design, build, test, and troubleshoot a microcontroller based term project that performs a real world control function. (MECH 90)
10. Build and test the student project. Troubleshoot any problem areas. (MECH 14)
11. Evaluate and analyze the cause of an inoperative or unresponsive personal computer, then formulate and execute a repair. (MECH 25)

### **Student Objectives/Learning Outcome(s) for the Selected Exercise**

Students will troubleshoot electronic systems using a structured approach including;

1. Failure Identification - produce a problem statement, composed of grammatically correct and complete sentences that **distinguish** a circuit's operational failure from expected performance.
2. **Analyze** a defined troubleshooting procedure to identify the critical thinking skills used to create an effective problem statement.

### **Student Objectives/Learning Outcome(s) for the Future Exercises**

3. Functional Inventory – **seek information** to produce a complete listing of the primary and secondary services performed by the components in a larger system or process.
4. Failure mode – use **logical reasoning** to identify common modes of component failures.
5. Isolation and elimination – use **logical reasoning** to identify tests to simplify the failure modes to a manageable scope.
6. Solutions Analysis – produce **transforming knowledge** that identifies the root cause of the failure, and proposes permanent and long term solutions

### **Critical Thinking Skills**

1. **Discriminating** - provide alternative explanations for a pattern of results that has many possible causes.
2. **Information Seeking** – identify additional information needed to evaluate a hypothesis / interpretation.
3. **Discriminating** – evaluate whether spurious relationships strongly support a claim.
4. **Logical Reasoning** – provide relevant alternative interpretations for spurious relationships.
5. **Discriminating** – provide relevant alternative interpretations of information.
6. **Information Seeking** – separate relevant from irrelevant information when solving real-world problems.
7. **Transforming Knowledge** – identify suitable solutions for a real-world problem using relevant information.
8. **Logical Reasoning** – deduce conclusions from information or evidence.

### **Framing Question(s)/Concept(s) for the Exercise**

1. How can the Mechatronics technician identify the correct problem to troubleshoot in a failed process?

### **Framing Question(s)/Concept(s) for future exercises**

2. What system components might contribute to the identified problem?
3. What are the most common failures experienced by those components?
4. What tests can be performed to eliminate components and their functions as contributors to the larger system failure?
5. What steps can be taken to eliminate the failure from future operations?

## Lesson 1 – Failure Identification Assessment/Student Products

### Pre-exercise Assessment

1. Establish students' understanding of circuit source, conductor, load and controls.
2. Establish a framework for failure identification.
  - a. What were the conditions at the time of the failure?
  - b. When does the equipment or system fail? Is the failure correlated to a specific time frame?
  - c. What components or equipment experienced or demonstrated the operational failure?
  - d. How has the circuit or equipment failed to meet operational requirements?.
3. Provide an example of a failure identification.
  - a. Conditions – At the time of failure the circuit was constructed on the Global Specialties trainer and was energized with 5 volts DC.
  - b. Failure Time Frame – The failure occurred immediately after the circuit was powered on, and remained in failure for the duration of the power application.
  - c. Failure Components – The LED's failed to meet operational requirements.
  - d. Operational Failure – The circuit failed to meet operational requirements by not producing an alternating LED flash at a frequency of 2.03 Hz.

### Post-exercise Assessment to Measure Success or Progress (summative with scoring rubric developed with students)

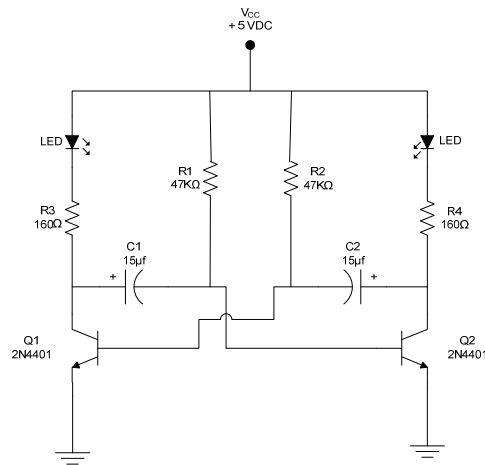
1. Students will write a problem statement meeting the established criteria.
2. Students will select from a list the critical thinking skills applied to the creation of an effective problem statement.

## Materials & Resources

### Materials

Quantity	Description
1	Solderless breadboard circuit trainer with a 5VDC power supply
1	Digital multimeter
2	160 $\Omega$ resistor
2	47K $\Omega$ resistor
2	15 $\mu$ F capacitor
2	Light emitting diodes (LED)
2	2N4401 bipolar junction transistor

### Circuit



## Exercise Details

### Prerequisite skills for student success

1. Understand the operation and configuration of a solderless breadboard trainer.
2. Understand the application of polarity sensitive components (transistor and diode).
3. Ability to read a schematic, and to translate the schematic into an actual circuit on the trainer.
4. Ability to observe circuit performance and determine if the design intent is met.

### Potential student misconceptions/misunderstandings or challenges with the exercise

1. Students taking their first electronics class will have little or no familiarity with electronic circuit construction, components, or schematics.
2. Many students explained the steps taken to repair a faulty circuit, but failed to write up the problem statement per the established criteria.

### Procedure – Circuit Assembly & Test

1. Construct the astable multivibrator circuit as shown on schematic diagram MECH10-01. Pay close attention to the proper orientation of polarized components (transistors and capacitors in this lab).

2. Connect the circuit to the +5 V power supply. Connect the circuit ground to the trainer ground bus.
3. Verify that the LED's alternate on-off. Have the instructor or lab assistant witness your functioning circuit and sign your lab handout.
4. Calculate and record the expected oscillation frequency using the frequency formula in the Formulas section of this lab assignment.
5. Count and record the number of cycles for a single LED over a 30-second period.  
\_\_\_\_\_ Cycles / 30-sec
6. Calculate and record the number of cycles per second \_\_\_\_\_ Hertz
7. Calculate and record the percent error between expected and measured frequency using the %Error formula below. \_\_\_\_\_ % Error

## Conclusions

1. Write a problem statement, composed of grammatically correct and complete sentences that summarize one operational failure of the circuit, trainer or test equipment. The problem statement must answer the following questions;
  - a. What were the conditions at the time of the failure?
  - b. When does the equipment or system fail? Is the failure correlated to a specific time frame?
  - c. What components or equipment experienced or demonstrated the operational failure?
  - d. How has the circuit or equipment failed to meet operational requirements?
2. Select the critical thinking skills from the list provided that support the creation of an effective failure identification.

## Closure – Major Points

1. Failure identification seeks to identify the right problem for further troubleshooting activities.
2. Failure identification records the conditions at the time of failure, the time frame correlated to the failure (continuous or intermittent), and the system function that failed to meet operational requirements.
3. Critical thinking skills used when forming failure identifications;
  - a. **Information seeking** - identify additional information needed to evaluate a hypothesis/interpretation.
  - b. **Discriminating** – separate relevant from irrelevant information when solving a real-world problem.
  - c. **Analyzing** – reframe problems, questions, issues

## Instructor Comments/Reflection

**Troubleshooting** is the identification, isolation, and elimination of functional failures. Mechatronics systems utilize computers and sensors to control complex mechanical and electrical labor saving devices. Mechatronics systems apply every engineering discipline, including statics, dynamics, thermodynamics, chemistry, electrical theory, digital data communication, and computer programming. This broad range of applied engineering leads to dramatic increases in the number and type of potential failures in Mechatronics systems. Failure modes can range from simple to enormously complex. Yet even with this level of complexity, Mechatronics systems provide reliable, and relatively trouble-free control of automation systems. The complexity of some Mechatronics systems may demand a more structured approach to equipment troubleshooting, repair, and replacement decisions.

For the Mechatronics Technician, troubleshooting uses many ***critical thinking skills*** and encompasses both science and art. Troubleshooting requires the systematic application of inductive and deductive reasoning; the careful observation and recording of data, experiences, cause, and effect; the ability to correlate seemingly unrelated data. Frequently poor data quality turns troubleshooting into an art instead of a science; playing the right hunches, creating new test procedures; verifying data and information. The goal of troubleshooting is to produce meaningful information to base repair / replace decisions.

Even with a structured approach, troubleshooting refuses to fit in a bottle, to adhere to strict formulas, or to follow strict rules of engagement. Every troubleshooting experience is different. It requires the systematic application of the scientific technique, but often advances only through experience, intuition, hunches, and luck. We know that experience has great value in shaping troubleshooting successes, with some technicians quickly able to distill complex failures into simple and elegant solutions. We know the more troubleshooting students do, the more success they will have.

## Student Assessment

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Student assessment is achieved through direct observation of circuit construction and performance, through a written failure identification problem statement and through the identification of critical thinking skills required to create an effective failure identification.

Students will;

1. Demonstrate the construction of an electronic circuit (astable multivibrator).
2. Observe the performance of the functioning circuit and compare it with the expected circuit performance.
3. Construct a failure identification problem statement using an established framework.
4. Associate critical thinking skills with the steps used in the creation of an effective problem statement.

# Student Assessment Rubric

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## Problem Statement Ratings

Criteria	<b>Exceeds -</b> excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>2 ½ max points</i>	<b>Meets –</b> satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>1 ¾ max points</i>	<b>Minimal –</b> Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>1 ½ max points</i>	Notes
<b>Conditions at the time of failure</b>				
<b>Failure time frame captured</b>				
<b>Failure components identified</b>				
<b>Operational failure identified</b>				

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Name

**Learning Objectives**

- Become familiar with electronic circuit construction using a proto-board trainer.
- Calculate the theoretical output frequency for an astable multivibrator circuit.
- Measure the output frequency for an astable multivibrator circuit through direct observation.
- Create a problem statement that accurately describes a problem associated with the circuit, trainer or test equipment performance
- Identify critical thinking skills required to write an effective problem statement

**Materials**

Quantity	Description
1	Global Specialties Circuit Trainer
1	Digital multimeter
2	160 $\Omega$ resistor
2	47K $\Omega$ resistor
2	15 $\mu$ F polarized capacitor
2	Light emitting diodes (LED)
2	2N4401 bipolar junction transistor

**Procedure – Circuit Assembly & Test**

1. Construct the *astable multivibrator* circuit as shown on schematic diagram MECH10-01. Pay close attention to the proper orientation of polarized components (transistors and capacitors in this lab).
2. Connect the circuit to the +5 V power supply. Connect the circuit ground to the trainer ground bus.
3. Verify that the LED's alternate on-off. ***Have the instructor or lab assistant witness your functioning circuit and sign your lab handout.***
4. ***Calculate and record*** the expected oscillation frequency using the *frequency* formula in the Formulas section of this lab assignment.
5. ***Count and record*** the number of cycles for a single LED over a 30-second period.  
\_\_\_\_\_ Cycles / 30-sec
6. ***Calculate and record*** the number of cycles per second \_\_\_\_\_ **Hertz**
7. ***Calculate and record*** the percent error between expected and measured frequency using the *%Error* formula below. \_\_\_\_\_ % Error

## Formulas

$$\%Error = \frac{\text{measured} - \text{expected}}{\text{expected}} \times 100\%$$

$$f = \frac{1}{0.700RC}$$

### Where;

**%Error** = % change between measured and expected values

**measured** = a value taken from direct measurement

**expected** = a value taken from component or process specifications

### Where;

**f** = frequency (Hertz)

**R** = circuit resistance (Ohms)

**C** = circuit capacitance (Farads)

## Conclusions

- a) Write a **problem statement**, composed of grammatically correct and complete sentences that summarize one operational failure of the circuit, trainer or test equipment. The problem statement must answer the following questions;
  - a. What were the conditions at the time of the failure?
  - b. When does the equipment or system fail? Is the failure correlated to a specific time frame?
  - c. What components or equipment experienced or demonstrated the operational failure?
  - d. How has the circuit or equipment failed to meet operational requirements?
- b) Select and include two critical thinking skills from the list provided that support the creation of an effective problem statement.

## Problem Statement Ratings

Criteria	Exceeds - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>2 ½ max points</i>	Meets – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>1 ¾ max points</i>	Minimal – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>1 ½ max points</i>	Notes – examples of text from student problem statement that illustrate critical thinking skills.
Conditions at the time of failure				
Failure time frame captured				
Failure components identified				
Operational failure identified				

### Grading Criteria

		Points Possible	Points Earned
<b>Documentation</b>	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	10	
<b>Circuit Function</b>	Circuit function verified (signature required)	5	
<b>Calculations</b>	Expected and measured frequency recorded, percent error accurate	5	
<b>Conclusions</b>	Problem statement meets the criteria illustrated above	10	
	<b>Total</b>	<b>30</b>	

### Lab Report Format

**Abstract** - a summary and high-level overview of the lab and its results

**Introduction** - State the objectives of the laboratory and list the equipment required

**Experiment** - Describe the procedure used to carry out the lab

**Data Results** - list data taken in table or graphical format where appropriate

**Conclusion** - State the conclusions drawn and lessons learned from the laboratory activities.

Answer any questions found within the lab procedure.

**Attachments** – grading criteria, verification signatures, circuit diagrams, lab procedures & notes

### Example Problem Statement

**Conditions** – At the time of failure the circuit was constructed on the Global Specialties trainer and was energized with 5 volts DC.

**Failure Time Frame** – The failure occurred immediately after the circuit was powered on, and remained in failure for the duration of the power application.

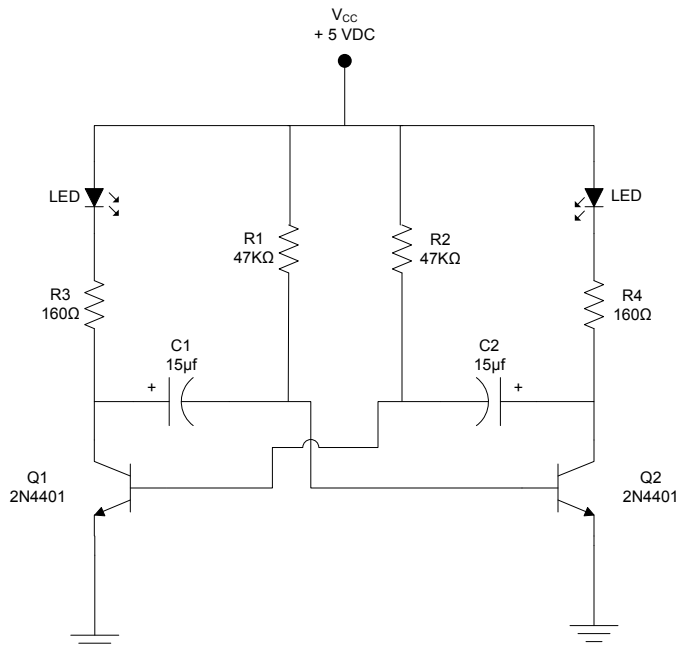
**Failure Components** – The LED's failed to meet operational requirements.

**Operational Failure** – The circuit failed to meet operational requirements by not producing an alternating LED flash at a frequency of 2.03 Hz.

## Key Critical Thinking Skills

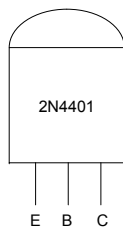
1	Summarize the pattern of results in a graph without making inappropriate inferences
2	Evaluate how strongly correlation-type data supports a hypothesis
3	Provide alternative explanations for a pattern of results that has many possible causes
4	Identify additional information needed to evaluate a hypothesis/interpretation
5	Evaluate whether spurious relationships strongly support a claim
6	Provide alternative explanations for spurious relationships
8	Determine whether an invited inference in an advertisement is supported by information
9	Provide relevant alternative interpretations of information
10	Separate relevant from irrelevant information when solving a real-world problem
11	Analyze and integrate information from separate sources to solve a real-world problem
12	Use basic mathematical skills to help solve a real-world problem
13	Identify suitable solutions for a real-world problem using relevant information
14	Identify and explain the best solution for a real-world problem using relevant information
15	Explain how changes in a real-world problem situation might affect the solution
16	Deduce conclusions from information or evidence
17	Interpret viability of conclusions, using evidence
18	Evaluate evidence or authority
19	Reframe problems, questions, issues

1. Identify which critical thinking skills are *most* important for your students
2. Of these, which is hardest to achieve?
3. Identify 1-2 strategies for incorporating important skills into your teaching.

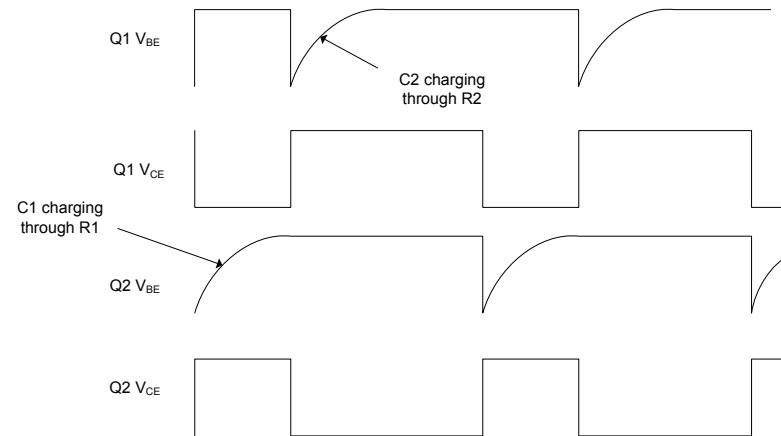


An astable (not stable) multivibrator is an RC oscillator that generates a square or rectangular waveform. This circuit has no stable state, constantly alternating each output from high to low at a frequency determined by the RC time constant.

$$T = 0.7RC$$



### TIMING DIAGRAM



### OUTPUT SEQUENCE

- STATE 1** - Q1 SWITCHES ON CAUSING THE COLLECTOR VOLTAGE TO DROP FROM VCC TO ABOUT 0.7 V. THE NEGATIVE GOING TRANSITION OF THE Q1 COLLECTOR IS COUPLED TO Q2 BASE THROUGH C1 CAUSING A REVERSE BIAS, TURNING Q2 OFF.
- STATE 2** - C1 CHARGES THROUGH THE Q1 EMITTER GROUND, THROUGH THE Q1 EMITTER / COLLECTOR, THROUGH C1 AND R1 TO +VCC.
- STATE 3** - WHEN C1 IS FULLY CHARGED THE Q2 BASE IS NO LONGER REVERSE BIASED CAUSING Q2 TO SWITCH ON. Q2 COLLECTOR VOLTAGE DROPS FROM VCC TO ABOUT 0.7 V. THE NEGATIVE GOING TRANSITION OF THE Q2 COLLECTOR IS COUPLED TO Q1 BASE THROUGH C2 CAUSING A REVERSE BIAS, TURNING Q1 OFF.
- STATE 4** - C2 CHARGES THROUGH THE Q1 EMITTER GROUND, THROUGH THE EMITTER / COLLECTOR OF Q2, THROUGH C2 AND R2 TO +VCC.
- STATE 5/1** - WHEN C2 IS FULLY CHARGED THE Q1 BASE IS NO LONGER REVERSE BIASES CAUSING Q1 TO SWITCH ON. Q1 COLLECTOR VOLTAGE DROPS FROM VCC TO ABOUT 0.7 V. THE NEGATIVE GOING TRANSITION OF THE Q1 COLLECTOR IS COUPLED TO Q1 BASE THROUGH C1 CAUSING A REVERSE BIAS, TURNING Q2 OFF.

$$T = 0.7RC$$

$$T = 0.7 \times 47K\Omega \times 15\mu F$$

$$T = 0.7 \times 47,000\Omega \times 15 \times 10^{-6}$$

$$T = 0.49 \text{ seconds}$$

**SIERRA**  
COLLEGE

**Mechatronics**  
*Real Skills Real Jobs*

MECH 10 – FUNDAMENTALS OF ELECTRONICS

ASTABLE MULTIVIBRATOR

DRAWN BY – S GILLETTE

SIZE	FSCM NO	DWG NO	REV
		MECH10-01	0
SCALE	NONE	SHEET	1 OF 1

JUNE 2011

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### Critical Thinking Objectives

- Demonstrate critical thinking skills through the development of a complete troubleshooting analysis of typical circuits used in MECH 10, Fundamentals of Electronics
  - Provide alternative explanations for a pattern of results that has many possible causes
  - Identify additional information needed to evaluate a hypothesis / interpretation
  - Evaluate whether spurious relationships strongly support a claim
  - Provide relevant alternative interpretations for spurious relationships
  - Separate relevant from irrelevant information when solving real-world problems
  - Identify suitable solutions for a real-world problem using relevant information
  - Deduce conclusions from information or evidence

### Lesson 1 – Failure Identification

Effective failure identification produces a **problem statement**, composed of grammatically correct and complete sentences that summarize an operational failure. Without an accurate problem statement, the entire troubleshooting sequence could fail to target the actual cause of the failure. A well-constructed problem statement answers several key questions in support of further troubleshooting efforts.

#### Activity

1. Build an electronic circuit to the specification shown in a circuit diagram.
2. Test the circuit and note any operational failures of the circuit, trainer or test equipment.
3. Write a **problem statement**, composed of grammatically correct and complete sentences that summarize **one** operational failure of the circuit, trainer or test equipment. The problem statement must answer the following questions;
  - a) What were the conditions at the time of the failure?
  - b) What components or equipment experienced or demonstrated the operational failure?
  - c) When does the equipment or system fail? Is the failure correlated to a specific time frame?
  - d) How has the circuit or equipment failed to meet operational requirements?

#### Problem Statement Ratings

Criteria	<b>Exceeds</b> - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>6 to 10 points</i>	<b>Meets</b> – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>3 to 5 points</i>	<b>Minimal</b> – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>0 to 2 points</i>
Conditions at the time of failure			
Failure components identified			
Failure time frame captured			
Operational failure identified			

## Lesson 2 – Functional Inventory

With a complete understanding of experiences and observations, and a well-formed problem statement, the next step in the troubleshooting sequence is to establish a clear understanding of the equipment and system functions. A **functional inventory** is a complete listing of the primary and secondary services performed by equipment trains in the larger process. The Mechatronics technician gains an understanding of system and equipment functions through experience, observation, and by consulting control narratives and operations and maintenance (O&M) manuals.

### Activity

1. Create a list of equipment level and health and safety functions provided by the **Global Specialties Trainer** to include;
  - a. **Equipment Level Functions** – the trainer provides low-level functions to a larger process system. For example,
    - i. The DC power supply provides regulated direct current to a circuit (list the fixed and variable voltages ranges.)
    - ii. The function generator provides variable frequency alternating signals to a circuit (list the frequency ranges and waveform types).
    - iii. The power switch energizes the trainer power supplies...
  - b. **Health and Safety Functions** – many system designs include features that reduce risk and enhance employee safety. List the health and safety functions of the **Global Specialties Trainer**. For example,
    - i. The trainer isolates the users from 120VAC power.

### Functional Inventory Ratings

Criteria	<b>Exceeds</b> - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>6 to 10 points</i>	<b>Meets</b> – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>3 to 5 points</i>	<b>Minimal</b> – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>0 to 2 points</i>
<b>Equipment Level Functions</b>			
<b>Health &amp; Safety Functions</b>			



### Lesson 3 – Failure Modes

A *failure mode* is the physical or functional cause of failure. A failure mode describes the way a failure occurs. All mechanical, electrical, instrument, and control equipment have multiple failure modes. We can often list common failure modes by equipment types. For example, pumps typically fail because of worn bearings, leaky seals, worn impellers, or eroded seal rings. Motors often fail from worn bearings, shorted stator windings, or broken rotor bars. Instruments fail from calibration drift, defective transducers, or faulty signal-conditioning circuits.

#### Activity

1. Select one of the functions provided by the *Global Specialties Trainer* (power supply, function generator, switches, LED's, speaker, terminal blocks.)
2. Create a list of *GS Trainer* all functional failure modes associated with the function selected in Step 1. For example;
  - a. **Mechanical Components** – The *GS Trainer* rocker switch that controls the 120 VAC power to the trainer fails due to a broken spring, charred contacts, or a broken wire.
  - b. **Electrical Components** – The DC power supply (an electrical component) fails to produce the rated voltage. The GS Trainer fuse opens due to over current.

#### Failure Mode Ratings

Criteria	Exceeds - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>6 to 10 points</i>	Meets – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>3 to 5 points</i>	Minimal – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>0 to 2 points</i>
Failure Modes			

## Lesson 4 – Isolation and Elimination

**Isolation and elimination** is the simplification of functional failures to a manageable scope. In complex automation control systems the number and variety of failure modes can be daunting to the Mechatronics technician. Effective troubleshooting requires the technician to isolate individual failure modes then test to see if that mode is responsible for the larger system failure.

The list of functional failures is the starting point for selecting isolation and elimination tests. Isolation and elimination tests should start with the simplest and progress to most complex test. **The goal is to discover the root cause of the failure with the simplest possible test.** Sorting the isolation and elimination tests by complexity is the best opportunity for the Mechatronics technician to prioritize the investigative tests.

### Activity

1. Select two of the GS Trainer failure modes.
2. Create a list of isolation tests appropriate to each failure mode and rank them by test complexity, from 0 (tactile), to 5 (intrusive).
3. Note – use Field Example 8-4 as a basis for organizing and presenting your results

### Isolation & Elimination Ratings

Criteria	<b>Exceeds</b> - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>6 to 10 points</i>	<b>Meets</b> – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>3 to 5 points</i>	<b>Minimal</b> – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>0 to 2 points</i>
<b>Tests Identified</b>			
<b>Test Ranked by Complexity</b>			
<b>Field Example 8-4 Compliance</b>			

## Lesson 5 – Solutions Analysis

**Solutions analysis** is the association of a failed isolation test with the functional failure. The Mechatronics Technician must establish a cause-effect relationship between the test result and the failure. Where there is no cause-effect relationship between the two, that equipment may be eliminated as the root cause of the functional failure. In complex systems, testing may reveal equipment failures that are not related to the functional failure being examined. Another test is selected and performed, with the results compared to the failure again. This iterative process continues until a clear cause-effect relationship is found.

### Activity

1. Build an electronic circuit to the specification shown in a circuit diagram.
2. Test the circuit and note any operational failures of the circuit, trainer or test equipment.
3. Write a **problem statement**, composed of grammatically correct and complete sentences that summarize **one** operational failure of the circuit.
4. Create a list of **functions** provided by the **circuit or components** to include;
  - a. Component Level Functions
  - b. Process Level Functions
5. Select one of the functions provided by the circuit or component and create a list of all **failure modes** associated with the function selected in Step 4.
6. Create a list of **Isolation and Elimination** tests appropriate to each failure mode and rank them by test complexity, from 0 (tactile), to 5 (intrusive). Note – use Field Example 8-4 as a basis for organizing and presenting your results.
7. Write a brief Solutions Analysis that establishes a cause & effect relationship between test results and the component or circuit failure.

### Solutions Analysis Ratings

Criteria	<b>Exceeds</b> - excellent grasp of criteria demands. Superior level of competence and understanding. Significant evidence of independent learning <i>6 to 10 points</i>	<b>Meets</b> – satisfactory grasp of criteria demands. Average level of competence and understanding. Some evidence of independent learning <i>3 to 5 points</i>	<b>Minimal</b> – Attempts to meet criteria demands are weak or missing. Little to no indication of independent learning <i>0 to 2 points</i>
<b>Problem Statement</b>			
<b>Functional Inventory</b>			
<b>Failure Modes</b>			
<b>Isolation &amp; Elimination</b>			
<b>Solutions Analysis</b>			