Lab 3 Circuit Appendix

How to alter your previous circuit to be a lead, lag, or lead-lag controller instead

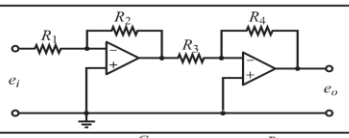
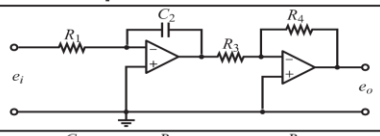
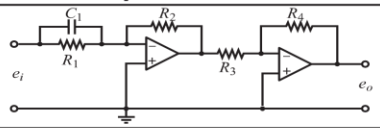
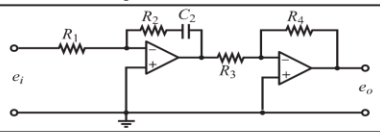
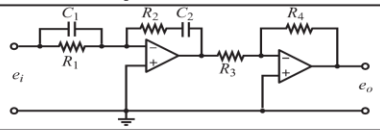
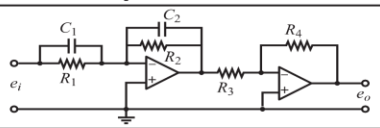
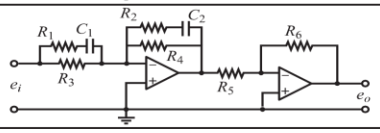
While the time crunch of lab 3 is daunting, this appendix hopes to make your lives much easier and save time when faffing with analogue circuits. Note again that this appendix is not to give you rules – feel free to stray from this guidance. If you want to use another approach, go for it.

Having made a proportional controller in lab 2, you'll be glad to know that you can just add a couple of capacitors to your circuit and have a PID (or Lead-lag or whichever variant you want to use) controller. With proper robust design around tolerances and reasonable gain values you should be able to go straight to Veroboard[1].

How to make a lag, lead, or lead-lag circuit

Using the proportional aspect of your opamp circuit (assuming you split the summing and proportion), you can alter your inverting (or noninverting) gain to any of the blocks in the nifty cheat sheet below to match the controller you've designed.

Table 3–1 Operational-Amplifier Circuits That May Be Used as Compensators

	Control Action	$G(s) = \frac{E_o(s)}{E_i(s)}$	Operational-Amplifier Circuits
1	P	$\frac{R_4}{R_3}\,\frac{R_2}{R_1}$	
2	I	$\frac{R_4}{R_3}\,\frac{1}{R_1C_2s}$	
3	PD	$\frac{R_4}{R_3}\,\frac{R_2}{R_1}\,(R_1C_1s+1)$	
4	PI	$\frac{R_4}{R_3}\,\frac{R_2}{R_1}\,\frac{R_2C_2s+1}{R_2C_2s}$	
5	PID	$\frac{R_4}{R_3}\,\frac{R_2}{R_1}\,\frac{(R_1C_1s+1)\,(R_2C_2s+1)}{R_2C_2s}$	
6	Lead or lag	$\frac{R_4}{R_3}\,\frac{R_2}{R_1}\,\frac{R_1C_1s+1}{R_2C_2s+1}$	
7	Lag–lead	$\frac{R_6}{R_5}\,\frac{R_4}{R_3}\,\frac{[(R_1+R_3)\,C_1s+1]\,(R_2C_2s+1)}{(R_1C_1s+1)\,[(R_2+R_4)\,C_2s+1]}$	

This sheet/table/image is taken from Modern[2] Control Engineering by Katsuhiko Ogata.

If you'd like to see the derivations of these circuits, they're available in the textbook these are taken from, from page 72 to page 85.

If you'd like this dated but useful textbook, I'd suggest buying it off Amazon or trying our library. Legally I cannot recommend sites such as this one, as these infringe on copyright.

[1] The word "should" depends on your analogue proficiency – if you're confident your old Veroboard works as intended then the upgrade will hopefully save time (instead of building a new circuit)

[2] Alas, it was published in 1970 and does not include digital control.