University of Utah
Electrical & Computer Engineering Department
ECE 2210 Lab 9
Control System (Servo)

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Note : Bring a book to lab that shows second order differential equation solutions (underdamped, critically damped, and overdamped) if you're not sure what they look like.

Objective
To see how many of the subjects that you have learned in this class relate to an electro-mechanical control system.

Equipment and materials from stockroom:
● Servo

Experiment
Power supply hookup
Turn off the power switch on the servo and hook it up to the power supply. Adjust the power supply to provide $\pm$ 6V as you did in the first lab. If you've forgotten how to do this, refer back to the lab handout for lab 1. Remember that you may be able to recall the $\pm$ 6 V configuration by simply hitting the **Recall** button twice (If no one else changed it in the meantime).
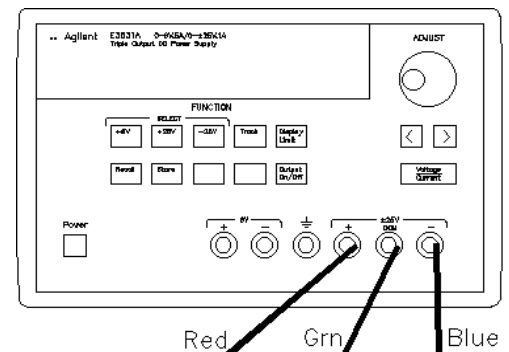
### Setup the Servo to minimize friction
Check the gears and turn them by hand (the red gear is the easiest to turn) to make sure that they are turning freely. The most common cause for binding is the rubber connector between the gear train and the motor position sensor pot. It needs to be pushed onto the pot shaft just the right distance. If it's pushed on the shaft too far, it causes the whitish-clear output gear to rub against the metal frame of the gear train. Too little and it causes the whitish-clear output gear to push the red gear against the white gear. Either way there's too much friction. When you're satisfied that the gears turn smoothly, turn on the power switch on the servo and make sure that it is functioning properly. Turn it back off for now. Make some mention of what you did in your lab notebook.

Setup the Function generator and Scope
Your wire kit should include a BNC "T" connector, connect it to the output of the function generator. Then wire the function generator, scope, and servo as shown in the next drawing with two BNC-to-BNC cables and one 10x probe. Connect the scope ground to the big green connector on the circuit board marked "Ground" (where that power supply is connected).

Turn on the function generator and set the **Ampl**itude to 50 mVpp (output will actually be 100 mVpp). Hit the **Shift** key, the **Store** key (shifted **Recall**), turn the knob 'till the display shows "STORE 1", and then hit the **Enter** key. This stores the current configuration of a 100mV, 1kHz sine wave as configuration "1". Now adjust the **Freq**uency to 500 mHz (0.5 Hz), the **Ampl**itude to 500 mVpp (output will actually be 1 Vpp), and set the waveform to a square wave. Store this

as configuration "2".   Make some mention of what you did in your lab notebook. NOTE: It needs to be a SQUARE WAVE !
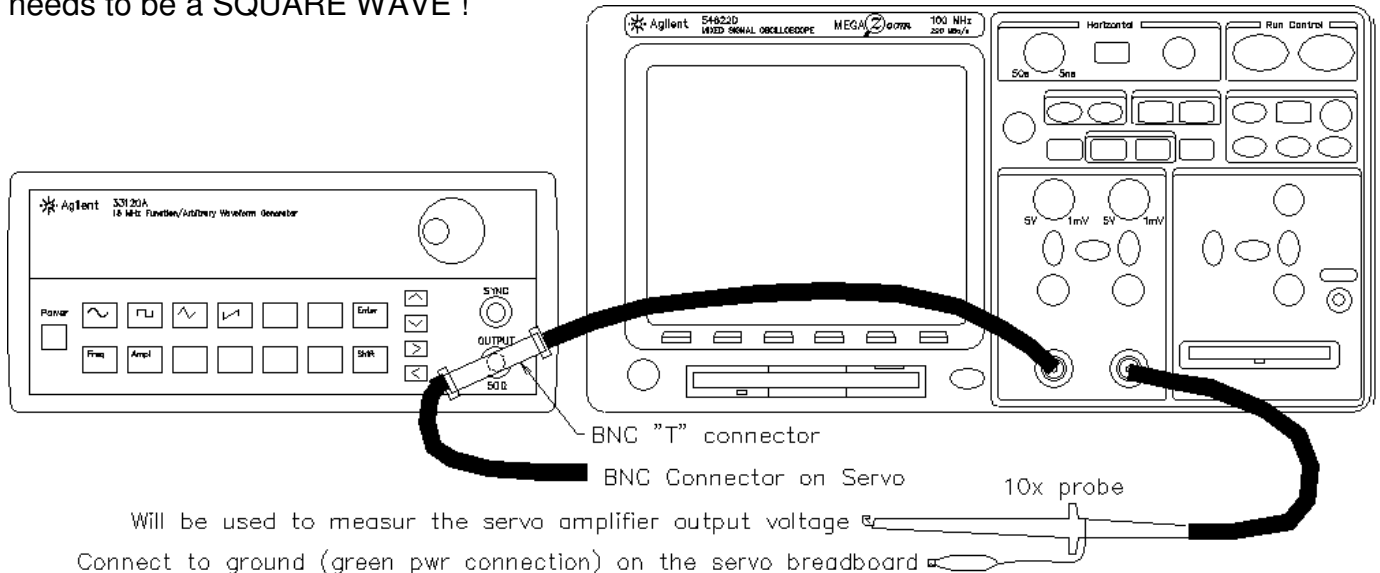
Observe how the gain knob affects the response of the servo

Turn down the gain of the servo to minimum (fully CCW). Turn on the servo. It should move back and forth in jerks, making one move every second. Slowly turn the gain knob through its entire range to get an idea of the different types of motion that the servo can make. Return the gain to minimum and observe how little the servo moves and how sluggishly it gets there. Does it overshoot its intended position? Do you think it even reaches its intended position? Slowly turn up the gain. What happens to the motion? Does it get a little more snappy? Does it move further than it did before and thus get closer to its intended position? The low-gain response was slow and had a lot of position error. The response gets much better as you turn up the gain. You can actually hear it get better. Continue to turn up the gain until you start to see (or hear) some overshoot. Just under this point is the optimal gain setting. Turn up the gain further until you get a little ringing (more than one overshoot). In class you've learned about the three types of second-order transient responses in terms of overdamped, critically damped, and underdamped. Relate these to the servo outputs you've observed at various gains.

Disconnect the function generator, turn up the gain all the way, and turn the input position knob to the center of its range. What is the servo doing now? Can the circuits that we studied do that?

Determine minimum gain for oscillation

Turn down the gain very slowly until the oscillation stops, then turn it back up just a hair. Try to get the oscillation started again by turning the "INPUT POSITION" knob a bit. Repeat this until you are satisfied that you've found the minimum gain needed for oscillation.

Measure the circuit gain

Disconnect the motor by pulling it's connector from the circuit board. Note that the circuit board is marked with a + and - at that connector and hook the scope CH2 to the + side. Reconnect the function generator and recall configuration "1" (Hit **Recall**, turn the knob 'till the display reads "RECALL 1", then hit **Enter**). Observe CH2 on the scope. If it doesn't show a sine wave, manually turn the red gear and thus the "Motor Position Sensor" until you see a full unclipped

sine wave.   Check that the scope CH2 is set to match the scope probe (1x or 10x) and then use the scope to find the gain. You may assume the input is 0.1 V_{pp}, so the gain is just $V_{opp}/.1 = 10xV_{opp}$. Disconnect the scope and reconnect the motor.

Determine minimum gain for ringing
Recall the function generator configuration "2". Turn down the gain very slowly and try to find the minimum gain needed for ringing (either direction of motion). Measure the gain as you did above.

Determine minimum gain for single overshoot
Repeat the above procedures to find the minimum gain for a single overshoot. This is closer to the actual minimum needed for ringing since overshoot is almost always really ringing.

The circuit has a range of gain from min to max of about 1.7 to 130. Confirm this with measurements if you want to.

Compare to calculations
Look at the calculations in the appendix. Do they correspond reasonably well with the cases that you have seen and the gains that you have measured? Notice that although the last one shows oscillation, the frequency is almost 5 Hz. Does your servo oscillate that fast? Does the oscillation continue to grow? The main reason for the discrepancies is that I've linearized and simplified the models. The theoretical response is much too fast because I've disregarded nonlinearities in the system, particularly power supply limits and amplifier clipping. There simply isn't enough power to really move that fast. The limits also keep the oscillations from growing without bounds. Additionally, I've simply modeled the time delays in the system by using an artificially high motor inductance value. Comment in your notebook.

Find the system block diagram in the appendix. You now have some experience with the gain box of this system and how it affects the system response. You will learn how it works in the last few weeks of this class. The motor and gears transfer function is beyond the scope of this class, although you may well be able to follow its derivation if you've had dynamics. You will learn more about these sorts of transfer functions in Mechatronics. The remaining transfer function you will find next. If you look back at the DC or Thevenin labs, you may be able to find the measurements that you need, and can skip taking new ones. Otherwise...

Find Kp, the transfer function of the potentiometers used as position sensors
The "INPUT POSITION" potentiometer translates shaft position into voltage. When the shaft is turned, the voltage on the center lead changes. Hook a voltmeter up to this center lead and circuit ground.

Measure the voltage at the two extremes of the potentiometer rotation. The potentiometer rotates about 270°. K_p is the change in volts per change in angle. Determine K_p as volts/deg and as volts/rad.

Conclusion
Conclude as always. As you've seen, very different kinds of systems can have similar characteristics.   That's why learning about transient electrical systems is worth your time and trouble. You will use similar tools to analyze other systems you may even care about.