LABORATORY ASSIGNMENT 1: INTRODUCTION TO MECHANISMS

Introduction

In this lab, we will reinforce the fundamental concepts from kinematics such as degrees of freedom, links and joints studied in class. We will build various mechanisms, study their motions, apply the position analysis techniques and build intuition on how they can be used in robotics applications. We will also discuss and reinforce basic digital switching circuits.

Objectives

1. Explain terms and concepts fundamental to the analysis of mechanisms.
2. Compute the mobility of simple mechanisms using the Gruebler (or Kutzbach) equations.
3. Compute the Grashof condition for simple mechanisms.
4. Apply position analysis for simple mechanisms.
5. Demonstrate intuitive knowledge of building a simple mechanism using the supplied components.
6. Create a SolidWorks assembly of a mechanism with an exploded assembly drawing and a bill of materials.
7. Demonstrate the ability to build and test digital output devices such as transistors and relays.

Pre-Lab

Review the Lab 1 material on the RBE Wiki, watch the pre-lab video and the SolidWorks Introduction Videos, and complete the SolidWorks Introduction Quizzes.

In-Lab

Using the links provided, choose the proper links to produce the required mechanisms. For each mechanism complete the attached data sheet to include in your lab report. Make sure to select link lengths appropriately so that you can trace coupler point trajectories on 8.5'' x 11'' paper.

1. Grashof four-bar linkage (See Figure 1) **(do all four inversions)**
    a. Inversion 1 (Figure 2-17a, page 57 Norton, 4th ed.)
    b. Inversion 2 (Figure 2-17a, page 57 Norton, 4th ed.)
    c. Inversion 3 (Figure 2-17b, page 57 Norton, 4th ed.)
    d. Inversion 4 (Figure 2-17c, page 57 Norton, 4th ed.)

    For each inversion, select an arbitrary coupler point and then trace the coupler curve for 360° of crank rotation. Do not create coupler curve tracings using the joints.
2. Non-Grashof four-bar (See Figure 2) **(do only one of the four inversions)**
    a. Inversion 1 (Figure 2-18a, page 58 Norton, 4th ed.)
    b. Inversion 2 (Figure 2-18b, page 58 Norton, 4th ed.)
    c. Inversion 3 (Figure 2-18c, page 58 Norton, 4th ed.)
    d. Inversion 4 (Figure 2-18d, page 58 Norton, 4th ed.)

    For the inversion chosen, select an arbitrary coupler point and then trace the coupler curve for the full range of crank rotation. Do not create coupler curve tracings using the joints.

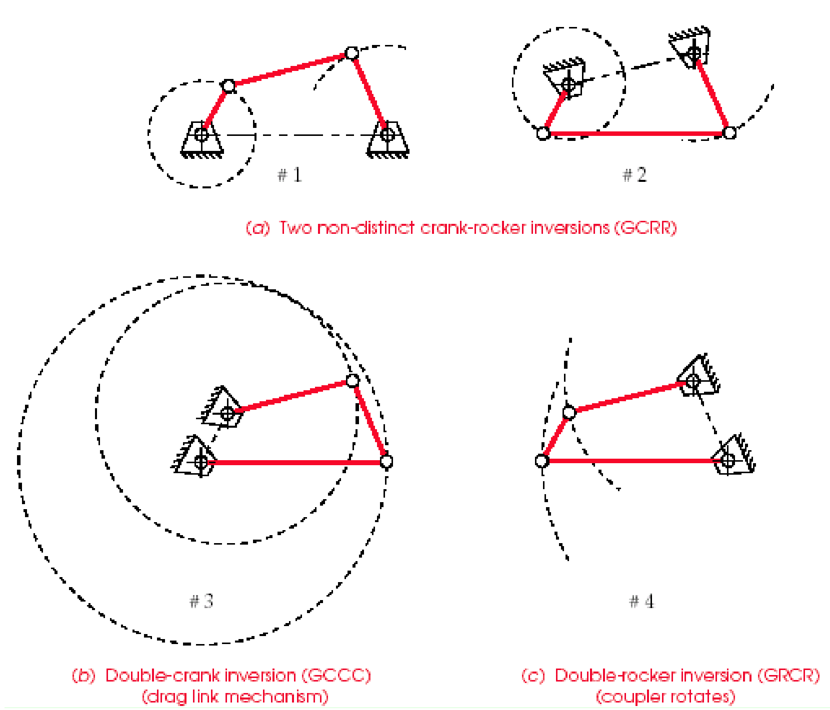

Figure 1: All inversions of the Grashof fourbar linkage

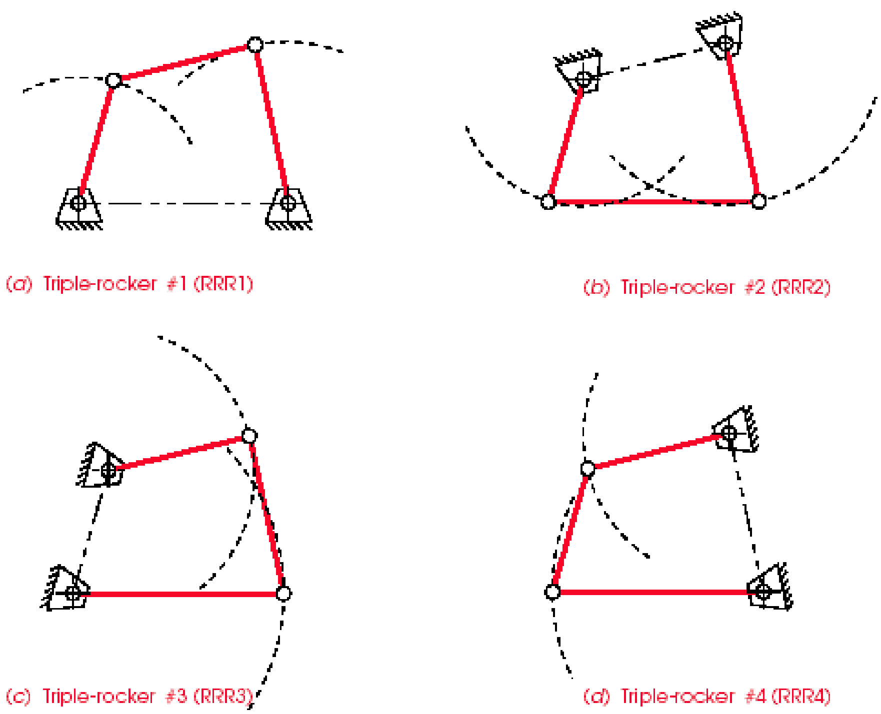

Figure 2: All inversions of the non-Grashof fourbar linkage

3. Discuss the problems encountered when constructing the physical three dimensional devices as compared to the theoretical planar mechanisms.

The next step is for each team member to use SolidWorks to design one of the following six-bar linkages. You must come up with your own lengths for the links.

After creating an assembly of the six-bar mechanism, a TA or SA may sign off on full rotational motion of the six-bar. In other words the mechanisms should be designed such that at least one link can rotate 360°. Team members should select different inversions and must create their own parts and six-bar assemblies.

NOTE: It is helpful to use the move tool and the collision detection in the SolidWorks assembly. Links cannot pass through each other.

4. Stephenson's Sixbar (See Figure 4)
    a. Inversion I (Figure 2-16a, page 56 Norton, 4th ed.)
    b. Inversion II (Figure 2-16b, page 56 Norton, 4th ed.)
    c. Inversion III (Figure 2-16c, page 56 Norton, 4th ed.)

   Or

   Watt's Sixbar (See Figure 4)
    a. Inversion I (Figure 2-16d, page 56 Norton, 4th ed.)
    b. Inversion II (Figure 2-16e, page 56 Norton, 4th ed.)

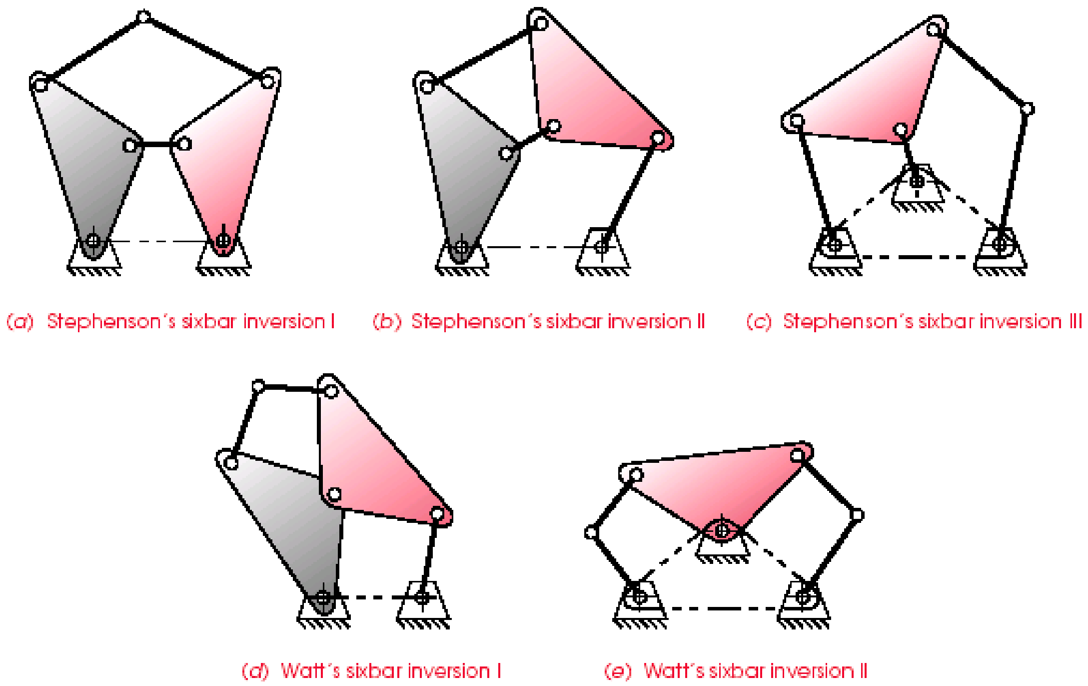

Figure 3: All distinct inversions of the six-bar linkages

Provide an eDrawing of the exploded assembly drawing with balloons and a bill of material for the six-bar mechanisms created by each team member.

5. Using the components from your team-kit build the following transistor switching circuit shown in Figure 5. The circuit utilizes an NPN transistor that is ideal for use as a low side switch. Transistors have 4 operating modes (shown in Figure 6) that are controlled by the relationship between the voltage differences present at each pin. When used as a switching circuit the transistor is setup to use the **Saturation** and **Cut-Off** modes based off a 0-5V digital input.

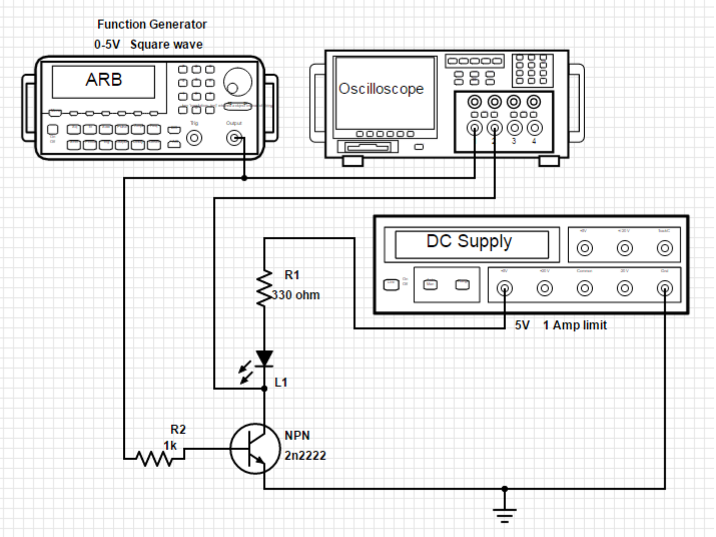

Figure 5: Transistor switching circuit

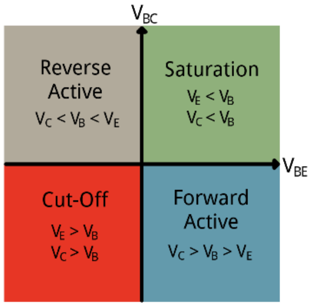

Figure 6: 4 operating modes of transistor

a. Use a signal generator to test the max switching frequency of the transistor and capture the input and output using the oscilloscope when the output duty cycle degrades to less than 40%. Use a 50% duty cycle, 0V to 5V square wave input.
b. Do some research and describe the 4 modes of operation of a transistor.
c. Under normal use cases which mode should not be utilized?
d. If you were given a PNP transistor instead would you design a high or low side switching circuit?
e. Why do most high power DC motor drivers use MOSFETS instead of BJT's?

6. Now hook up your transistor circuit to switch on and off a relay as shown in Figure 7.

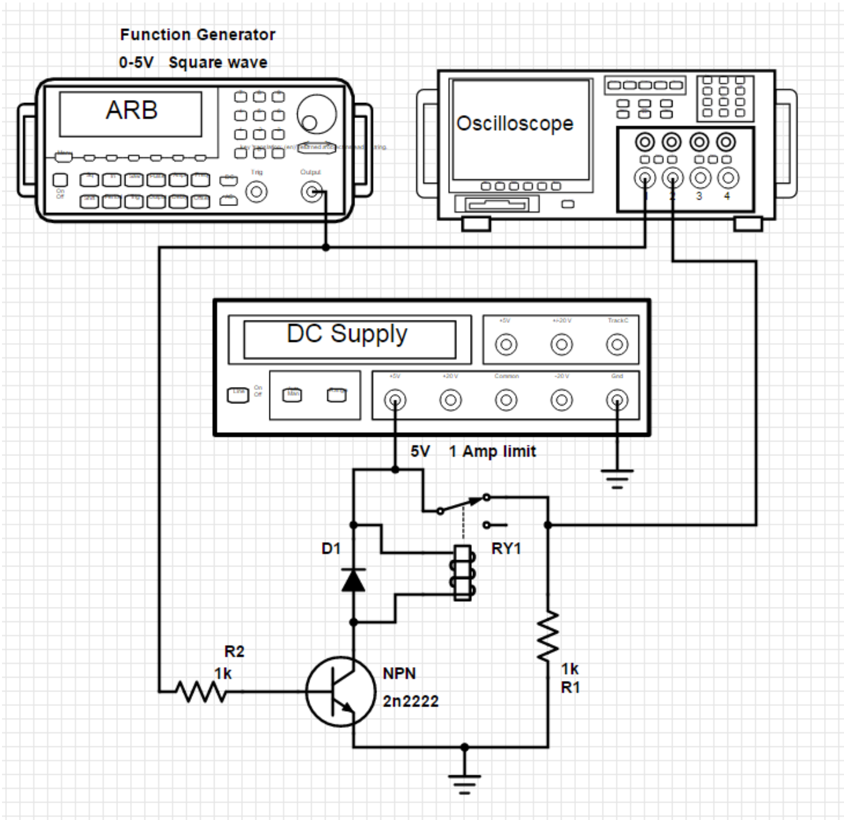

Figure 7: Transistor switching circuit with added relay

   a. Determine the maximum speed the relay can switch by comparing an input frequency to an output frequency. The maximum frequency is when the relay is no longer releasing. Bouncing of the contact should be ignored for this exercise
   b. How long (time) would the relay last at this frequency, both at the rated load and at no load?
   c. What other benefits does a relay have? Mention at least 3 of them.

Post-Lab

1. Select one of the four-bar mechanisms built in the lab and perform the position analysis (using the equations for θ_3 and θ_4 derived in class) for a given configuration and θ_2 value. State all assumptions and show all your work. (Using Mathcad would be a good idea)
2. Repeat part 1 using the Linkage software. Include a screen shot of the four-bar mechanism (with a coupler curve for a point not on a joint) created with the Linkage software, as well as its corresponding table that includes θ_3 and θ_4. Compare your results to those obtained in part 1. If you don't get the same values, you have done something incorrectly.
3. Present all the data collected and answer all appropriate questions on the Lab 1 worksheet.