Lecture 3 – Part 2

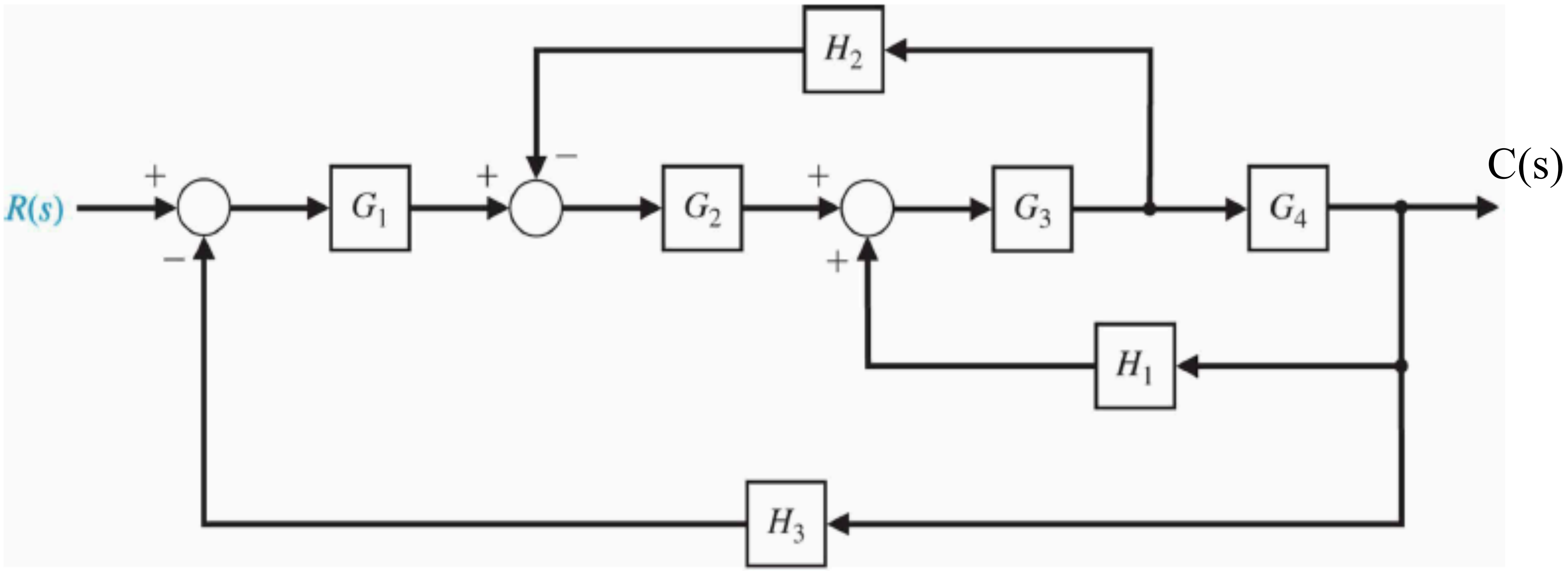
Block Diagrams

- Block Diagram Reduction
- Electromechanical Design Example

Block Diagram Reduction

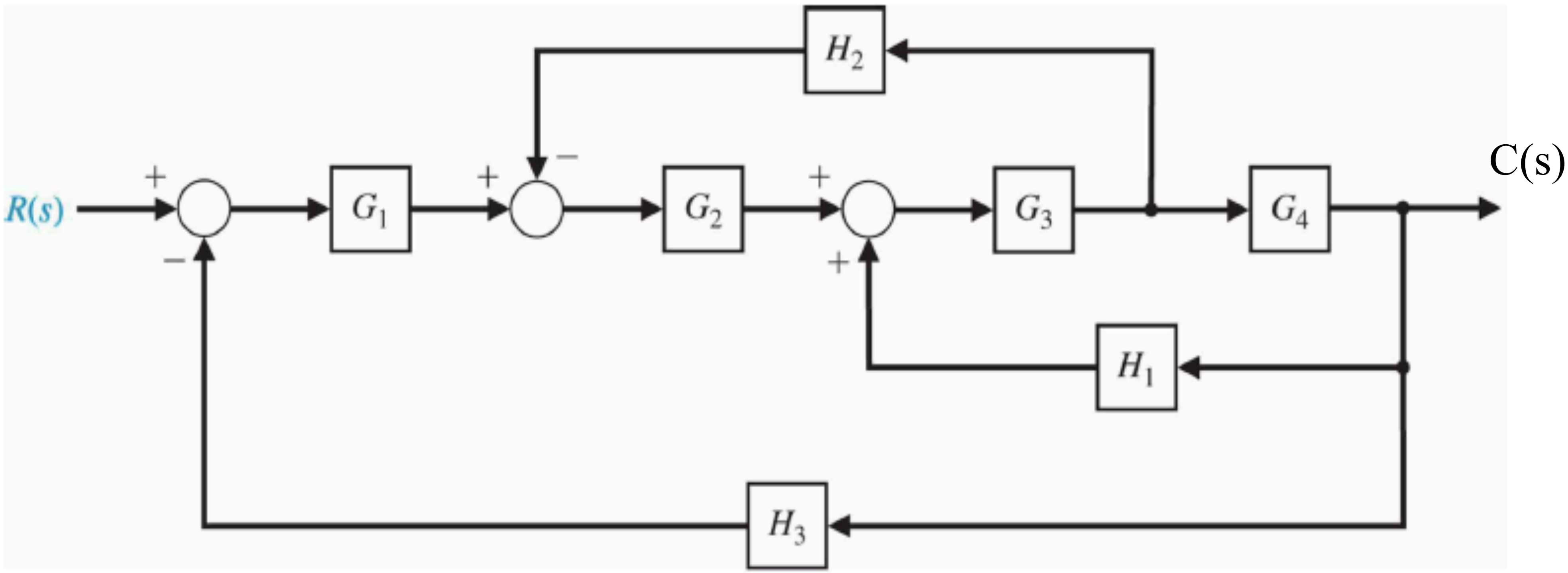
This is where we follow logical procedures to reduce the complexity of a block diagram to it's lowest level (see rules on slide 3 for reference).

Here is a multiple loop feedback control system. There are three separate feedback loops. Two are negative, one is positive.



The positive feedback signal is $H_1(s)C(s)$, so the loop $G_3(s)G_4(s)H_1(s)$ is a positive feedback loop.

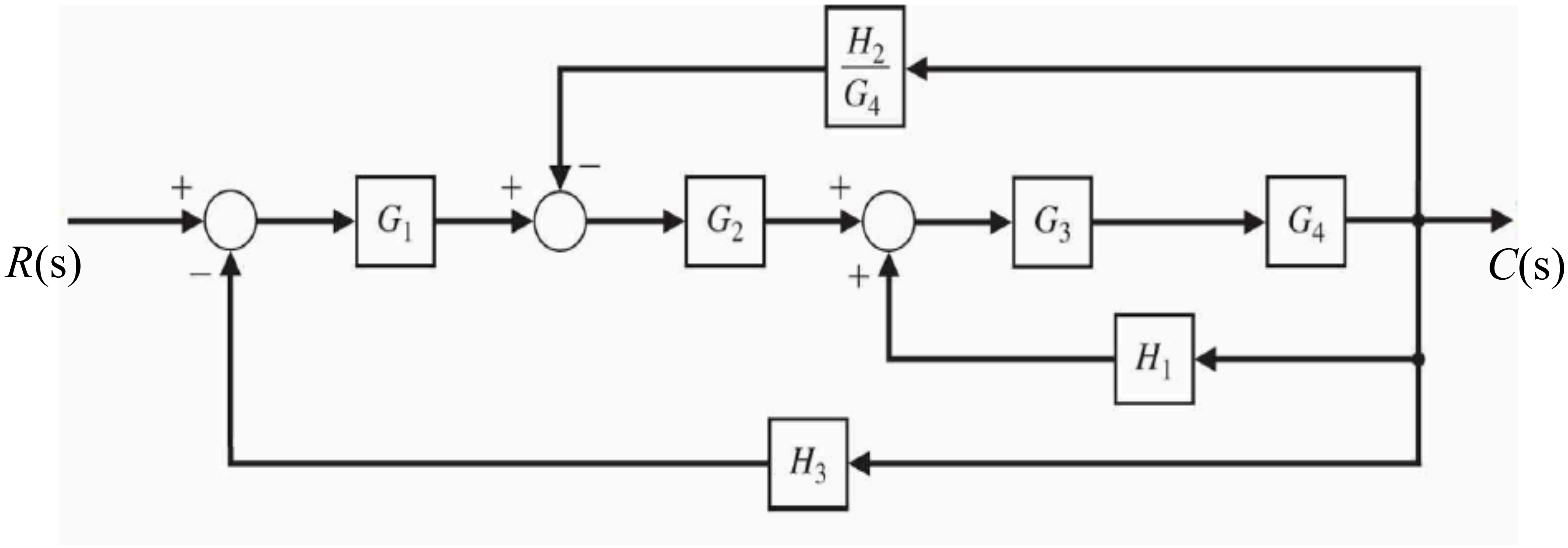
We go back to slide 3 and find a useful rule – rule 6 – which allows us to eliminate feedback loops using the generalised overall transfer function.



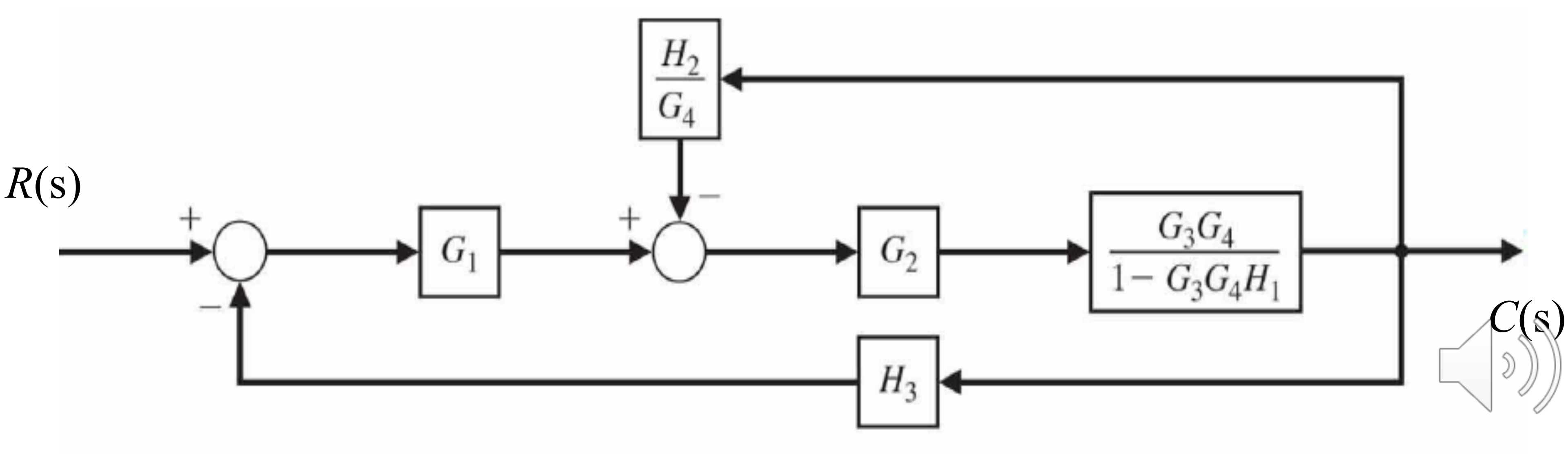
In order to eliminate the positive feedback loop we need to do something about the line that drives H_2(s). This is very easy. We simply move the feed from between G_3(s) and G_4(s) to behind G_4(s), and divide H_2(s) by G_4(s) to compensate. This is rule 4 on slide 3.

We can then combine G_3(s) and G_4(s) into one transfer function G_3(s)G_4(s), and then we have what we need to apply rule 6.

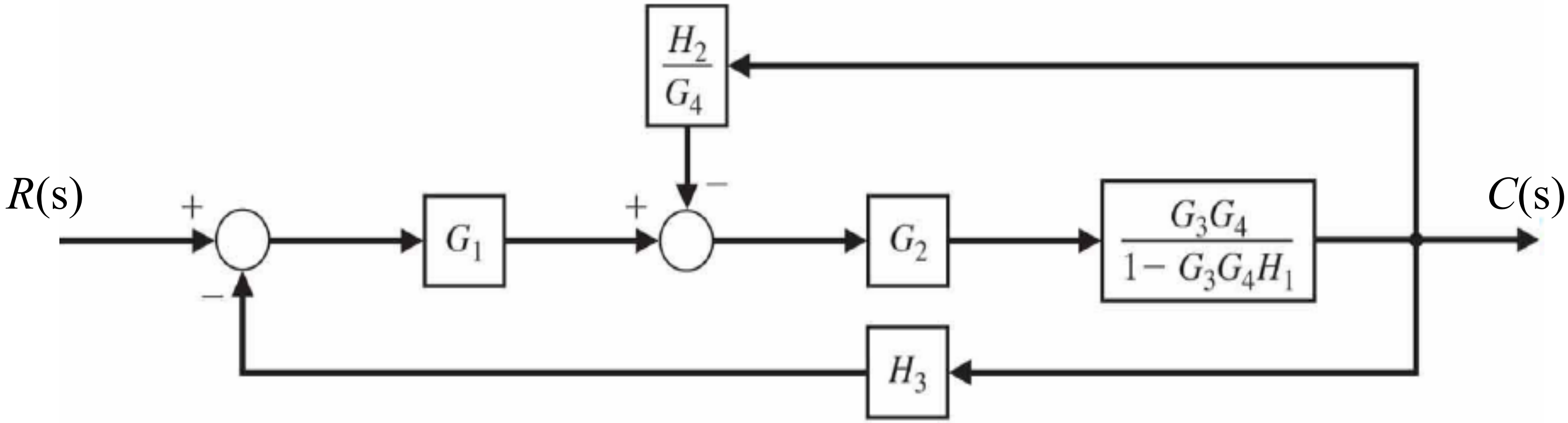
So, moving the feed point behind G_4(s) first of all …



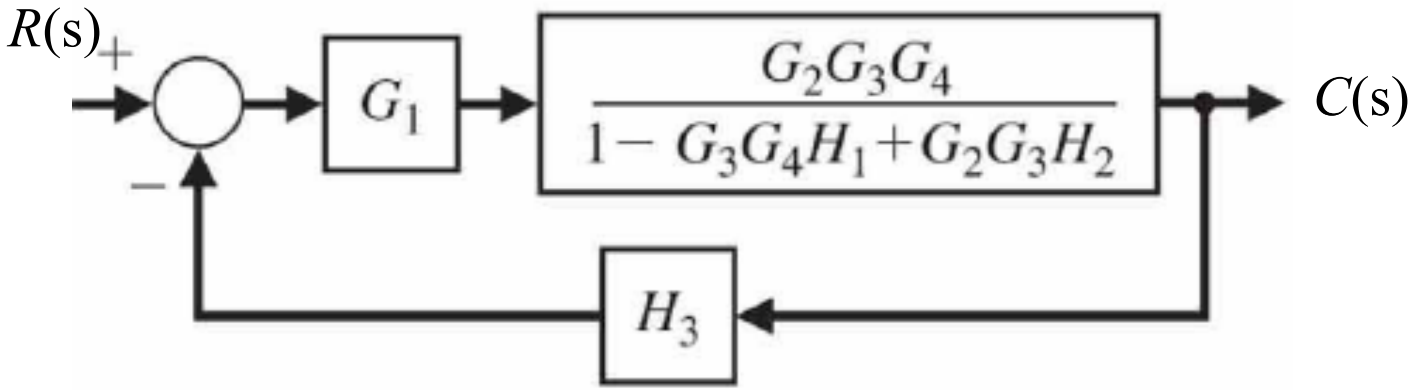
Having done this we can now combine G_3(s) and G_4(s) into one transfer function G_3(s)G_4(s) and then apply rule 6 to get this:



Repeating the previous diagram:



Applying rule 6 again, this time to the upper feedback loop reduces the system down to this:



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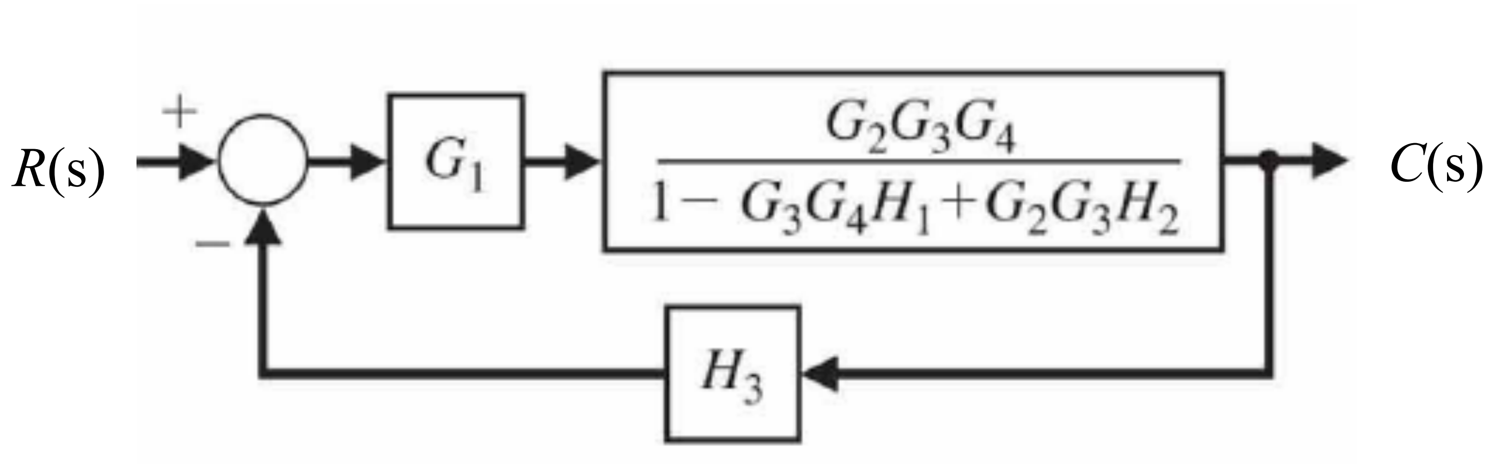
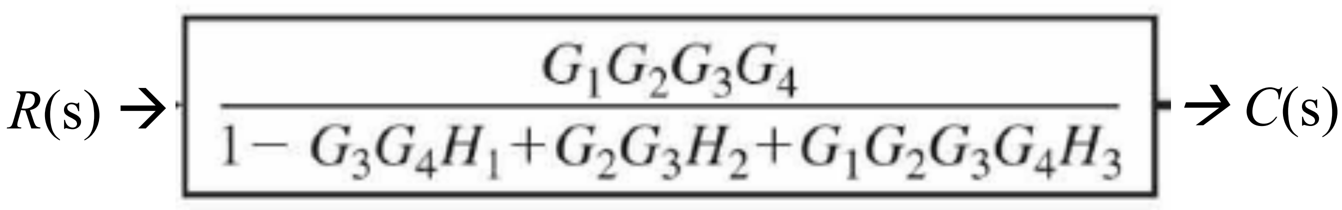
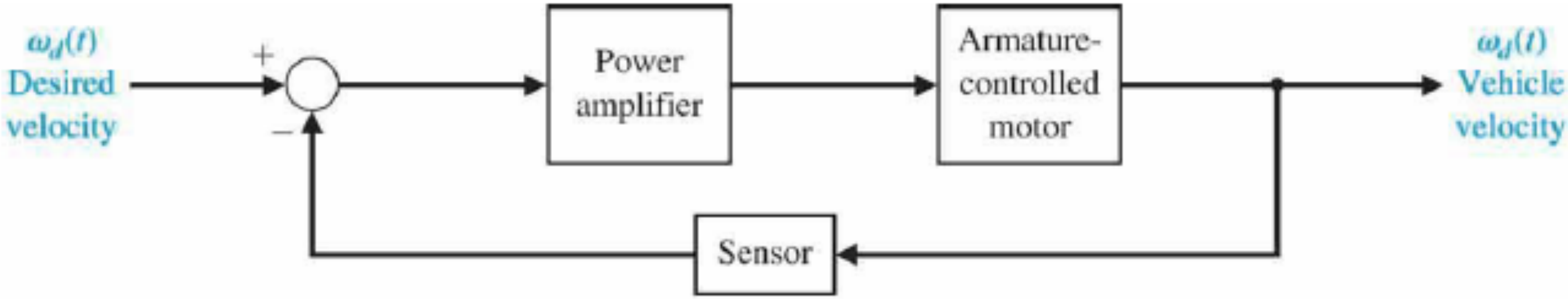


Applying rule 6 for a third time finally reduces the system down to its lowest level of complexity:



You can see that the denominator shows the two negative feedback loops (+ve terms) and the single positive feedback loop (-ve term). There is a limit to the practicality of this technique for really complex systems, but it can be very useful for systems of medium complexity. Very big systems need *Signal Flow Graph* analysis.

Design Example – Train Traction Motor Control



This is the functionality that we need for controlling the armature controlled DC traction motor of a typical train. The requirement is to obtain the block diagram for the control system.

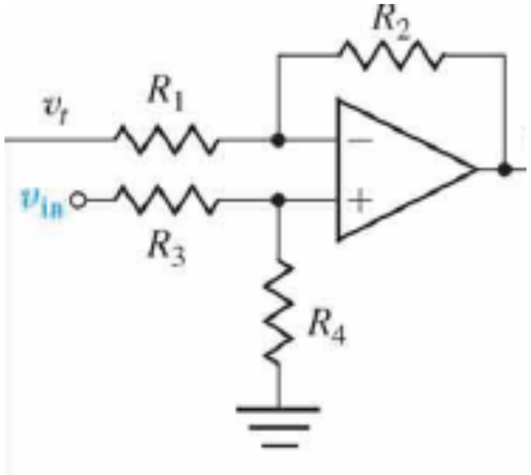
We start this off by using our knowledge of such plant to identify typical technology that could implement the functions in the diagram.

The armature controlled DC motor has its own negative feedback loop controller, which we can implement directly. The sensor will be a tachometer which generates a voltage that is linearly proportional to velocity, and the power amplifier will almost certainly be a differential pre-amplifier with a nonlinear power output stage – which we will be able to linearise on the basis that we will not overdrive it electrically.

The input to the power amplifier is voltage V_1 and the output is voltage V_2. Linearisation of the amplifier gives a useable voltage gain of 540 (typical) so the transfer function for the power amplifier is

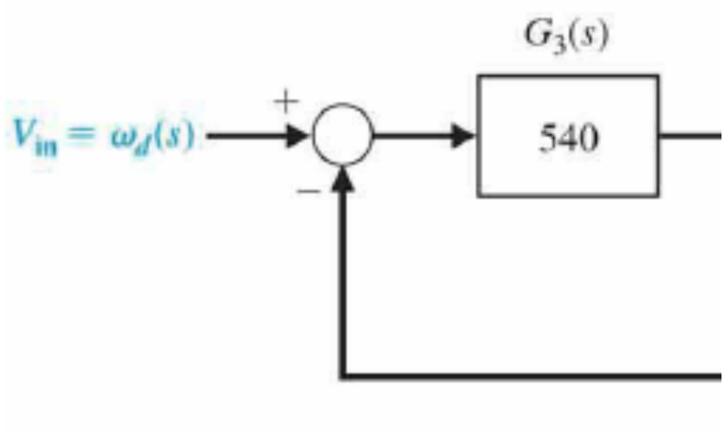
$V_2 = 540\ V_1$.

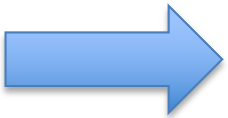
The differential pre-amplifier could well look like this electrically:



Conventional electronic design principle can be used to define the voltage gain characteristic of the amplifier and the values of the resistors needed to get stable operation and an output that is the exact difference between the input V_{in} and the tachometer output V_{t}.

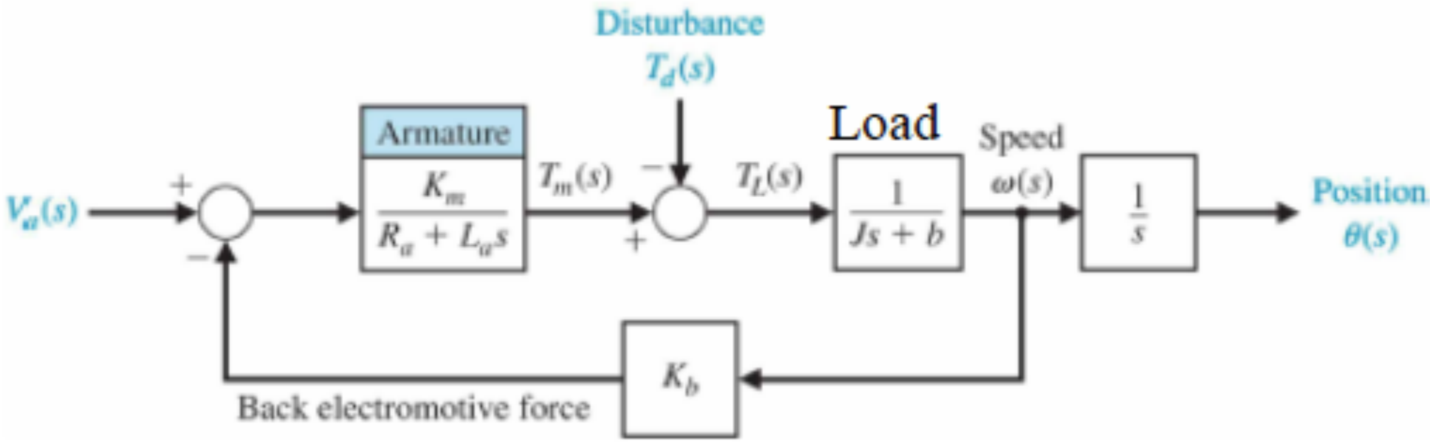
This deals with the sensor (tachometer), the power amplifier, and the differential pre-amplifier (the summing junction where the feedback signal is subtracted from the input signal). This means we have part of the block diagram …





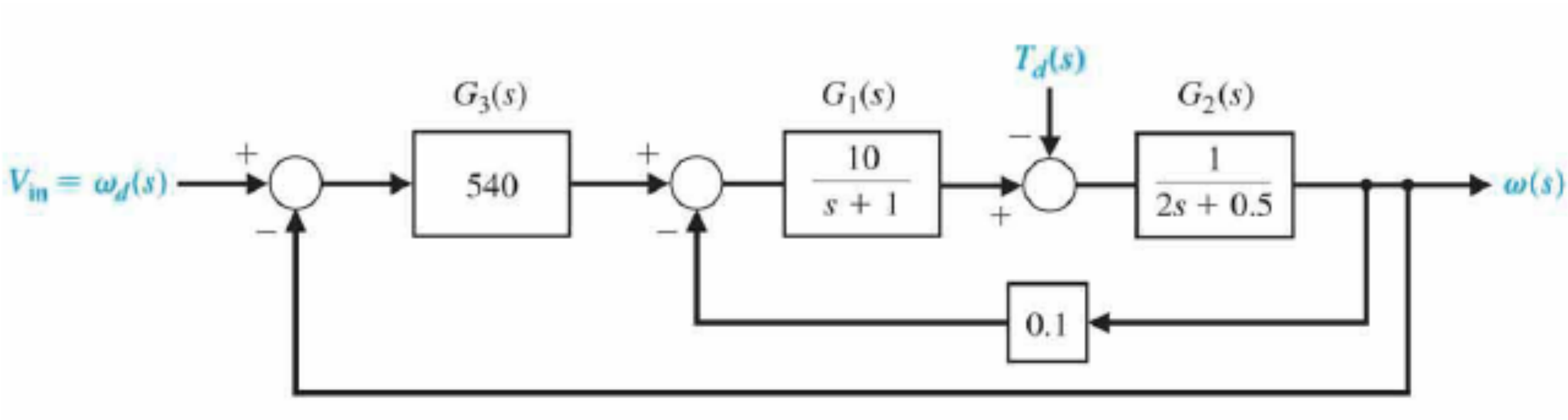
This feeds the necessary block diagram for the armature controlled DC motor. We can use the system that we evolved in Tutorial 2.

The output from G_3(s) feeds in here



The parameters that we need for the armature, load, and K_b blocks can be obtained from an appropriate traction motor supplier. We take typical values as follows:

$$K_m = 10 \qquad J = 2$$
$$R_a = 1 \qquad b = 0.5$$
$$L_a = 1 \qquad K_b = 0.1$$



We will examine this further, later, in order to explore the likely response behaviour of this speed controller. Computer simulations of control systems are extremely useful, because:

- System performance can be observed under all possible conditions
- Real system performance can be extrapolated to test extreme cases without damage to expensive plant
- System trials can be completed much more quickly using simulations
- Computer simulations are much cheaper than real system trials.

Class exercise 1:

Active suspension system for an off-road vehicle

Off-road vehicles experience major disturbances as they traverse rough terrain. A useful active suspension system can be built on the basis of a sensor that 'looks ahead' at the road conditions. Define the bump disturbance by T_d(s), the desired deflection by R(s), and the output (the bounce displacement of the vehicle) by C(s), and the transfer function for the vehicle dynamics as G(s). Then try to draw a block diagram for the active suspension system as a control system.

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