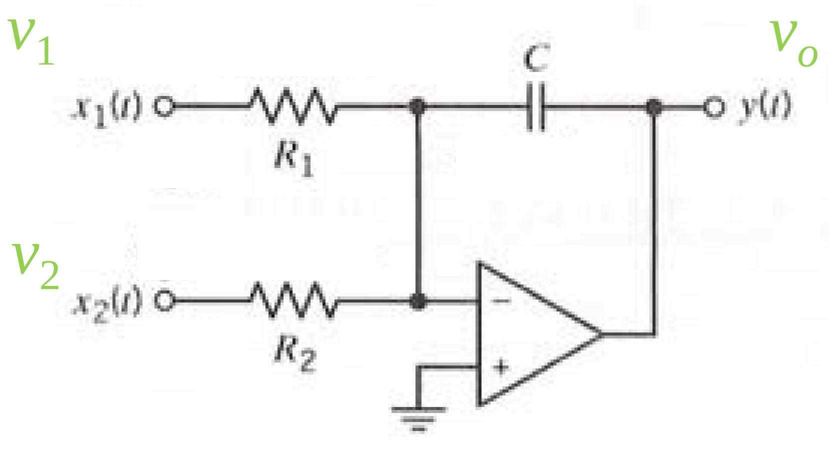
Summing Integrator



입력을 각각 적분하여 합하는 회로.

$$v_p = v_n = 0$$

Op amp의 입력단자에서**KCL** 적용**.**

$$\frac{0 - v_1}{R_1} + \frac{0 - v_2}{R_2} + C\frac{d}{dt}(0 - v_o) = 0$$

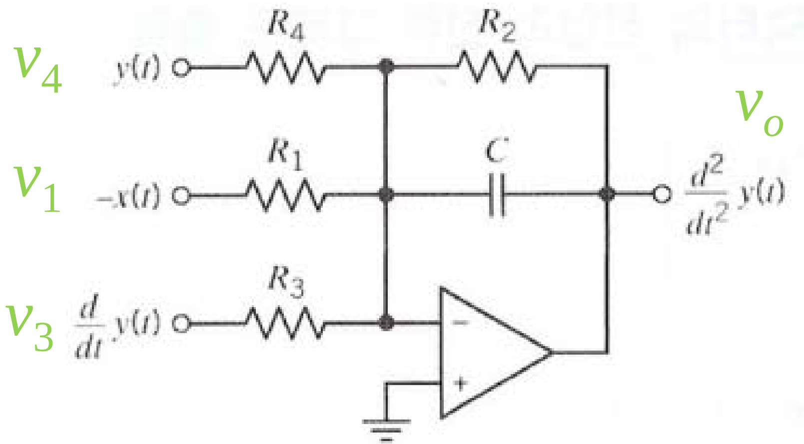
$$\frac{dv_o}{dt} + \frac{v_1}{R_1 C} + \frac{v_2}{R_2 C} = 0$$

$v_1 = x_1, v_2 = x_2, v_o = y$ 이므로

$$y(t) = -\left[\int_0^t \frac{x_1(\tau)}{R_1 C} d\tau + \int_0^t \frac{x_1(\tau)}{R_2 C} d\tau\right]$$

Summing Integrator using Output as Input

출력을 입력으로 활용하여 입력을 각각 적분하여 합하는 회로.



$$v_p = v_n = 0$$

Op amp의 입력단자에서**KCL** 적용.

$$\frac{0-v_1}{R_1} + \frac{0-v_o}{R_2} + \frac{0-v_3}{R_3} + \frac{0-v_4}{R_4} + C\frac{d}{dt}(0-v_o) = 0$$

$$\frac{dv_o}{dt} + \frac{v_1}{R_1C} + \frac{v_o}{R_2C} + \frac{v_3}{R_3C} + \frac{v_4}{R_4C} = 0$$

$v_1 = -x, v_o = y'', v_3 = y', v_4 = y$ 이라하면

$$y''(t) = -\left[\int_0^t \frac{-x(\tau)}{R_1C}d\tau + \int_0^t \frac{y''(\tau)}{R_2C}d\tau + \int_0^t \frac{y'(\tau)}{R_3C}d\tau + \int_0^t \frac{y(\tau)}{R_4C}d\tau\right]$$

Solutions of Linear Differential Equations

선형 상미분방정식의 해를 **Op amp** 회로를 이용하여 구할 수 있다.

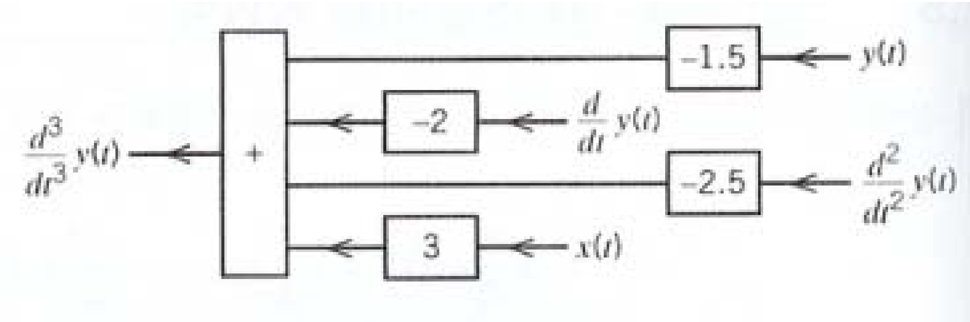
$$2\frac{d^3}{dt^3}y(t)+5\frac{d^2}{dt^2}y(t)+4\frac{d}{dt}y(t)+3y(t)=6x(t)$$

편의상 초기 조건은 영이라 하자. $\frac{d^2}{dt^2}y(t)=0,\ \frac{d}{dt}y(t)=0,\ y(t)=0,$

선형미분방정식의 꼴을 3계 미분항을 기준으로 정리한다.

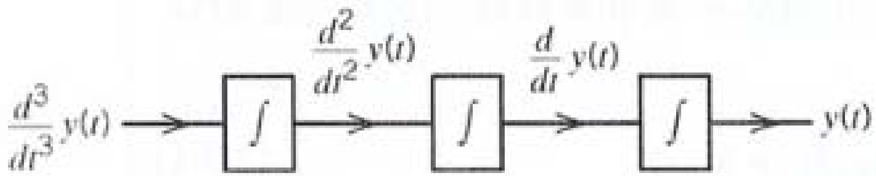
$$\frac{d^3}{dt^3}y(t)=3x(t)-\left[2.5\frac{d^2}{dt^2}y(t)+2\frac{d}{dt}y(t)+1.5y(t)\right]$$

합산 회로를 이용하면 그림과 같다.

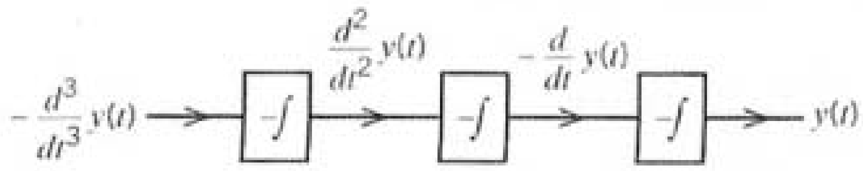


Inverting Integrators

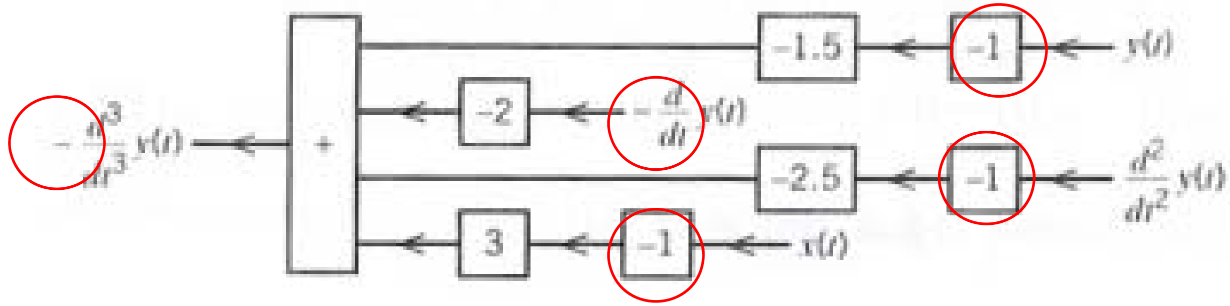
3계 미분항을 한 번씩 적분을 하면 **2**계 미분항, **1**계 미분항, 원 함수가 된다.



Op amp 적분기(반전 적분기)를 사용하면 출력의 부호가 바뀌게 된다. 최종 출력 y(t) 가 양의 부호를 갖도록 조정한다.

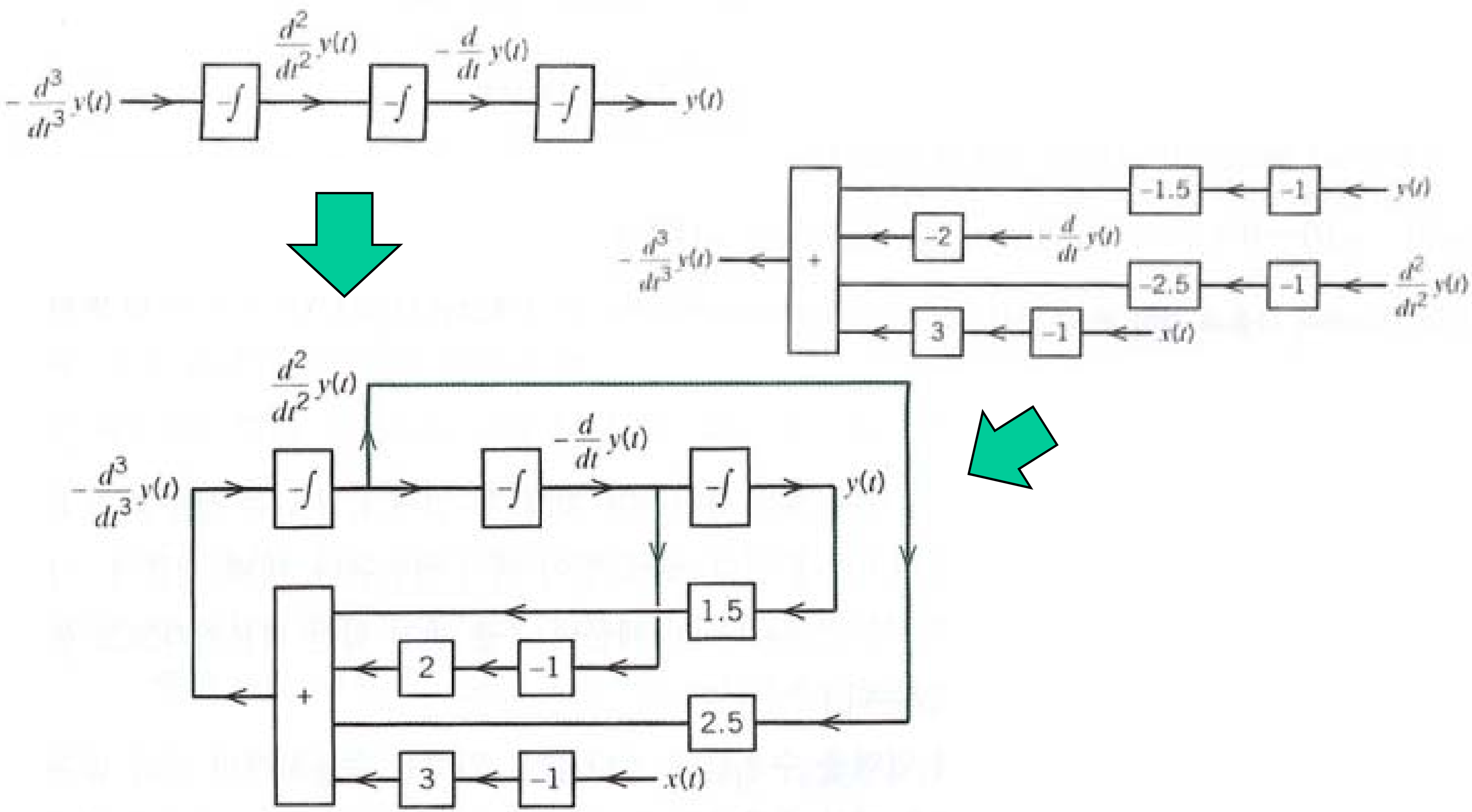


$$-\frac{d^3}{dt^3}y(t) = -3x(t) + \left[2.5\frac{d^2}{dt^2}y(t) + 2\frac{d}{dt}y(t) + 1.5y(t)\right]$$



Block Diagram

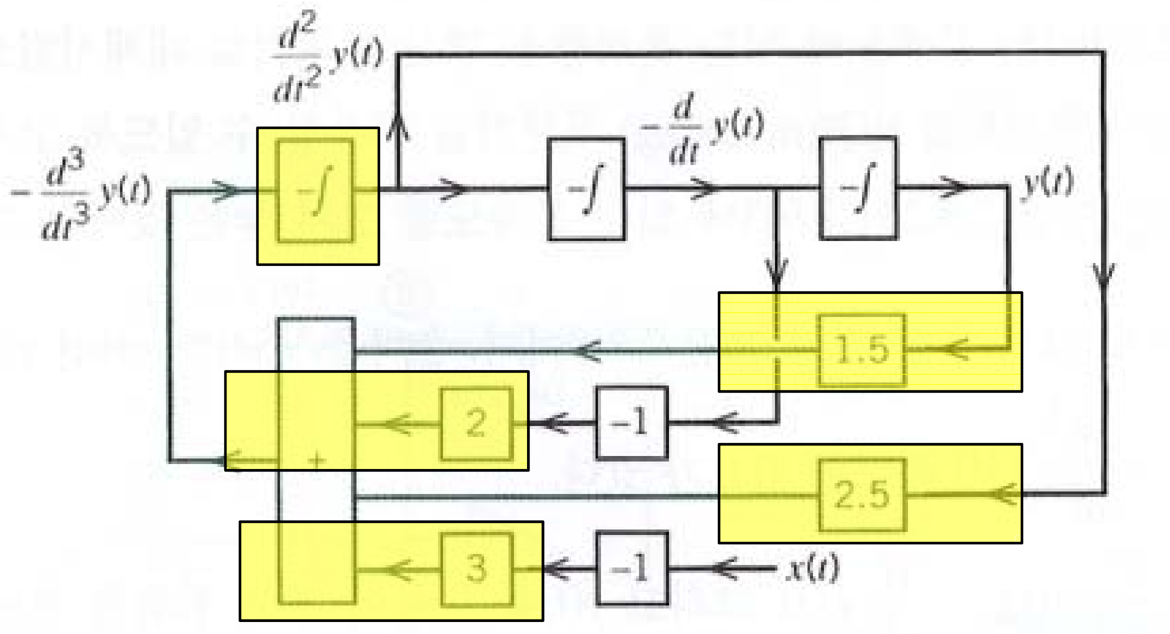
반전 적분기와 합산회로를 적용하여 블록 다이아그램을 완성한다.



Block Diagram with Summing Integrator using Output as Input

반전 적분기와 합산회로를 적용하여 블록 다이아그램을 완성한다.

$$-\frac{d^3}{dt^3}y(t) = 3\{-x(t)\} + 2.5\frac{d^2}{dt^2}y(t) + 2\left[-\left\{-\frac{d}{dt}y(t)\right\}\right] + 1.5y(t)$$

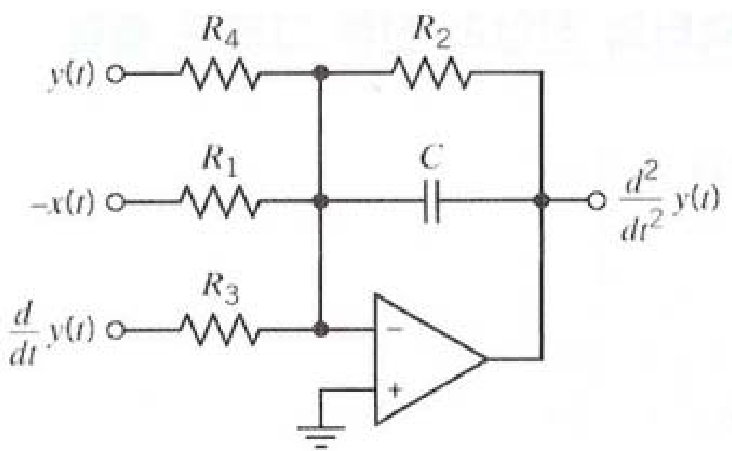


Summing Integrator using Output as Input

$$-\frac{d^3}{dt^3}y(t) = 3\{-x(t)\} + 2.5\frac{d^2}{dt^2}y(t) + 2\left[-\left\{-\frac{d}{dt}y(t)\right\}\right] + 1.5y(t)$$

$$y''(t) = -\left[\int_0^t \frac{-x(\tau)}{R_1C}d\tau + \int_0^t \frac{y''(\tau)}{R_2C}d\tau + \int_0^t \frac{y'(\tau)}{R_3C}d\tau + \int_0^t \frac{y(\tau)}{R_4C}d\tau\right]$$

$$-y''(t) = \int_0^t \frac{-x(\tau)}{R_1C}d\tau + \int_0^t \frac{y''(\tau)}{R_2C}d\tau + \int_0^t \frac{y'(\tau)}{R_3C}d\tau + \int_0^t \frac{y(\tau)}{R_4C}d\tau$$



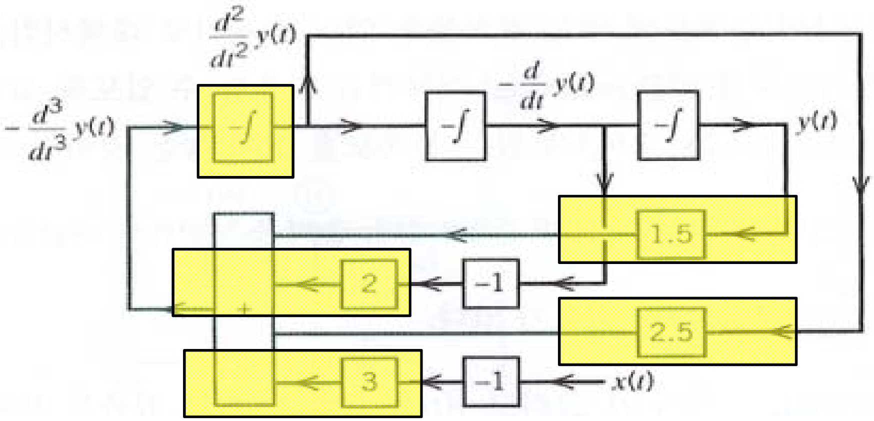
$$\frac{1}{R_1C} = 3,\ \frac{1}{R_2C} = 2.5,\ \frac{1}{R_3C} = 2,\ \frac{1}{R_4C} = 1.5$$

커패시터를 1 μF으로 선정하면
각 저항 값을 구할 수 있다.

$$R_1 = \frac{10^6}{3},\ R_2 = \frac{10^6}{2.5},\ R_3 = \frac{10^6}{2},\ R_4 = \frac{10^6}{1.5}$$

Op Amp Circuits for Linear Differential Equation

$$2\frac{d^3}{dt^3}y(t)+5\frac{d^2}{dt^2}y(t)+4\frac{d}{dt}y(t)+3y(t)=6x(t)$$



$$C=10^{-6}\,\mathrm{F},$$

$$R_1=\frac{10^6}{3},\ R_2=\frac{10^6}{2.5},\ R_3=\frac{10^6}{2},\ R_4=\frac{10^6}{1.5}$$