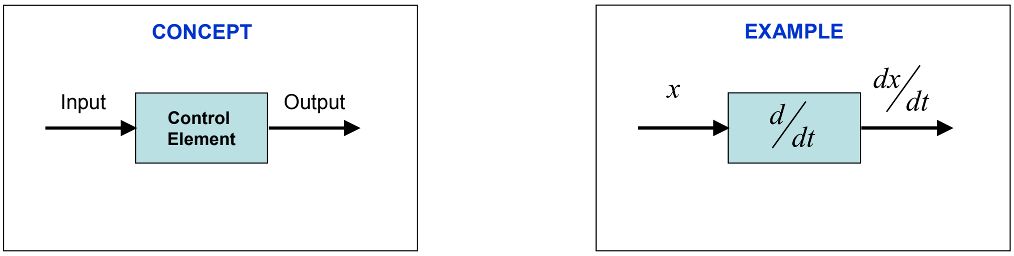
Block Diagram & Signal Flow

Rectangular block diagram represents the cause-and-effect relationship between the input and output of a physical system.

Control element represents any of the system component such as controller, process, sensor, transmitter, transducer, control valve, metering pump, solenoid valve, etc.

Arrow represents the direction of signal flow.

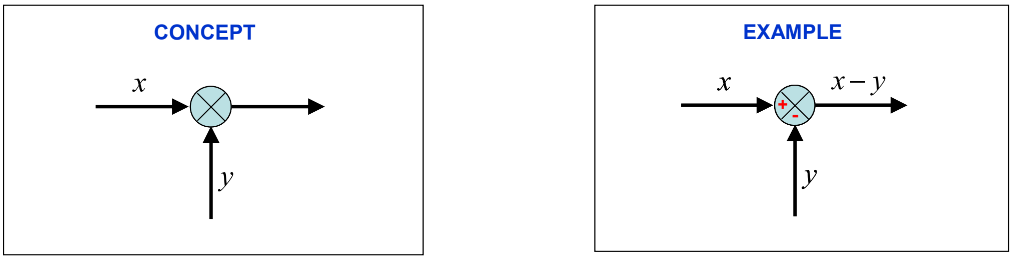


(a) (b)

Fig. 1: Concept (a) and example (b) of block diagram.

Signal Operations

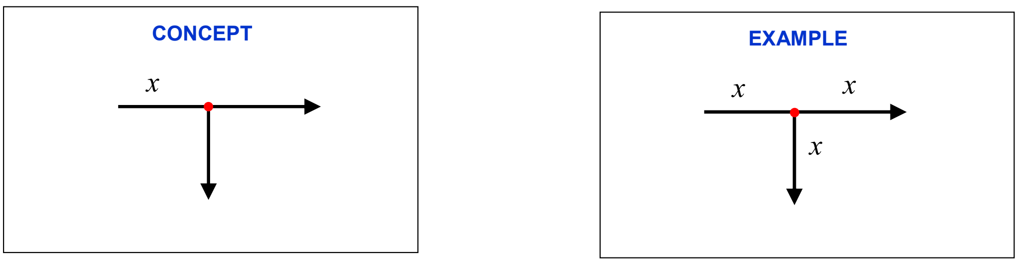
Circle block diagram represents the signals operation. A negative or positive sign is placed inside the circle to represent deduction or addition of the respective signals.



(a) (b)

Fig. 2: Concept (a) and example (b) of addition and deduction of signals using circle.

Takeoff point is a point where the signal is diverted into multiple flows which has similar values to various operators or control elements.



(a) (b)

Fig. 3: Concept (a) and example (b) of signal splitting.

Examples

Example No. 1

Draw a block diagram for the following equation:

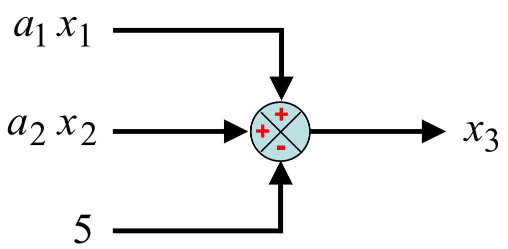
$$x_3 = a_1 x_1 + a_2 x_2 - 5$$

Step 1

a. Identify control elements: a_1 and a_2
b. Identify signals: x_1, x_2 and 5

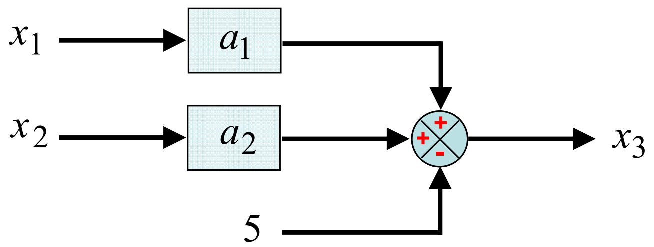
Step 2

Identify summing junction and arrows



Step 3

Draw and label complete block diagram.

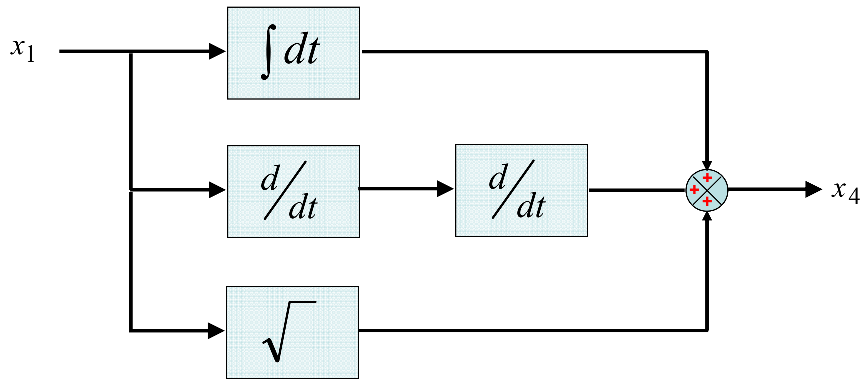


Example No. 2

Draw a block diagram for the following equation:

$$x_4 = \int x_1\, dt + \frac{d^2 x_1}{dt^2} + \sqrt{x_1}$$

Answer



Transformation Theorem

Canonical Form: The reduced (simplest) form of a complicated block diagram. Figure 4 below shows a canonical form of a control system.

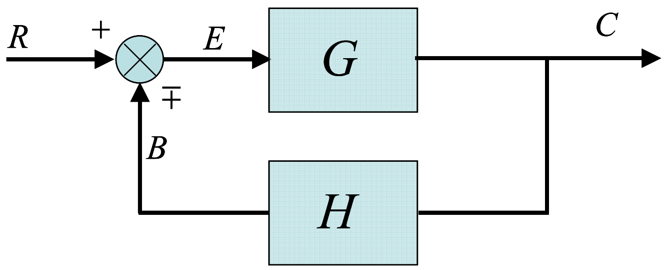


Fig. 4: Canonical form of a control system.

The relationship between the signals (B, C, E & R) and the control elements (G & H) are shown below.

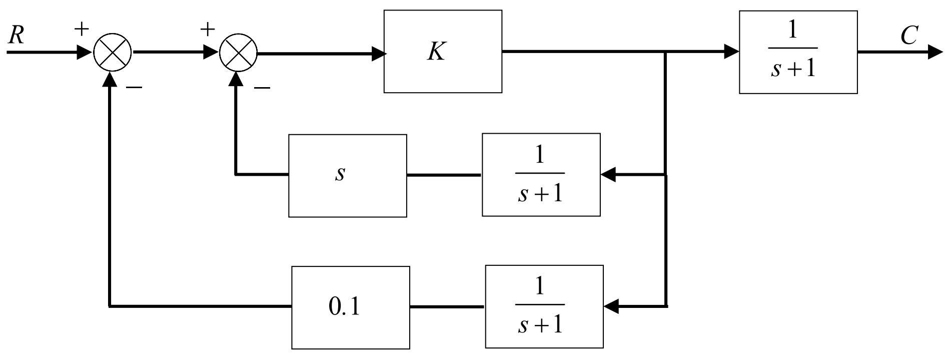
$$\frac{E}{R} = \frac{1}{1 \pm GH} \qquad \frac{B}{R} = \frac{GH}{1 \pm GH} \qquad \frac{C}{R} = \frac{G}{1 \pm GH}$$

Definition:

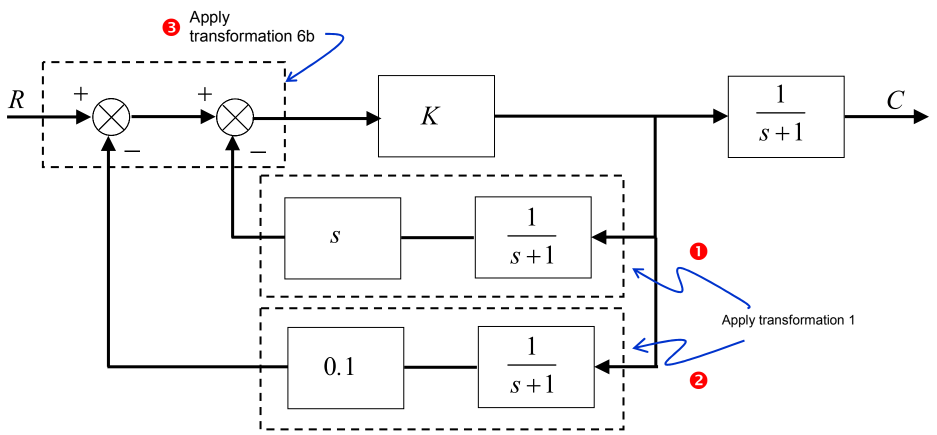
G = direct tansfer function = forward transfer function
H = feedback transfer function
GH = loop transfer function = openloop transfer function
C/R = closed-loop transfer function = control ratio
E/R = actuating signal ratio = error ratio
B/R = primary feedback ratio

Example No. 3

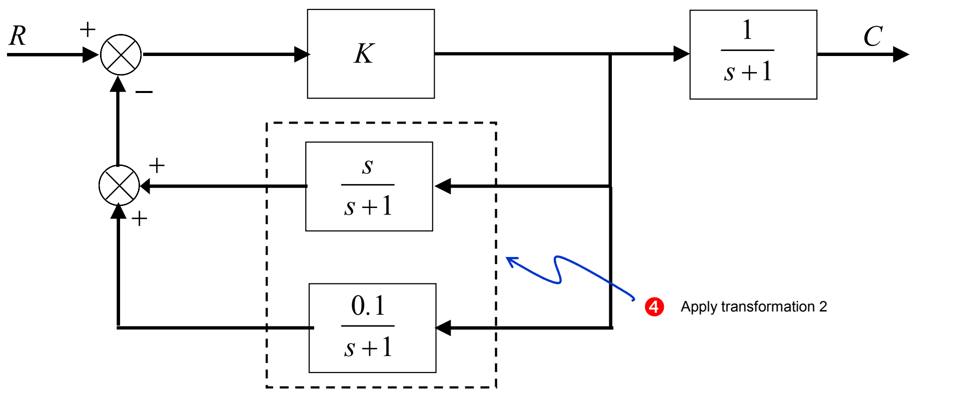
Reduce the following block diagram to canonical form, isolating block K in the forward loop.Then, calculate C/R.



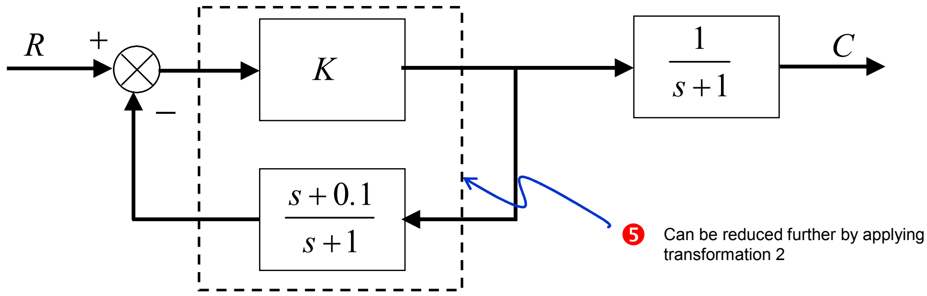
Step 1



Step 2

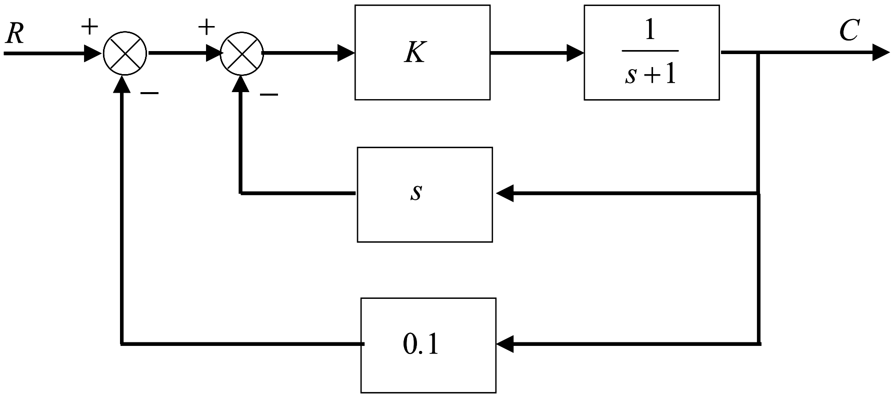


Step 3 - Finally



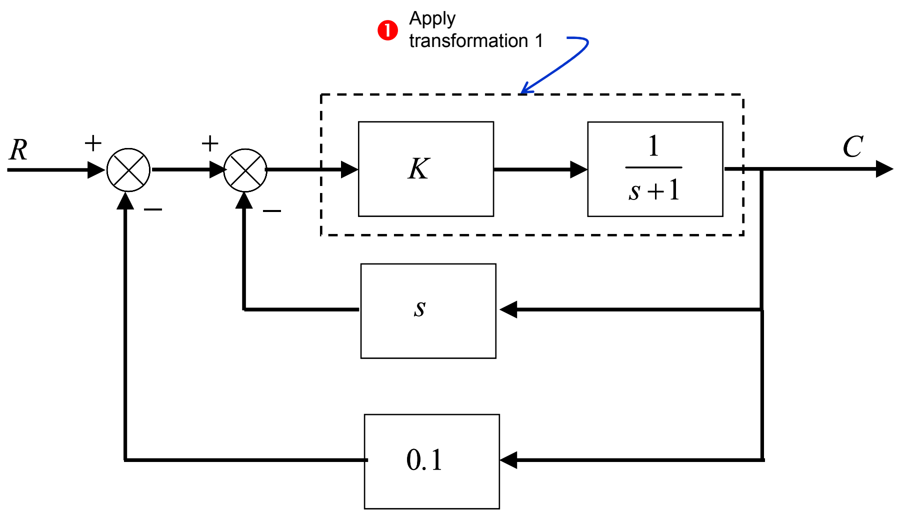
Example No. 4

Reduce the block diagram below to canonical form.

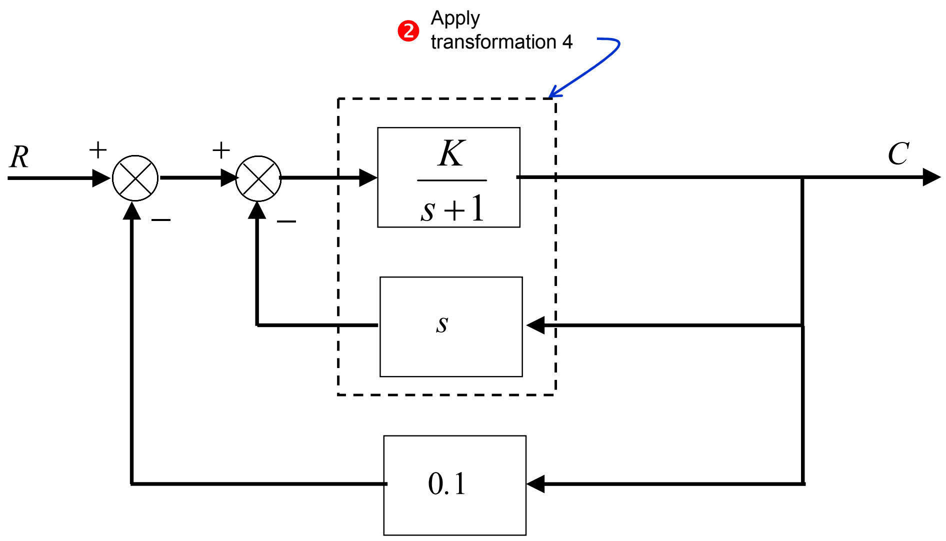


Answer

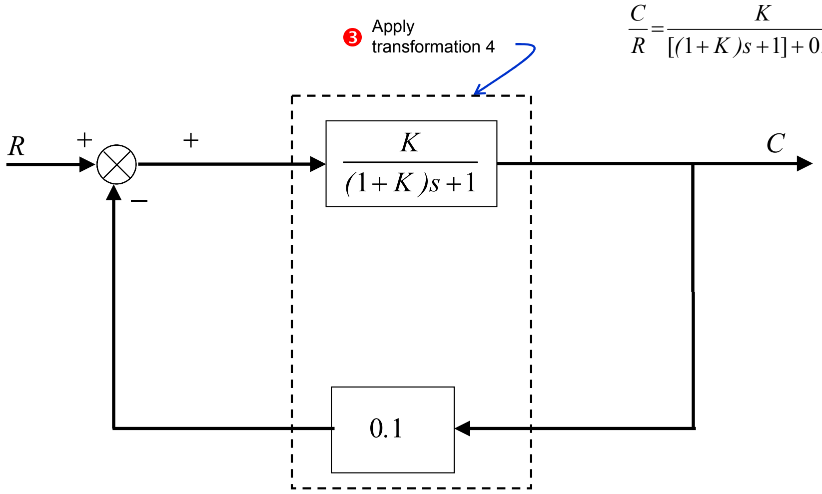
Step 1



Step 2



Step 3 - Finally

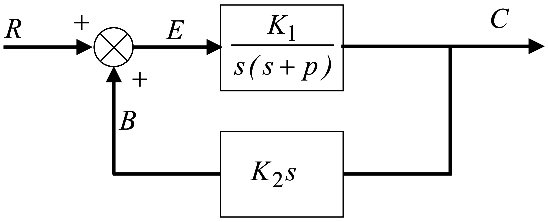


$$\frac{C}{R} = \frac{K}{[(1+K)s+1]+0.1K}$$

Exercise

Calculate C/R of the following control system.

(a) System 1



(a) System 2