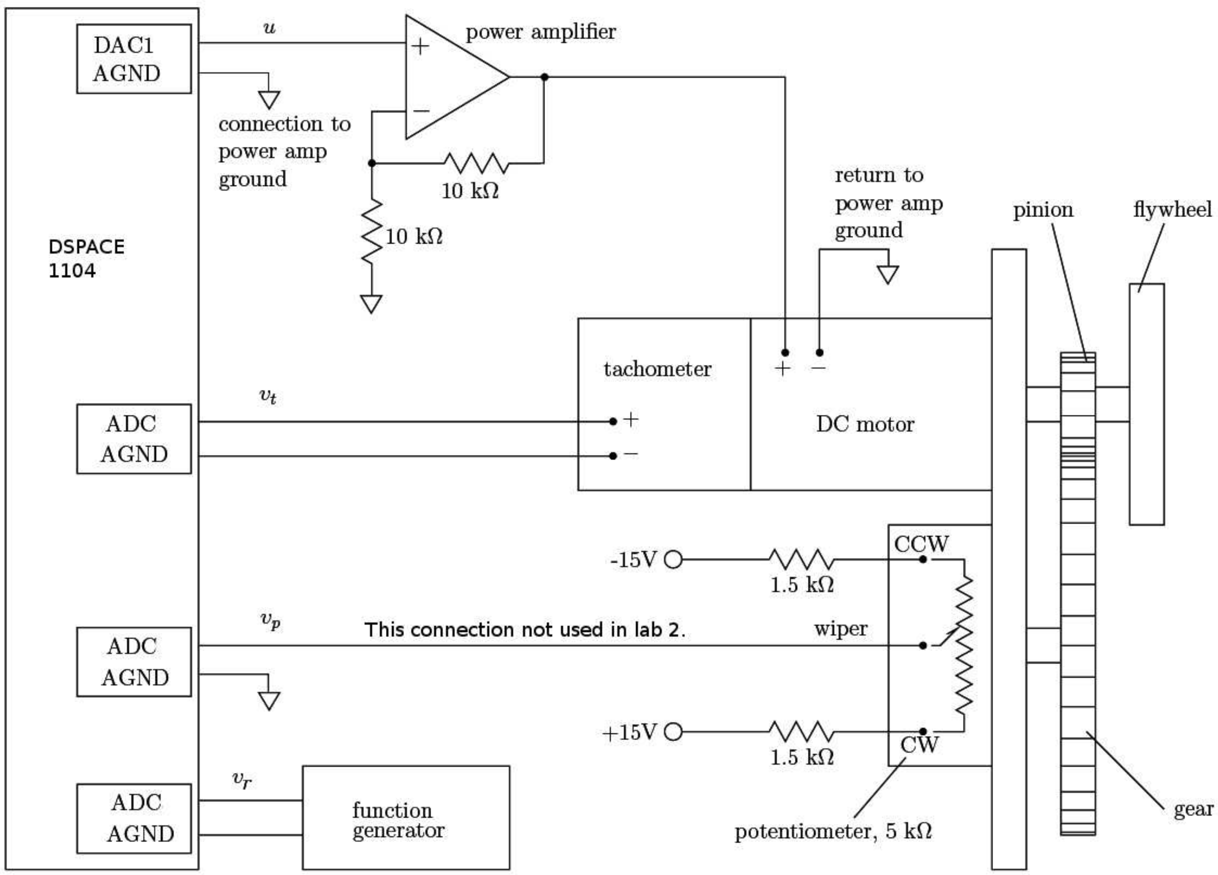
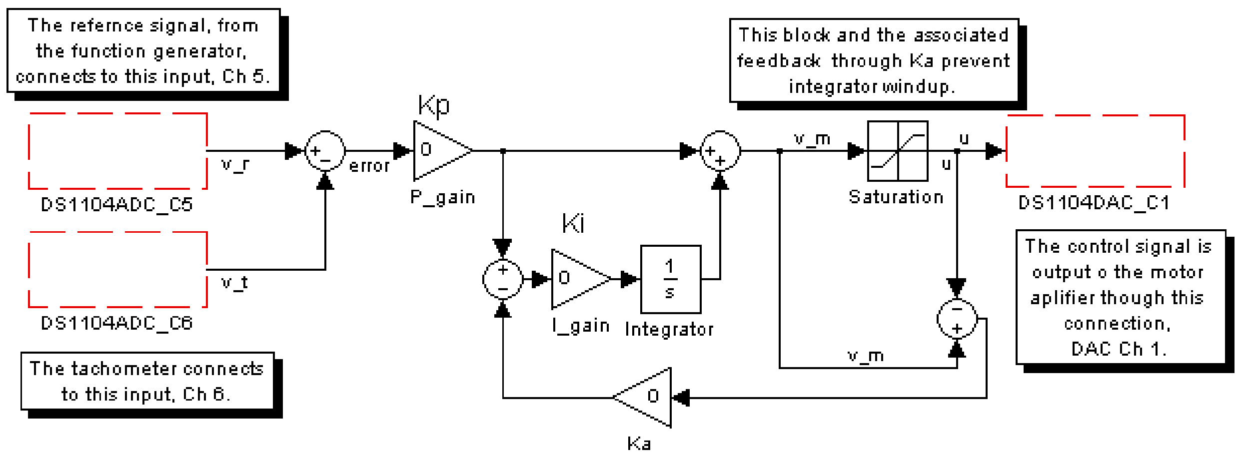
2.140: Week of 3/12
2.14: Week of 3/19



In this lab, we implement a speed controller for a DC motor. A tachometer connected to the motor shaft provides the feedback signal v_t proportional to velocity, and the function generator provides the "reference" voltage v_r. A schematic of the system is shown above, including the power op-amp that drives the motor. The motor parameters are:

R	7.5	Ω	armature resistance
L	5.55	mH	armature inductance
K_T	0.024	N·m/A	torque constant
J	1.5×10^{-5}	kg·m^2	total inertia of motor and payload
K_v	0.023	V/(rad/sec)	tachometer constant

The controller is implemented in dSpace as illustrated in the block diagram on the following page. This controller and a GUI that allows you to vary system parameters will be provided in lab.



The difference between the reference voltage v_r and the tachometer signal v_t is an error signal, on which the controller acts to produce the motor command u.

At the output of the controller is a saturation block; this nonlinear element is used to prevent integrator windup. If the input v_m to the saturation block is below the saturation limit v_s—a voltage that we choose—then the motor command u is equal to v_m, and the feedback branch through K_a has no effect. But if the input v_m exceeds v_s, then u is set equal to v_s and the feedback branch through K_a acts to limit the integrator. For the analysis in this prelab, we assume that v_m stays below the limit v_s and ignore the feedback branch though K_a.

1. Unless we plan to operate the system at very high frequencies, we can neglect the motor inductance. Under this assumption, show that the transfer function from amplifier input u to tachometer output v_t is
$$\frac{v_t}{u} = \frac{2K_v}{K_T(\tau_m s + 1)} \tag{1}$$
where K_v and K_T are as given above and $\tau_m = JR/K_T^2 \approx 200$ ms is the mechanical time constant. (Assume that the power op-amp behaves ideally.)

2. If we set K_i to zero, we have a proportional controller. Choose a value of K_p that results in a time constant of 0.05 seconds. Sketch the response of velocity siganl v_t to a step in the reference voltage v_r. Also sketch the command signal u. Do you expect there to be a steady-state error? What happens as the gain K_p is increased?

3. Next, design a proportional plus integral controller (i.e., choose K_p and K_i) to make the closed-loop system have a 10-90 rise time of 60 ms and an overshoot of 15%; for this system, this is equivalent to requiring that $\omega_n \geq 30$ rad/sec and $\zeta \geq 0.5$.

4. The integrator in a control system can accumulate large values if the system runs against a limit. Therefore, in practice, we limit the integrator using an "anti-windup" scheme. Please read the handout on this topic posted on the course web page before coming to lab. We will experiment with windup in lab.