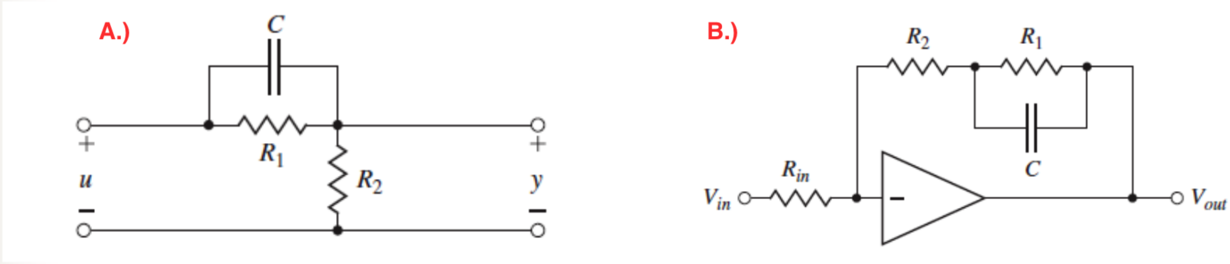
- Q1: Read the paper and write a summary (a minimum of half a page) to describe what you have learned from it. (20 points)

Stuart Bennett, "Brief History of Automatic Control," IEEE Control Systems Magazine, Vol. 16, No. 3, June 1996

After reading *Brief History of Automatic Control*, by Stuart Bennett, I was introduced to an analysis of the progression of advancements made towards automatic input feedback control systems over four main time periods that encompassed major breakthroughs in the functionality of these systems, being Early Control (<1900), the Pre-Classical Period (1900-1940), the Classical Period (1935-1960), and Modern Control (>1955). Much of the article emphasized mechanisms that were used in each time period that signified an improvement in the automatic control systems used. In Early Control, thermal control was a topic of focus that sparked interest in the field of feedback-based systems in the later 18th century. This was in light of the invention of the steam engine governor by James Watt in 1788, which provided the ability to handle the speed of early steam engines and forged a method to prevent the system from overworking itself if speeds got too fast. However, with this breakthrough, came many flaws and areas of improvement. For instance, the governor "provided only proportional control and hence exact control of speed at only one operating condition," which resulted in it being labeled as a moderator, rather than a governor. Over the years, improvements upon this design were worked on, with the goal being to transcend beyond the control barriers of Watt's strictly integral design. In the mid 19th century, Charles T. Porter and Thomas Pickering invented derivations of Watt's initial design that could be utilized at higher speeds, and provide more real-world practicality. In the years leading up to these inventions, research was simultaneously performed on how dynamic motion of the governor could be described using differential equations, but both met difficulties when they attempted to determine the conditions for stable behavior. In the late 19th century, James Clerk Maxwell was able to obtain sufficient stability conditions for differential equations that represented mechanical governors up to the fourth order, which provided significant support in the applications that were done to improve temperature, pressure and fluid stability to mechanical systems, as they continued to increase in size. With this, the need for emphasis on closed-loop systems became apparent, and near the end of the 19th century, the breakthrough invention of the servo motor was brought by Jean Joseph Fareot, while working to design a range of steering engines and other closed-loop position control systems. This marked the end of the Early Control era, with the future of control systems becoming heavily influenced by closed-loop systems as the Pre-Classical Period began. This period offered a wide range of measuring, indicating, and recording devices, but toward the end of the period the use of controllers began to increase, as systems became more complex. With controllers being widely popularized, regulation was a new area of interest. A notable invention was the automatic ship-steering mechanism devised by Elmer Sperry that incorporated PID control and automatic gain adjustment to compensate for the disturbances caused when the sea conditions changed. With most devices in this time period being designed without any clear understanding of the dynamics of the system to be controlled and of the measuring and actuating devices used for control, the Classical Period was sprung into effect, which sparked an interest in understanding control system analysis and design. With a more in-depth understanding of control system design, many possibilities were available, as the electric age began to arise. This was especially true with wireless communication, where efforts by AT&T and Bell Labs were made to work on a better balance between the gain of wanted signals and the attenuation of unwanted signals. While there had proved to be challenges, it brought up the importance of negative feedback in a system, as it played an equally important role as positive feedback when it came to an effective balance. The incorporation of block diagrams allowed for more complex systems to be modeled, as the modern era approached. Modern Control has been heavily influenced by the invention of the digital computer. With such an advanced machine, more focus was placed on digital applications of control theory, as electrical components became more confined and the demand for precision increased. The focus was shifted towards multivariable control problems and multivariable feedback filtering, where feedback theory focused around communications and signal processing. It has become evident that control theory applications have yet another target: the online world. While it began as a purely physics-based application, it has proven to be an important part of maintaining proper functionality of engineered systems to continue keeping up with technological advancements, and any flaws that come with such advancements.

Q2: For the two circuits shown below (50 points)



- 1: Write the dynamic equations and find the transfer functions.

A.)

Cs^{-1} and R_1 are in parallel: $\frac{\frac{R_1}{Cs}}{R_1+Cs^{-1}} = \frac{R_1}{1+CsR_1}$

Equate voltage of u(s) and y(s): $y(s) = u(s)[\frac{R_2}{R_2+\frac{R_1}{1+CsR_1}}] = u(s)[\frac{R_2+CsR_1R_2}{R_2+R_1+CsR_1R_2}]$

Transfer function (output/input): $\frac{y(s)}{u(s)} = \frac{R_2+CsR_1R_2}{R_2+R_1+CsR_1R_2}$

B.)

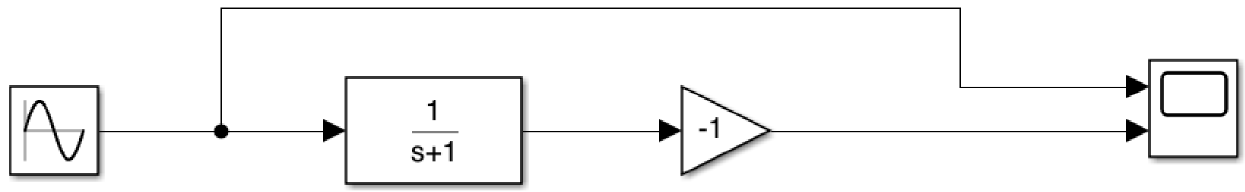
Cs^{-1} and R_1 are in parallel: $\frac{\frac{R_1}{Cs}}{R_1+Cs^{-1}} = \frac{R_1}{1+CsR_1}$

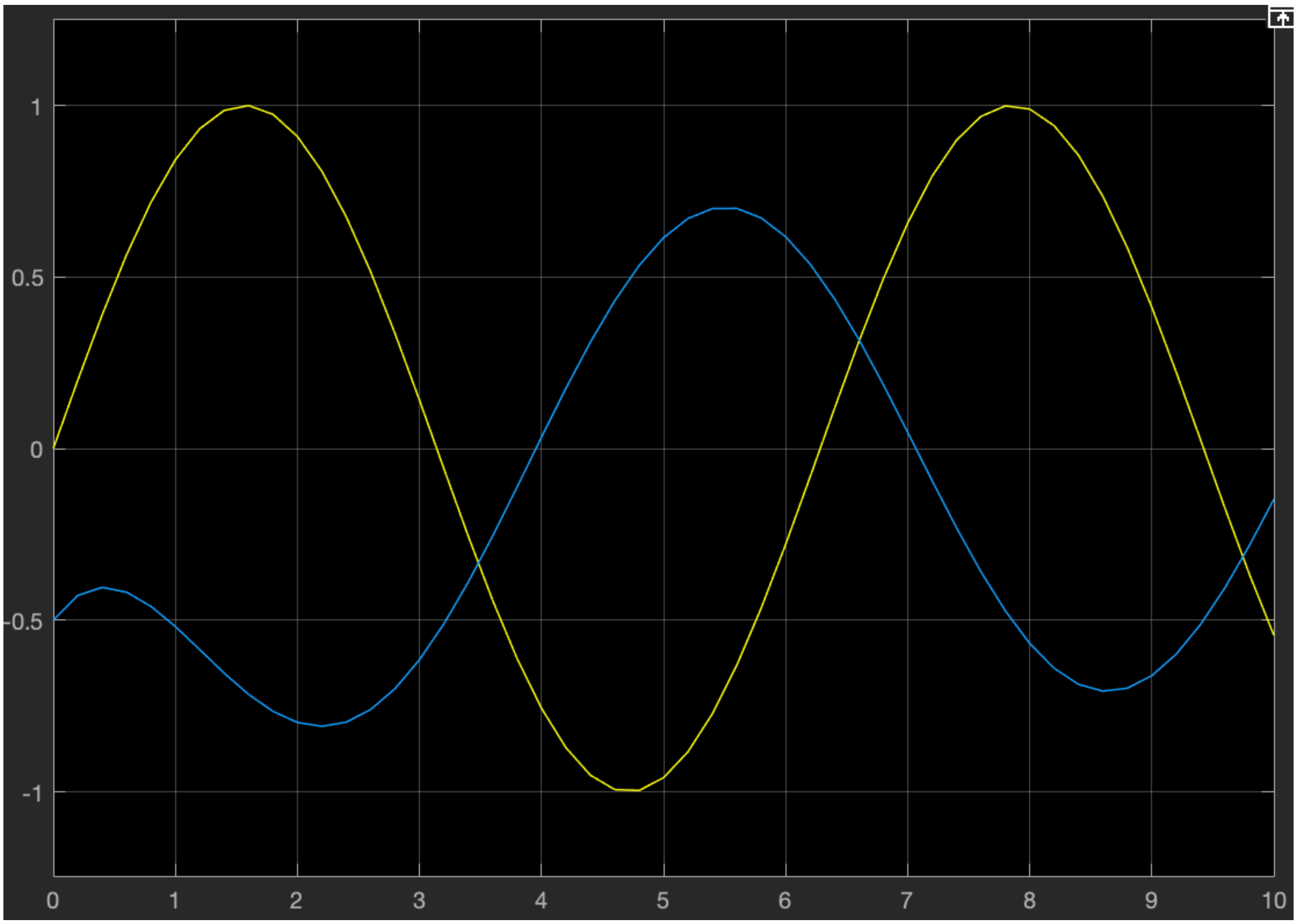
Use nodal analysis: $\frac{V_1-V_{in}}{R_{in}} + \frac{V_1-V_{out}}{R_2+\frac{R_1}{1+CsR_1}} = 0$ where $V_1 = 0$: $\frac{-V_{in}}{R_{in}} = \frac{V_{out}}{R_2+\frac{R_1}{1+CsR_1}}$

Transfer function (output/input): $\frac{V_{out}}{V_{in}} = \frac{-(R_2+\frac{R_1}{1+CsR_1})}{R_{in}}$

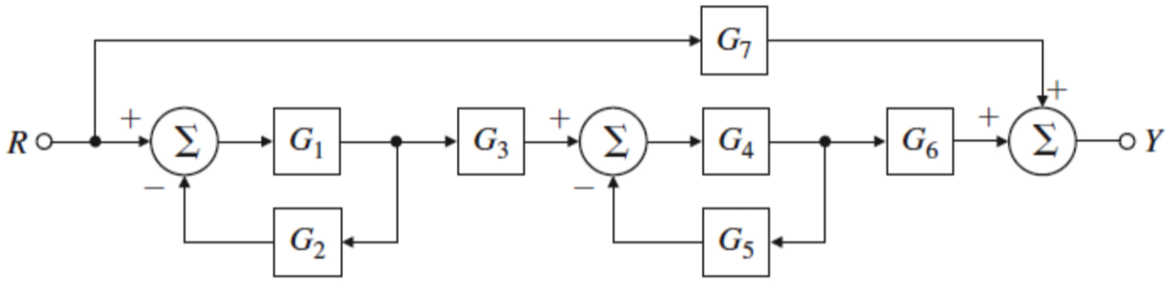
- 2: draw a Simulink block diagram and the time response of the second circuit, with $R_1 = R_2 = R_{in} = C = 1$, $v_{in} = \sin(t)$, $v_{out}(0) = 0$.

Transfer function (output/input): $\frac{V_{out}}{V_{in}} = \frac{-(R_2+\frac{R_1}{1+CsR_1})}{R_{in}} = \frac{-((1)+\frac{(1)}{1+s})}{(1)} = -(1+\frac{1}{1+s})$


1
s+1
-1


1
0.5
0
-0.5
-1
0
1
2
3
4
5
6
7
8
9
10

Q3: Find the transfer function for the below block diagram (30 points)



G_1 and G_2 are in a feedback loop: $\frac{G_1}{1+G_1G_2}$

G_4 and G_5 are in a feedback loop: $\frac{G_4}{1+G_4G_5}$

Becomes:

Top -> G_7

Bottom -> $\frac{G_1}{1+G_1G_2}$ ~ G_3 ~ $\frac{G_4}{1+G_4G_5}$ ~ G_6

Bottom can be simplified by multiplying all terms together:

$$\frac{G_1}{1+G_1G_2} \times G_3 \times \frac{G_4}{1+G_4G_5} \times G_6 = \frac{G_1G_3G_4G_6}{(1+G_1G_2)(1+G_4G_5)}$$

Combine top and bottom by adding:

$$\frac{G_1G_3G_4G_6}{(1+G_1G_2)(1+G_4G_5)} + G_7 = \frac{G_7(1+G_1G_2)(1+G_4G_5) + G_1G_3G_4G_6}{(1+G_1G_2)(1+G_4G_5)}$$

Transfer Function:

$$\frac{Y}{R} = \frac{G_7(1+G_1G_2)(1+G_4G_5) + G_1G_3G_4G_6}{(1+G_1G_2)(1+G_4G_5)}$$