16-899: Actuation and Sensing Mechanisms in Robotics Systems

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Lab #2:
Control of Pneumatic Artificial Muscles using Pulse Width Modulation (PWM)

(Lab report due 11/2/2015)

READ THE HANDOUT BEFORE COMING TO LAB AND ASK ANY QUESTIONS YOU HAVE EARLY ON

In this lab, you will perform open-loop pressure control for the muscle using PWM signal from an Arduino microcontroller and an external power source. PWM can be used for simulating an analog signal using a digital source [1]. To do this, you will use two valves. One valve is used to inject air for contracting the muscle , and the other is used to exhaust air for relaxing the muscle. The valves will be connected in series. Refer to [2] for information on the valve. The first part will require a 12 V power source, a multimeter, and basic electronics tools. You can choose to do this in the lab or on your own if you have the equipment. The second part can only be done in the lab.

Materials

- Arduino Uno board
- Breadboard
- NPN transistor
- Proportional valve
- Pneumatic muscle
- Jumper cables
- Push to connect
- 1/4" OD tube
- 1/8" OD tube
- Female crimp pins

Experiments

Part 1

1. Connect your transistor to the breadboard, each pin in a different conducting lane.
2. Use one of the PWM-enabled pins on the Arduino as the switch for the transistor.
3. Connect power source at 12 V to one of the electric pins of the valve (Inserting the pins of the valve on the breadboard is the easiest).
4. Connect the other pin of the valve to the collector of the transistor.
5. Connect the emitter of the transistor to ground.
6. Adjust the PWM signal of the Arduino based on the limitations of the proportional valve. You can use [3] and other sources in order to accomplish this.
7. Connect the circuit for the second valve in parallel to the circuit of the first valve.

Part 2

8. Connect a piece of ¼" tube to the airport of your muscle and use a push-to-connect valve to convert to the smaller tube 1/8" in order to be able to connect it to the valve.
9. On the valve, you will see a side that has two ports and a side that has one. We will use the side that has one as our exhaust.
10. Connect the 1/8" tube from the push to connect and connect it to the inner port of the valve on the side that has two ports. Refer to [2] for technical sheet if needed.
11. The outer port on this same side will be connected to a push to connect valve and the big port will be connected to the airline.
12. The tests will be done at 60 psi.
13. Set your muscle on the Mark 10 and pretension at around 2.45 V. Use the "Mark-10 ESM301 Analysis_ContinuousWindow_MultiChannel_2015_0715" LabView VI to perform a square wave of force with the controller developed. Do it at different duty cycles (50%, 75%, and 100%).
14. The VI will export your data automatically.

Results

1. (40 pt.) Provide a graph of Force vs. Time with duty cycles of 25%, 50%, 75%, and 100% duty cycle for each muscle you made in Lab 1.
   Prepare three plots (muscles 1, 2, and 3). Each plot should include the following five periods for each duty cycle:
   a. Wait for 2 seconds.
   b. Contract muscle with the selected duty cycle for 3 seconds.
   c. Hold muscle for 3 seconds.
   d. Release muscle with the same duty cycle for 3 seconds.
   e. Fully release muscle for 2 seconds.
2. (5 pt.) Provide the frequency of the PWM you used.
3. (10 pt.) Provide the rise and fall times of each experiment for each duty cycle.
4. (10 pt.) Provide photos and description of your experimental setup.

Discussion

1. (5 pt.) Why is the use of PWM important?
2. (10 pt.) What are the advantages and limitations of PWM?
3. (5 pt.) Describe alternatives to PWM to control actuators in general. What other alternatives can be used for this particular actuator?
4. (5 pt.) Why does the PWM signal needs to be adjusted for the valve used? Why should PWM be adjusted in general?
5. (10 pt.) How did you determine your PWM frequency? What is the highest frequency you can use for the valve provided?

References

[1] What is a Pulse Width Modulation (PWM) Signal and What is it Used For:
http://digital.ni.com/public.nsf/allkb/294E67623752656686256DB800508989

[2] Parker X-Valve Datasheet:
http://www.parker.com/Literature/Literature%20Files/Precision%20Fluidics%20Division/UpdatedFiles/X-Valve.pdf

[3] Adjusting PWM Frequencies:
http://playground.arduino.cc/Main/TimerPWMCheatsheet