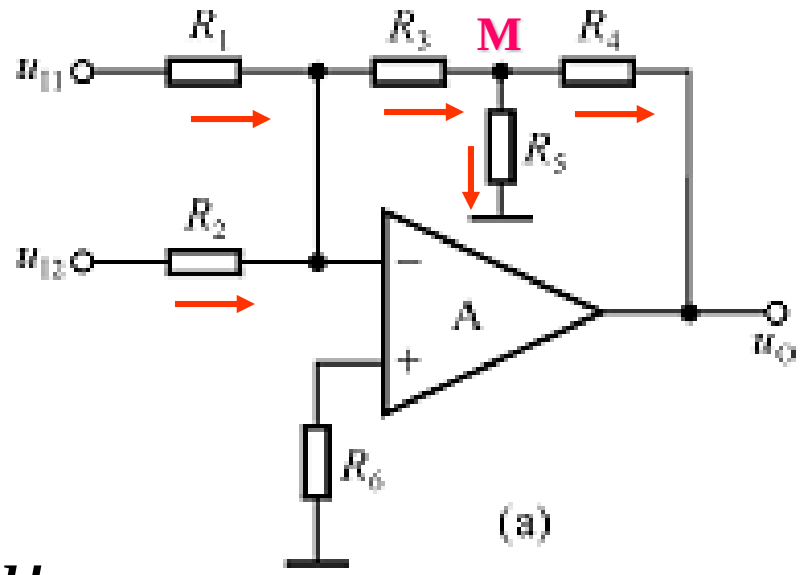
**6-1** 试求下图所示各电路输出电压与输入电压的运算关系式。

解答：




（a）反相求和运算电路；

$$u_M = -R_3\left(\frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2}\right)$$

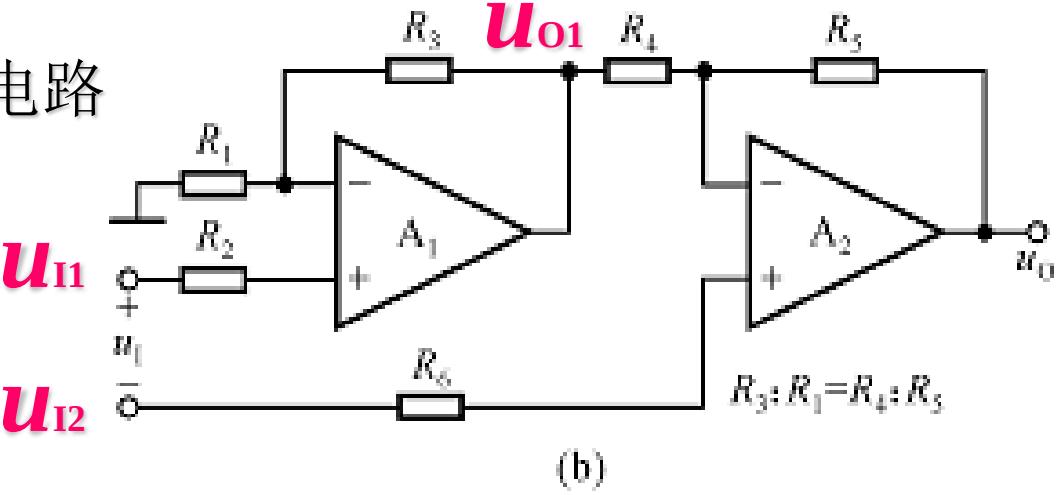
$$i_{R4} = i_{R3} - i_{R5} = \frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2} - \frac{u_M}{R_5}$$

$$u_O = u_M - i_{R4}R_4 = -\left(R_3 + R_4 + \frac{R_3R_4}{R_5}\right)\left(\frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2}\right)$$

# 6-1 解答：

（b）$A_1$组成同相比例运算电路

$A_2$组成加减运算电路



(b)

$$u_{O1}=(1+\frac{R_3}{R_1})u_{I1}$$

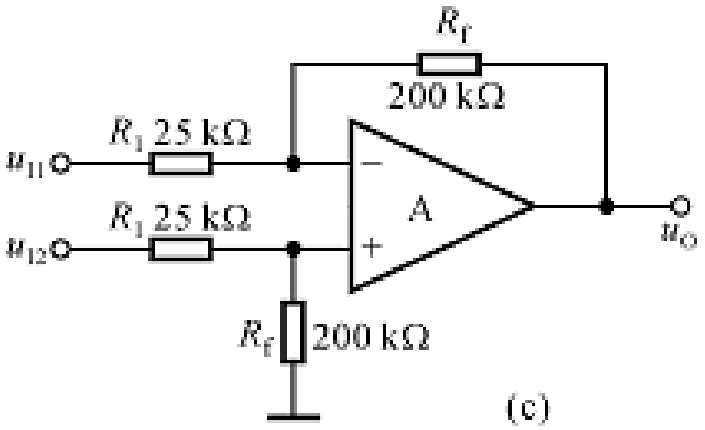
$$u_O=-\frac{R_5}{R_4}u_{O1}+(1+\frac{R_5}{R_4})u_{I2}$$

$$=-\frac{R_5}{R_4}(1+\frac{R_3}{R_1})u_{I1}+(1+\frac{R_5}{R_4})u_{I2}=(1+\frac{R_5}{R_4})(u_{I2}-u_{I1})$$

$$=-(1+\frac{R_5}{R_4})u_I$$

# 6-1 解答：

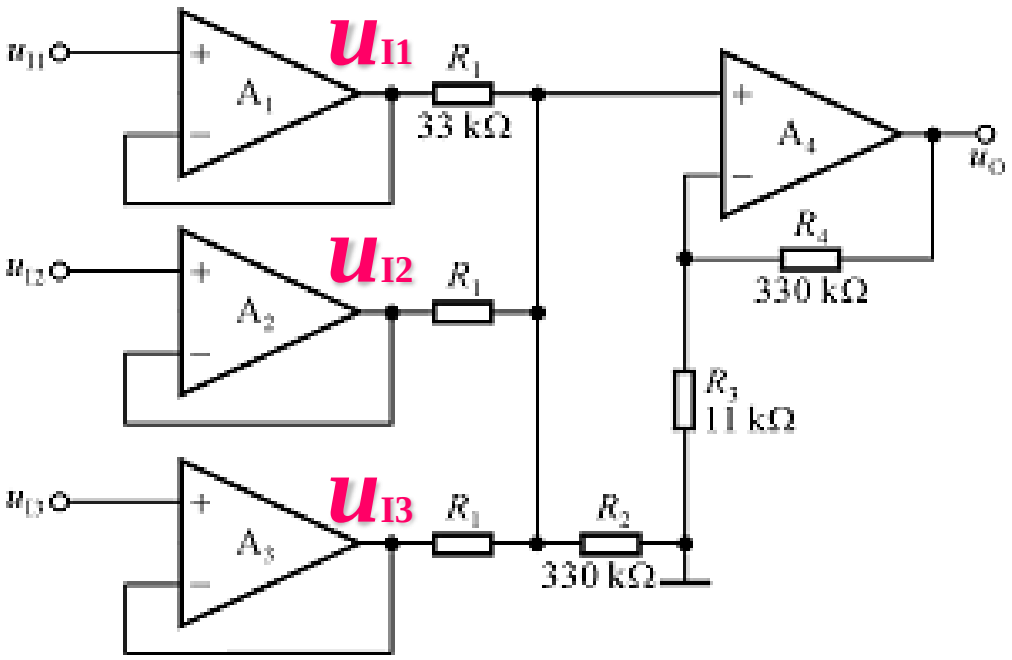
（c）A 组成差分比例运算电路

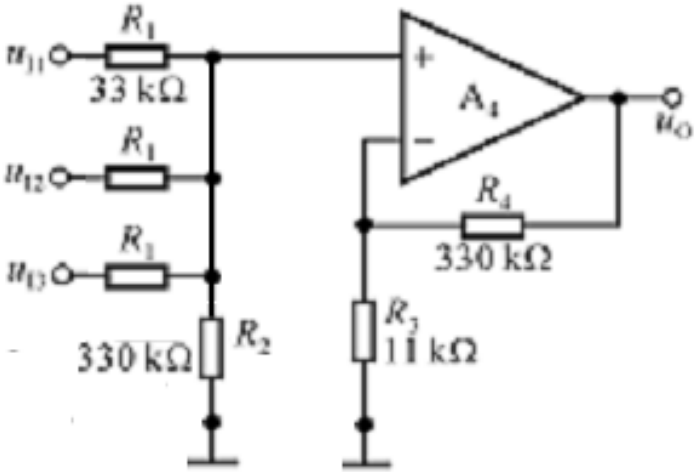



$$u_o = \frac{R_f}{R_1}(u_{I1} - u_{I2}) = 8(u_{I1} - u_{I2})$$

**6-1 解答：** （d）$A_1$、$A_2$、$A_3$ 均组成为电压跟随器，$A_4$组成反相求和运算电路

等效电路



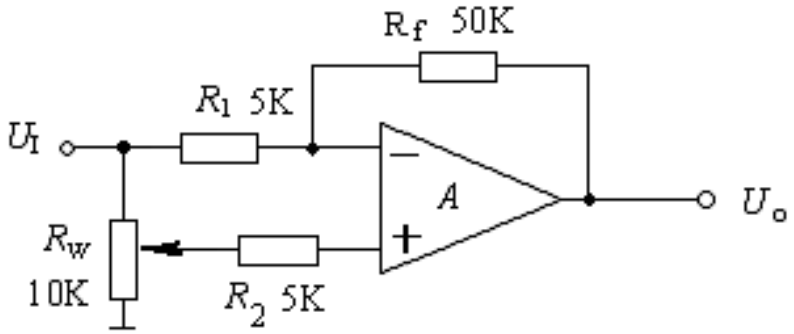

$$u_O = (1+\frac{R_4}{R_3})u_P$$

$$\frac{u_{i1}-u_P}{R_1}+\frac{u_{i2}-u_P}{R_1}+\frac{u_{i3}-u_P}{R_1}=\frac{u_P}{R_2}$$

$$u_O = 10\ (u_{I1}+u_{I2}+u_{I3})$$

**6-2** 理想运放电路如图所示：（1）设电位器动臂到地的电阻为$KR_W$，$0 \le K \le 1$。试求该电路电压增益的调节范围。

（2）已知运放的最大输出限幅值$U_{oM}$=14V，Ui有两种取值1V或2V，求对应的Uo分别为多少？




解答：

（1）运放构成减法运算电路。

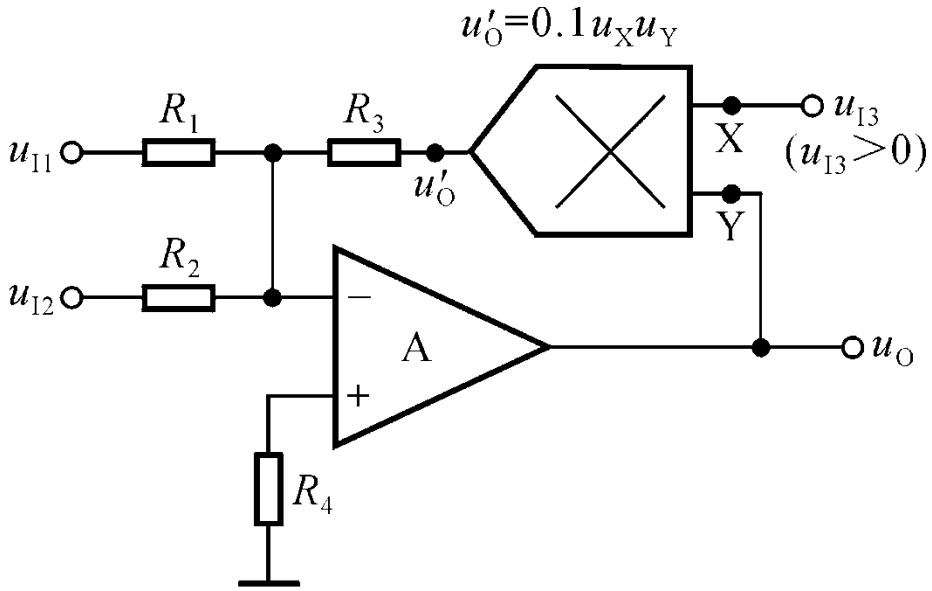
$$U_I' = 0 \sim U_I$$

$$U_o = -\frac{R_f}{R_1}U_I + (1+\frac{R_f}{R_1})U_I' = -\frac{R_f}{R_1}U_I \sim U_I$$

（2）当$U_i$=1V时， $U_o$=-10V~-1V

当$U_i$=2V时， $U_o$=-14V~-2V

## 6-3　求出图示各电路的运算关系。

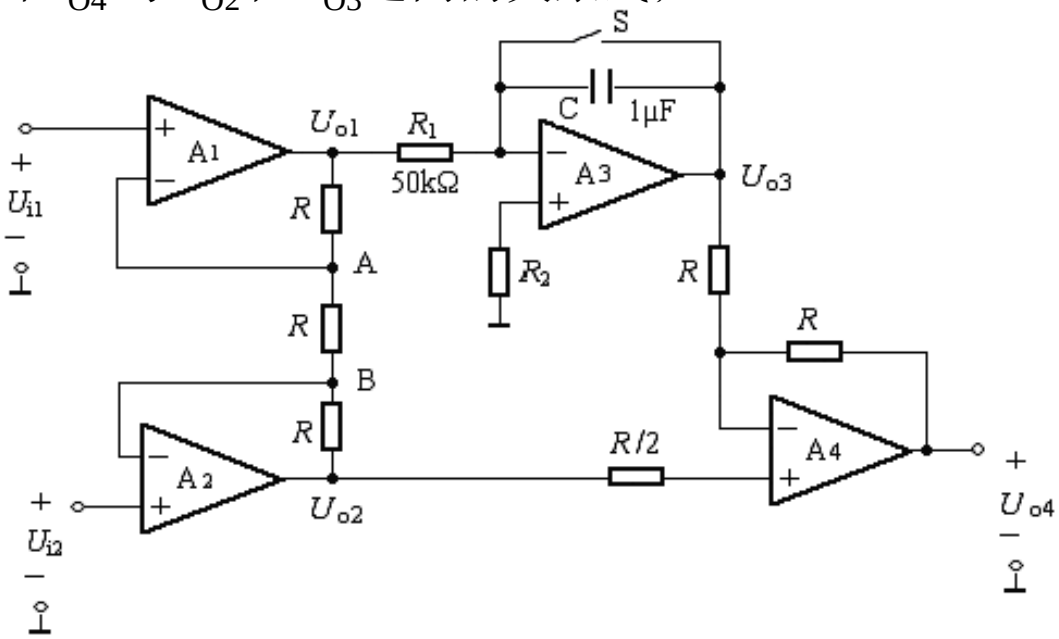



6-3 解答：实现求和除法运算

$$u_0' = -R_3\left(\frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2}\right) = ku_0u_{I3}$$

$$u_0 = -\frac{R_3}{ku_{I3}}\left(\frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2}\right)$$

**6-4** 如图所示电路，已知： $U_{I1}$= 4V和$U_{I2}$ = 1V 。 1） 当开关S打开时，写出$U_{O3}$和$U_{O1}$之间的关系式；2）写出$U_{O4}$ 与$U_{O2}$和$U_{O3}$之间的关系式；3）当开关S闭合时，分别求 $U_{O1}$ $U_{O2}$ $U_{O3}$ $U_{O4}$ 对地电位；4）设t = 0时将S打开，问经过多长时间$U_{O4}$ =0？




## 6-4 解答：

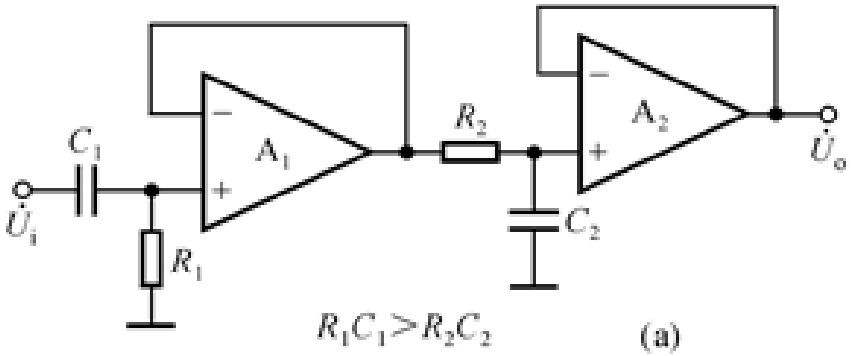
1) $$U_{O3} = -\frac{1}{R_1 C}\int U_{o1}dt = -20\int U_{o1}dt(V)$$

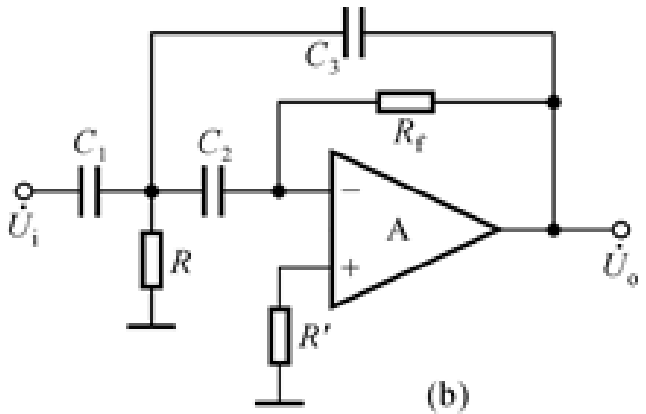
2) $$U_{O4} = 2U_{o2} - U_{o3}$$

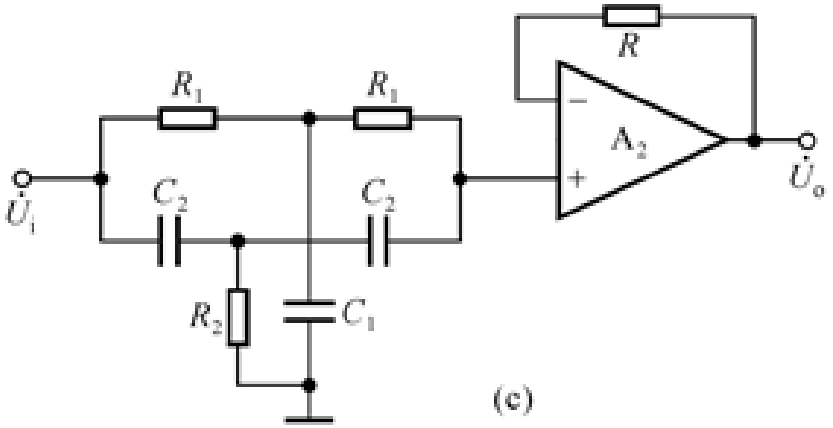
3) $U_{o1} = 7V$　　$U_{o2} = -2V$　　$U_{o3} = 0V$　　$U_{o4} = 2U_{o2} = -4V$

4) $t = 28ms$

6-5 试说明下图所示各电路属于哪种类型的滤波电路，是几阶滤波电路。



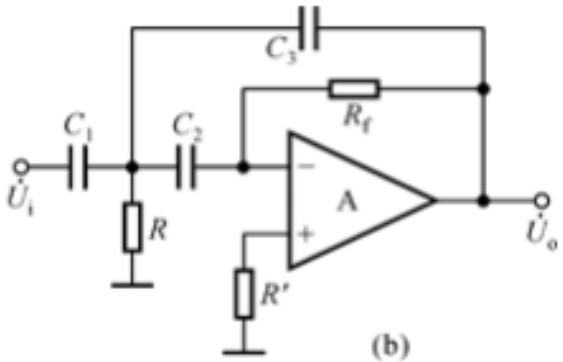




**解答：**

图（a）二阶带通滤波器。

图（b）二阶高通滤波器。

图（c）二阶带阻滤波器。




$$\frac{u_M}{\frac{1}{sC_2}} = \frac{-u_o}{R_f} \Rightarrow u_M = \frac{-u_o}{sR_fC_2}$$

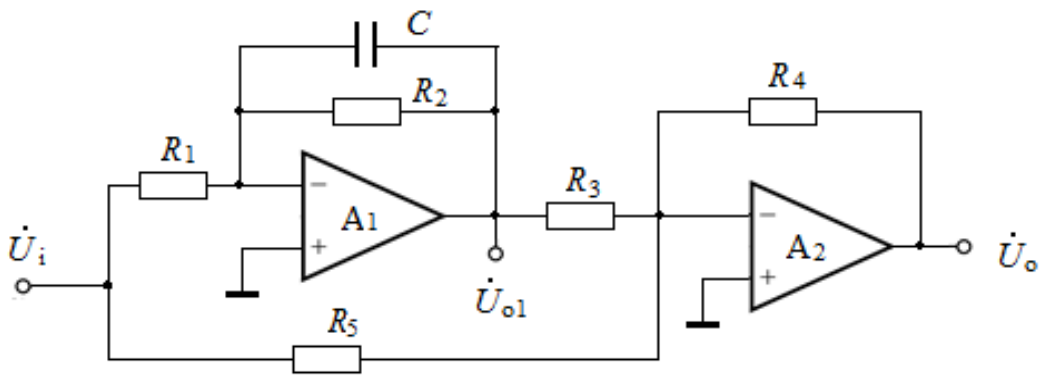
$$\frac{u_i - u_M}{\frac{1}{sC_1}} = \frac{u_M - u_o}{\frac{1}{sC_3}} + \frac{u_M}{\frac{1}{sC_2}} + \frac{u_M}{R} \Rightarrow sC_1(u_i - u_M) = sC_3(u_M - u_o) + sC_2u_M + \frac{u_M}{R}$$

$$\dot{A}_u = -\frac{s^2R_fRC_1C_2}{s^2R_fRC_2C_3 + sR(C_1 + C_2 + C_3) + 1}$$

**6-6** 电路如图所示。已知$R_1=R_2$，$R_3=R_4=R_5$，且运放性能均为理想。

（1）分别求$\dot{A}_{u1}=\frac{\dot{U}_{o1}(j\omega)}{\dot{U}_i(j\omega)}$和$\dot{A}_u=\frac{\dot{U}_o(j\omega)}{\dot{U}_i(j\omega)}$的表达式。

（2）说明运放A1是哪种滤波电路？整个电路又构成了哪种滤波电路？




[解] (1) $\dot{A}_{u1}=\dfrac{\dot{U}_{o1}}{\dot{U}_i}=-\dfrac{R_2 /\!/ \dfrac{1}{j\omega C}}{R_1}=-\dfrac{R_2}{R_1}\dfrac{1}{1+j\omega R_2 C}=-\dfrac{1}{1+j\omega R_2 C}$

(2) 因为 $\dot{U}_o=-\dfrac{R_4}{R_3}\dot{U}_{o1}-\dfrac{R_4}{R_5}\dot{U}_i=-\dot{U}_{o1}-\dot{U}_i=-\dot{A}_{u1}\dot{U}_i-\dot{U}_i$

$\dot{A}_u=\dfrac{\dot{U}_o}{\dot{U}_i}=\dfrac{-\dot{A}_{u1}\dot{U}_i-\dot{U}_i}{\dot{U}_i}=-\dot{A}_{u1}-1=+\dfrac{1}{1+j\omega R_2 C}-1=-\dfrac{j\omega R_2 C}{1+j\omega R_2 C}$

(3) 因为当 $\omega\to 0$ 时，$|\dot{A}_{u1}(\omega)|\to 1$，$|\dot{A}_u(\omega)|\to 0$；当 $\omega\to\infty$ 时，$|\dot{A}_{u1}(\omega)|\to 0$，$|\dot{A}_u(\omega)|\to 1$。故运放 $A_1$ 组成一阶低通有源滤波电路；整个电路又是一阶高通有源滤波电路。