SIMON FRASER UNIVERSITY

SCHOOL OF ENGINEERING SCIENCE

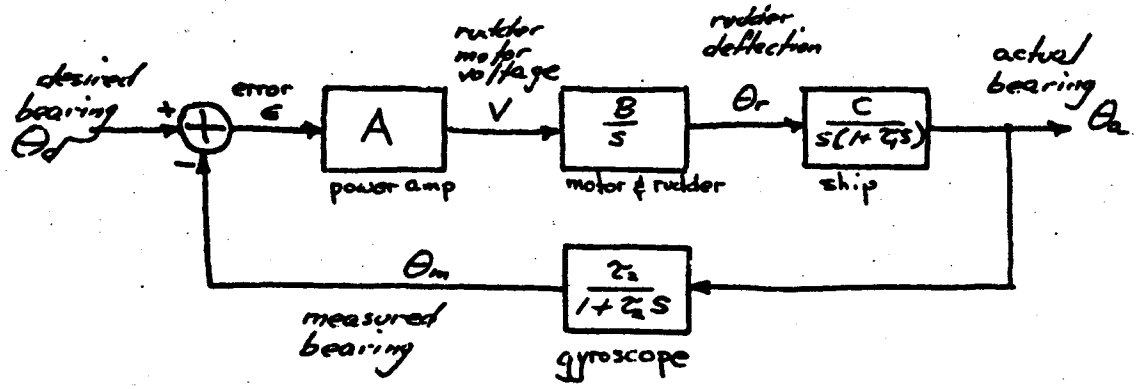
ENSC 380 LINEAR SYSTEMS

NOTES ON BLOCK DIAGRAM SIMPLIFICATION

1. INTRODUCTION

Engineers make complicated systems work. Since the design of such systems is difficult, many techniques have been devised to simplify the analysis and communication of the results. One such technique is the block diagram.

In the block diagram, component subsystems are represented by blocks, each containing the transfer function of that component. The interaction between the subsystems is depicted by lines, along which flow the variables. This gives a structural description of the system to accompany the equations, making visualization of the behaviour easier. A typical block diagram is shown below.



An Inertial Guidance System

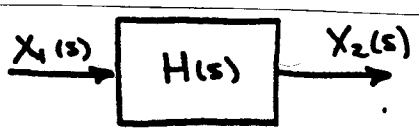
Once the block diagram is obtained, the next step is to obtain the system transfer function from those of the subsystems. That's the process these notes address. Section 2 describes the elements of a block diagram and Section 3 contains the basic manipulation rules. Section 4 contains several examples of block diagram reduction to a single transfer function.

Obtaining the block diagram of a system in the first place is a more difficult problem. It is dealt with elsewhere in the course.

2 ELEMENTS OF A BLOCK DIAGRAM

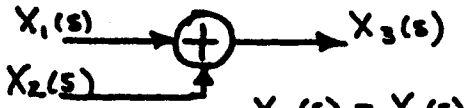
Block diagrams contain the three structural elements illustrated below.

Subsystem block:



$$X_2(s) = H(s)\,X_1(s)$$

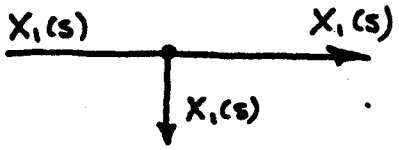
Summing junction:



$$X_3(s) = X_1(s) + X_2(s)$$

A negative sign beside the junction indicates subtraction.

Pickoff point:



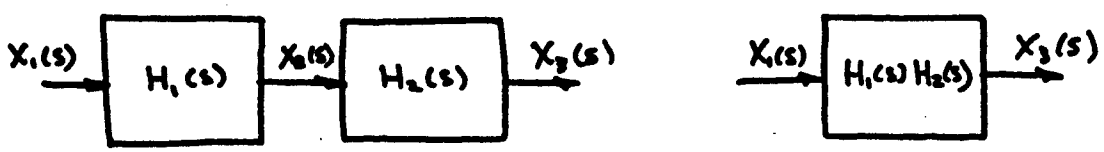
3. BLOCK DIAGRAM MANIPULATIONS

This section describes ways to transform a block diagram into an equivalent one. This is normally done in order to simplify the diagram, with the ultimate objective of obtaining a network of only one block containing the system transfer function.

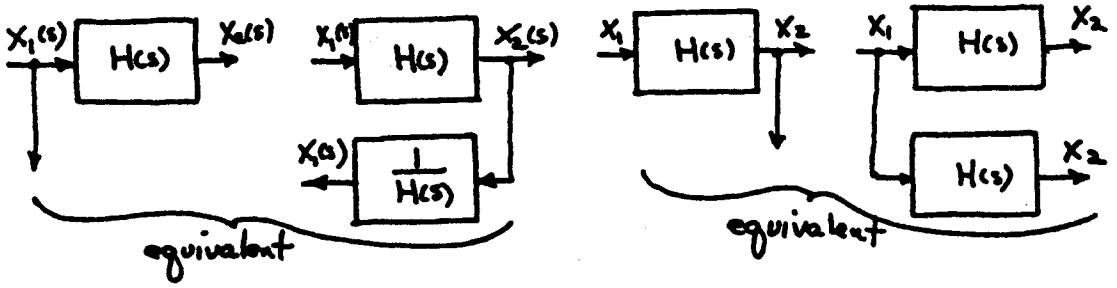
The various operations shown below – shifting pickoff points, collapsing loops and so on – are simply pictorial representations of algebraic operations. In other words, in simplifying a block diagram, you are solving a set of linear equations.

In performing the transformations below, you simply make sure that the system behaviour is the same before and after.

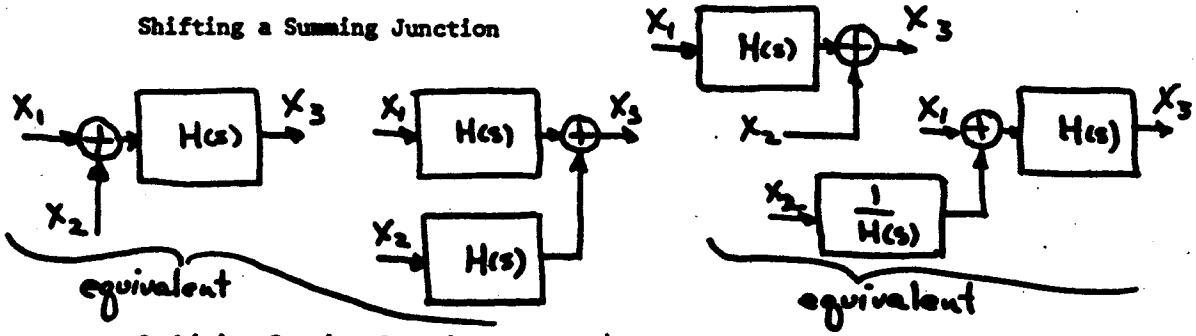
Combining Blocks



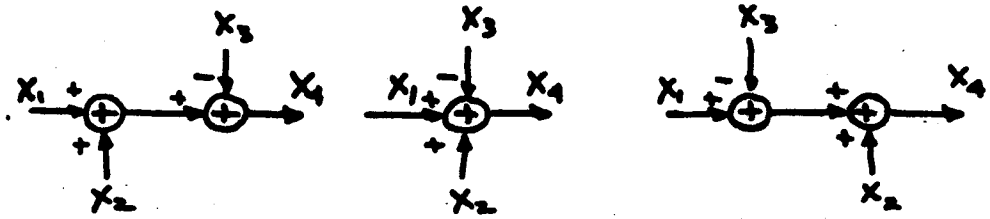
Shifting a Pickoff Point



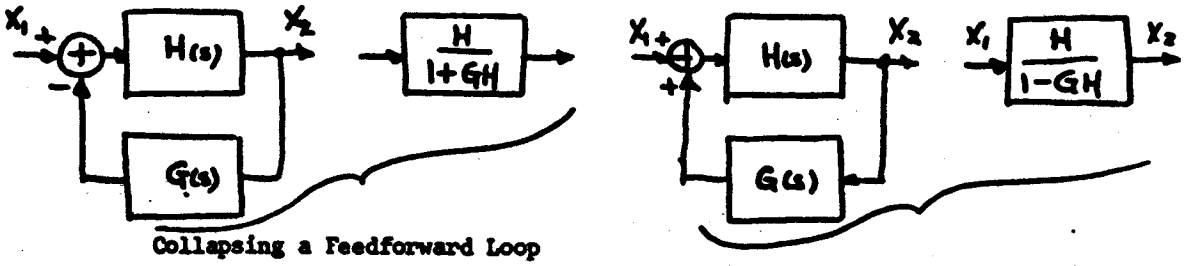
Shifting a Summing Junction



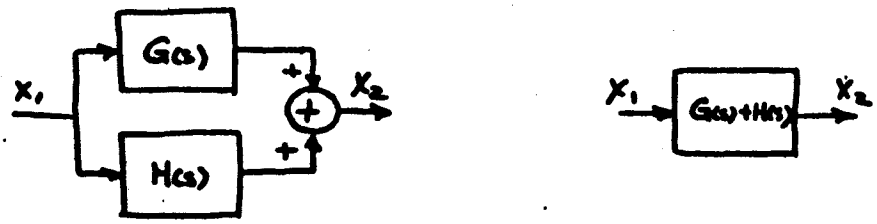
Combining Summing Junctions



Collapsing a Feedback Loop



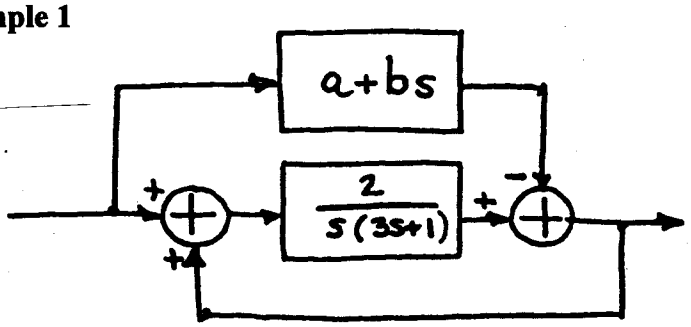
Collapsing a Feedforward Loop

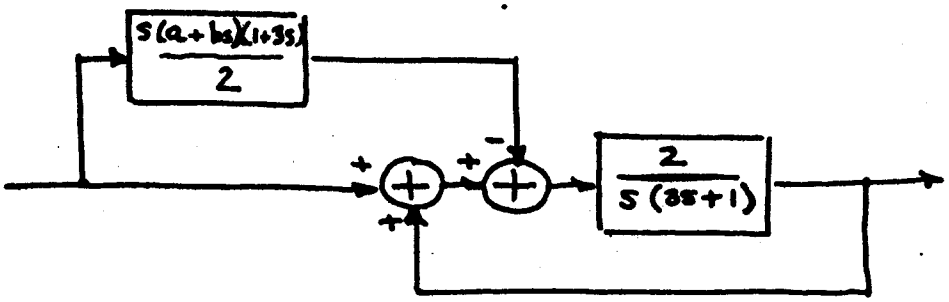


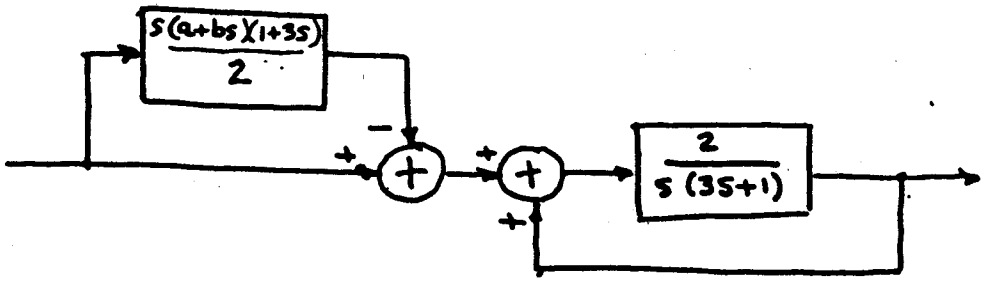
4. SELECTED EXAMPLES

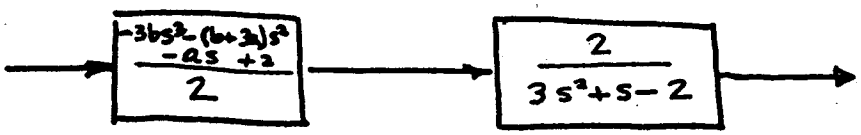
The strategy in reducing these diagrams is first to decouple loops, if necessary, then collapse them. Experience is the best guide, so practice is advisable.

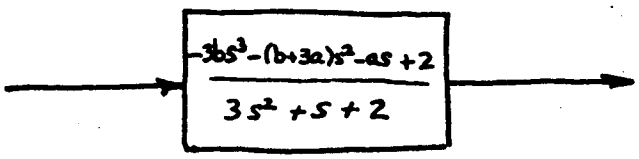
Example 1



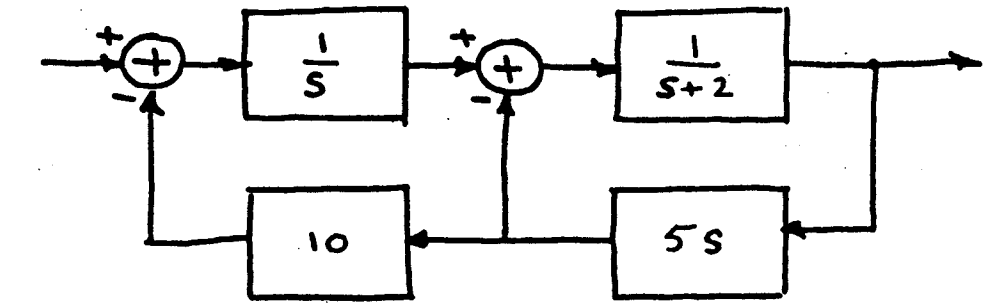


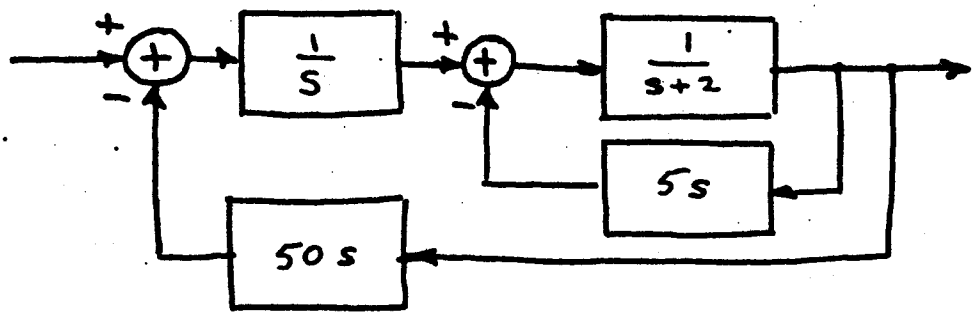


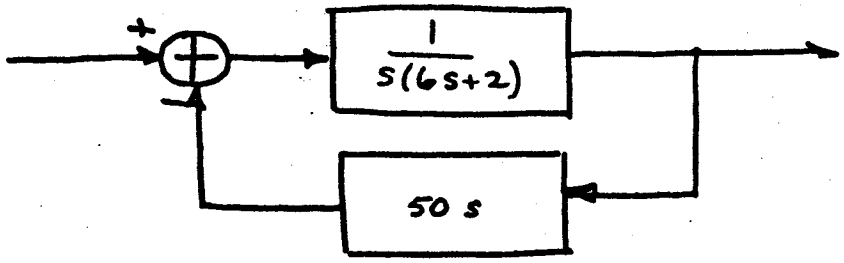


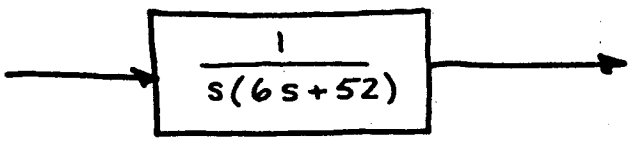


Example 2

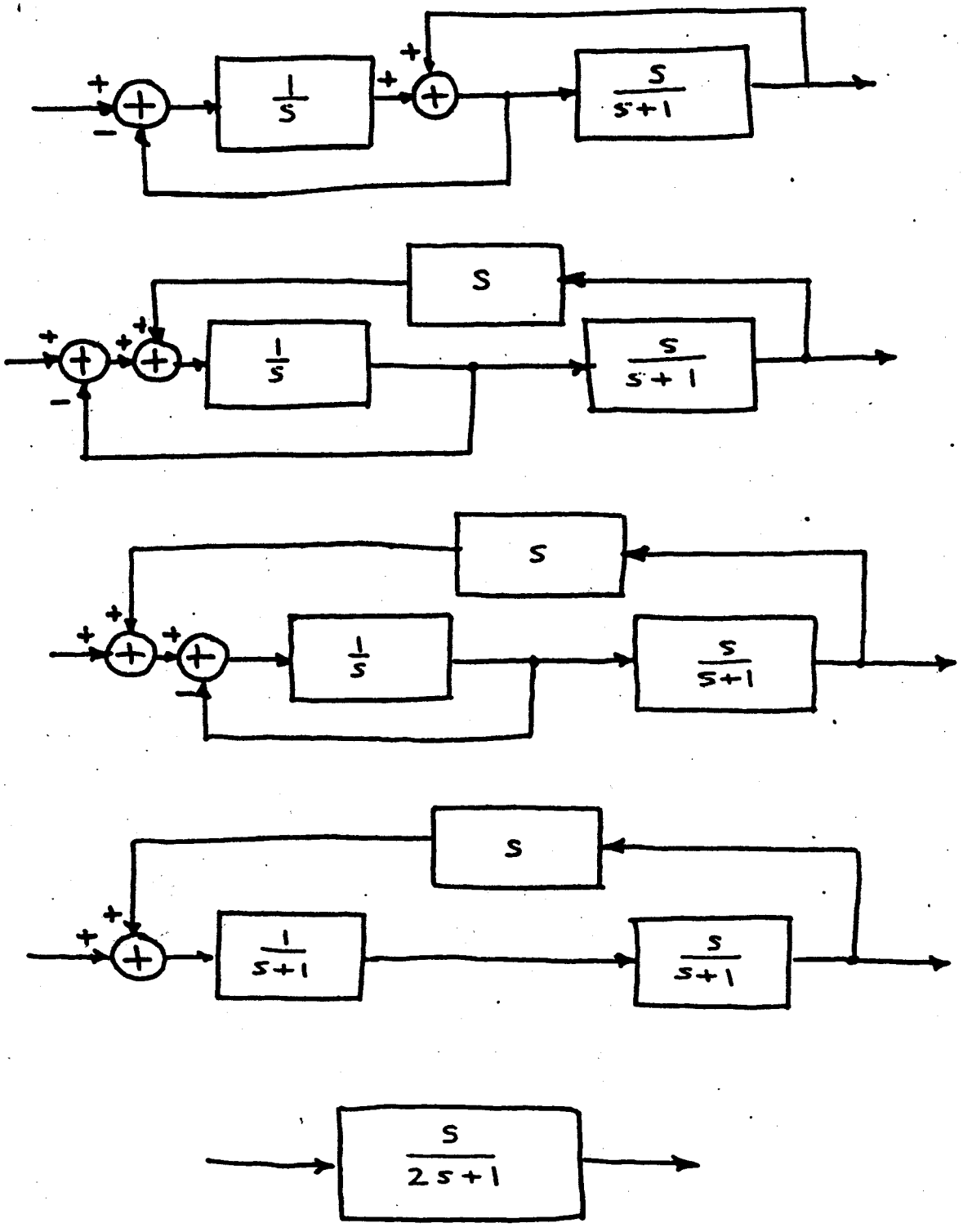




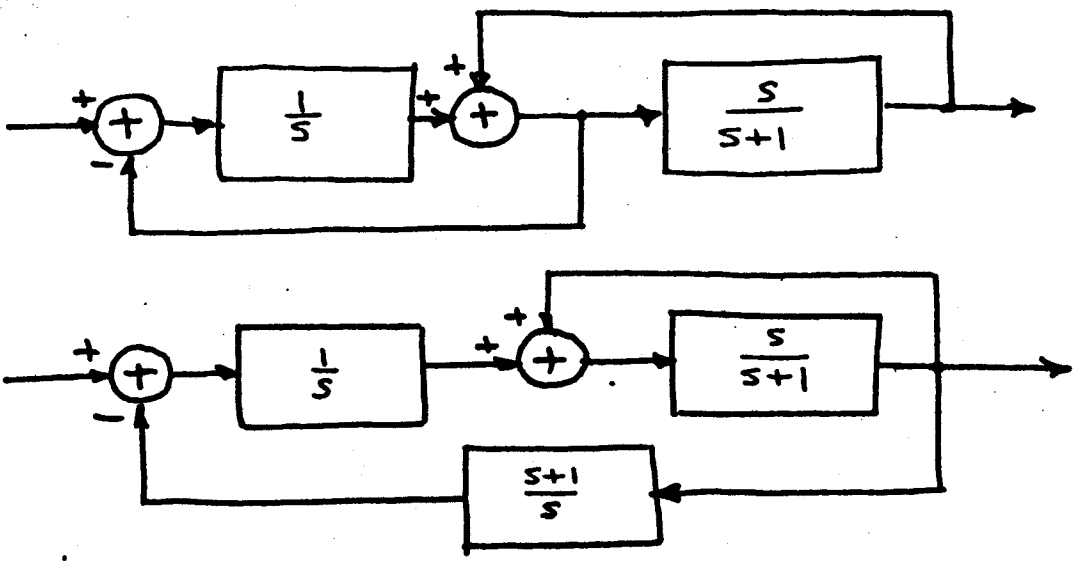


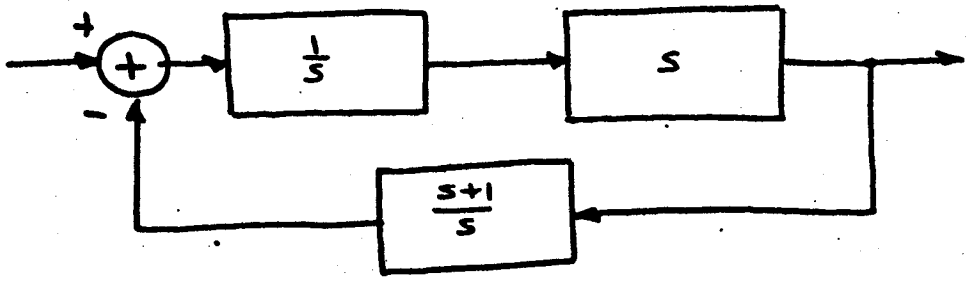


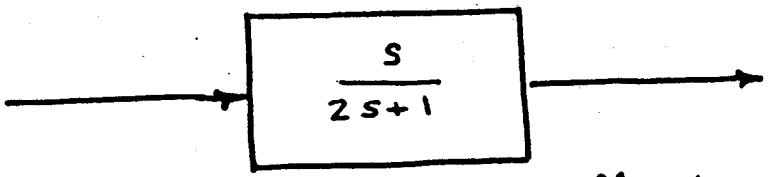
Example 3



Example 4

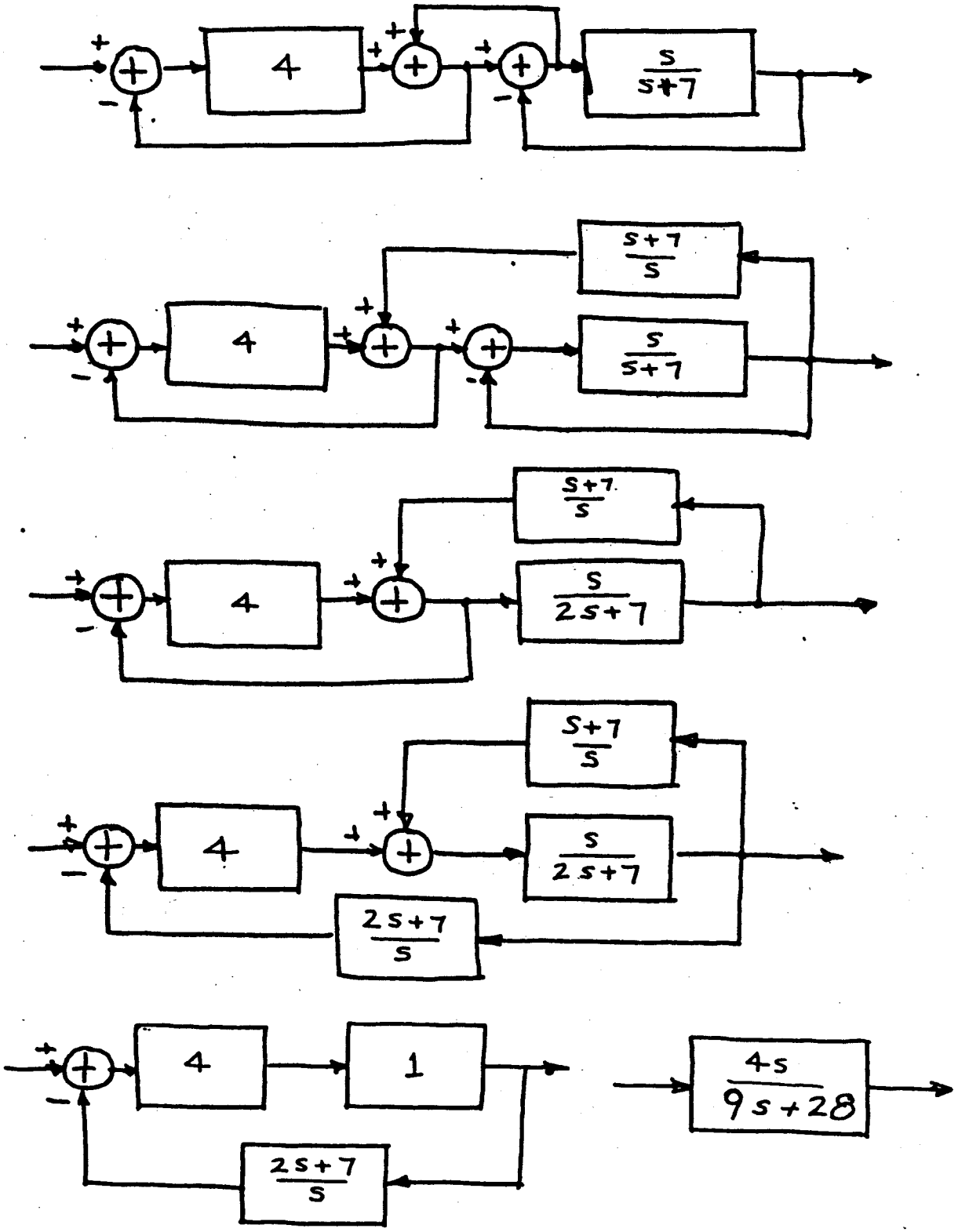




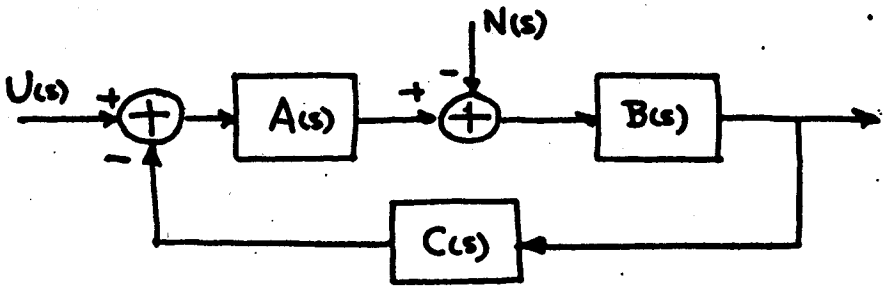


Same as #3, just a different sequence of steps

Example 5

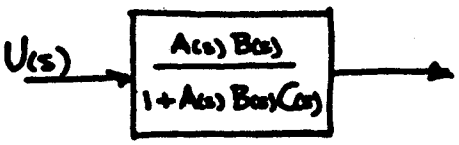

4
$\frac{s}{s+7}$
$\frac{s+7}{s}$
4
$\frac{s}{s+7}$
$\frac{s+7}{s}$
4
$\frac{s}{2s+7}$
$\frac{s+7}{s}$
4
$\frac{s}{2s+7}$
$\frac{2s+7}{s}$
4
1
$\frac{2s+7}{s}$
$\frac{4s}{9s+28}$

Example 6

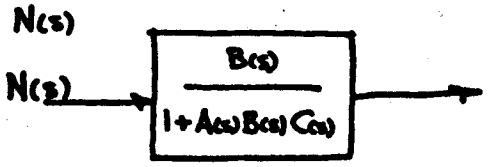


Use superposition — compute response to inputs separately:

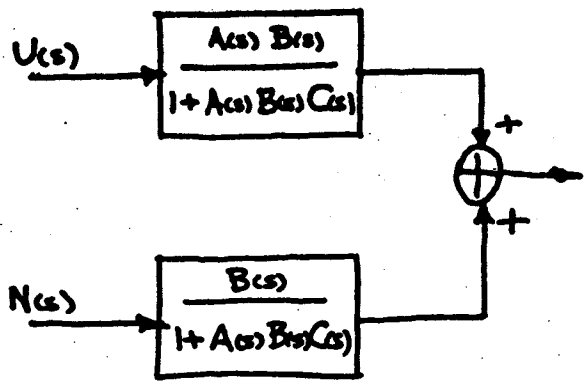
First, U(s)



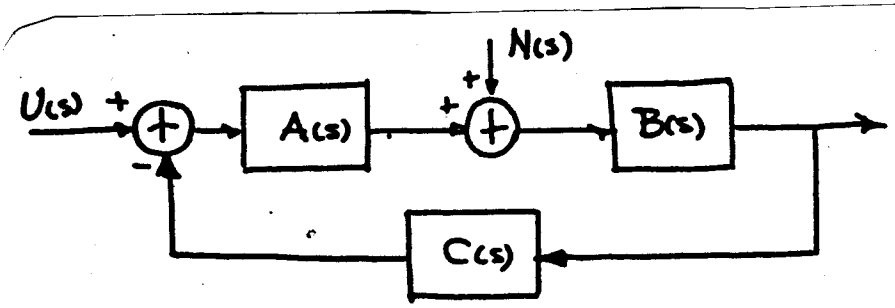
Then N(s)



Hence,



Example 7



same as 7 — different approach