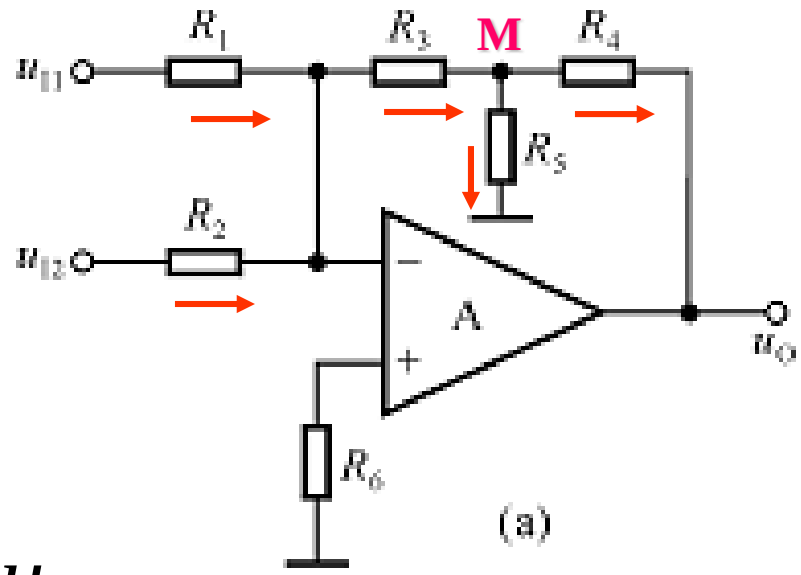
6-1 试求下图所示各电路输出电压与输入电压的运算关系式。

解答：



（a）反相求和运算电路；

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

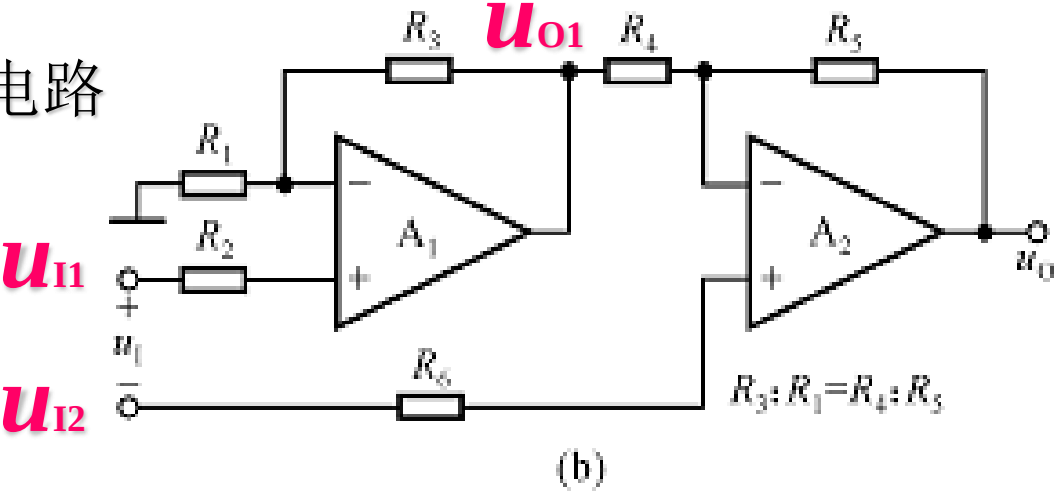
$$i_{R4} = i_{R3} - i_{R5} = \frac{u_{I1}}{R_1} + \frac{u_{I2}}{R_2} - \frac{u_M}{R_5}$$

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

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)

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

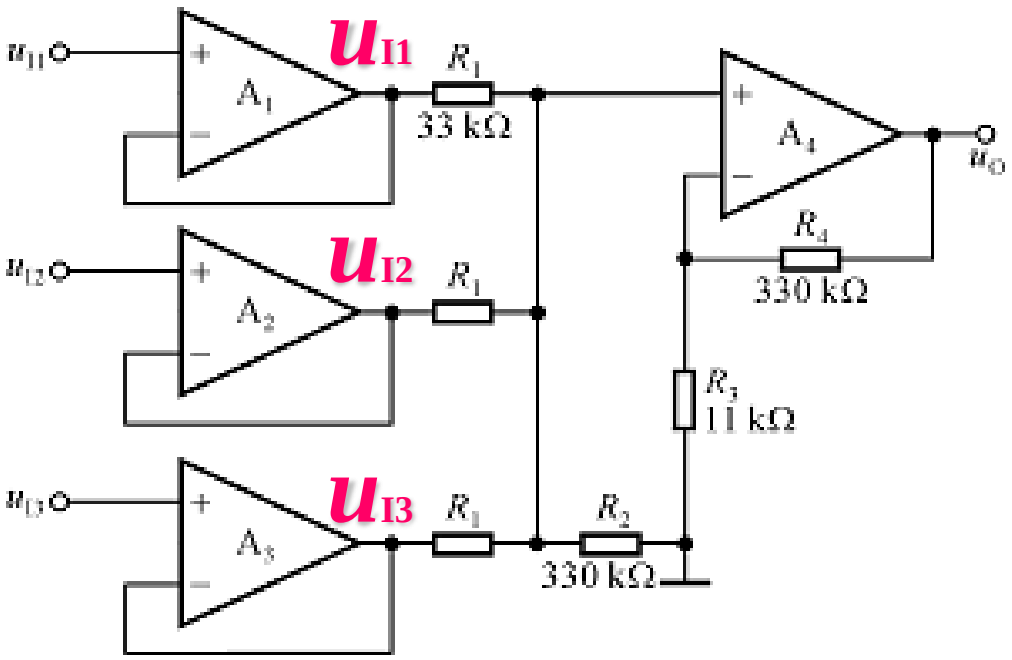
$$u_O=-\frac{R_5}{R_4}u_{O1}+(1+\frac{R_5}{R_4})u_{I2}$$

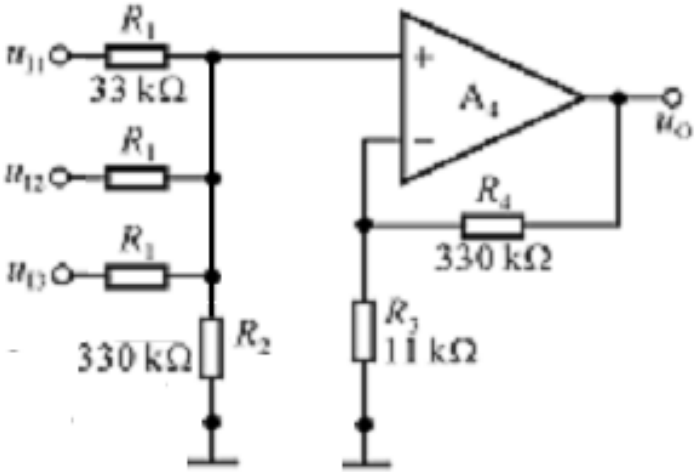
$$=-\frac{R_5}{R_4}(1+\frac{R_3}{R_1})u_{I1}+(1+\frac{R_5}{R_4})u_{I2}=(1+\frac{R_5}{R_4})(u_{I2}-u_{I1})$$

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

6-1 解答： （c）A_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



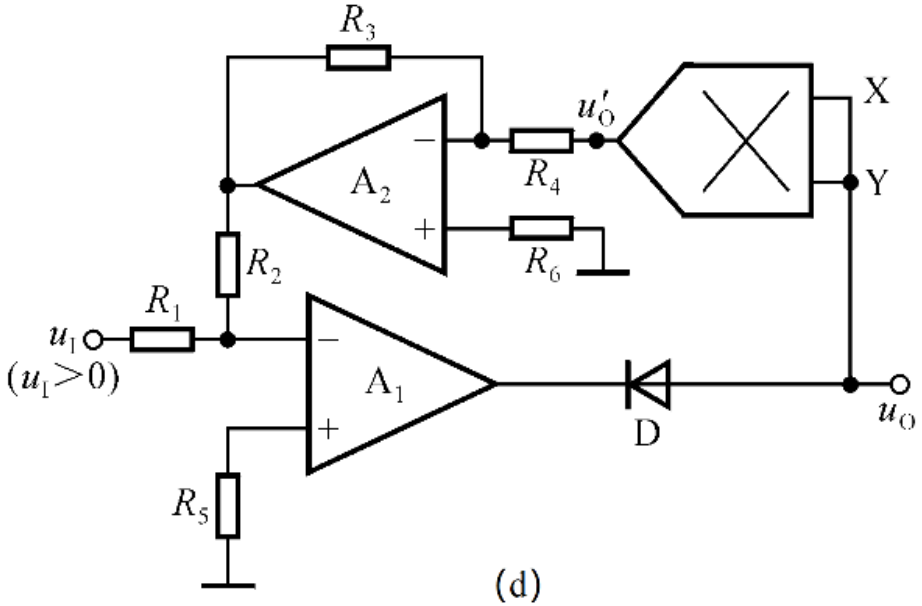


$$u_O = (1+\frac{R_4}{R_3})u_P$$

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

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

6-1 解答：　（d）



(d)

$$u_{O2} = -\frac{R_2}{R_1}\cdot u_I = -\frac{R_3}{R_4}\cdot u'_O = -\frac{R_3}{R_4}\cdot k u_O^2$$

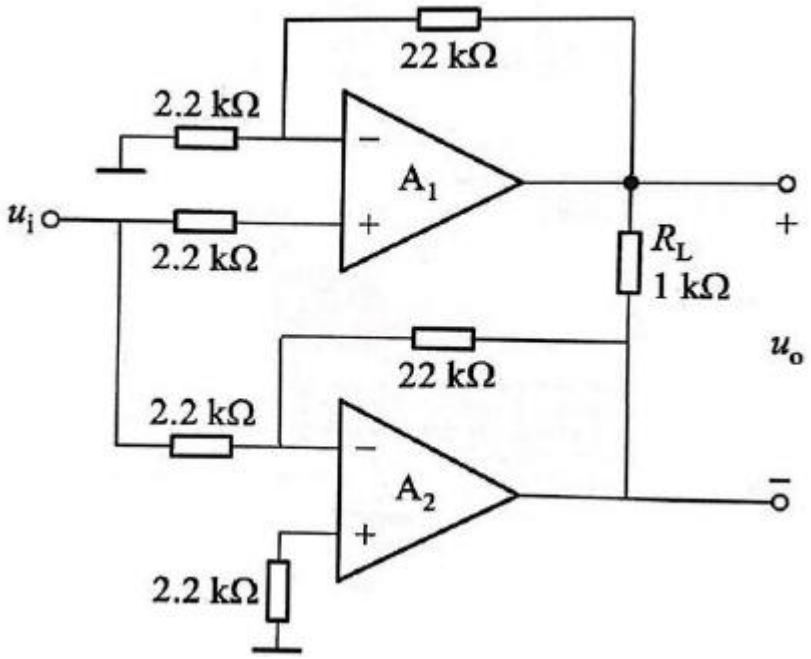
$$u_O = \sqrt{\frac{R_2 R_4}{k R_1 R_3}\cdot u_I}$$

6-2 试求图6-2所示电路的输出电压*uo*，*已知ui=1V*。

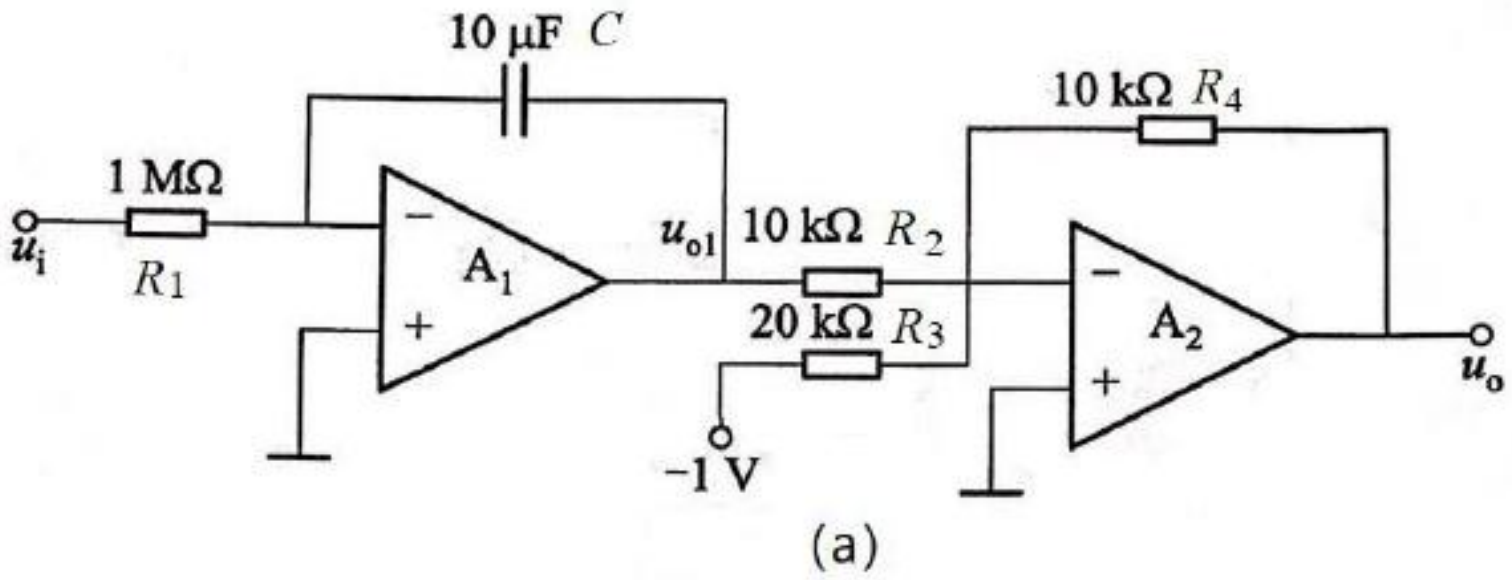
Uo1 = 11V

Uo2 = -10V

Uo = 21V



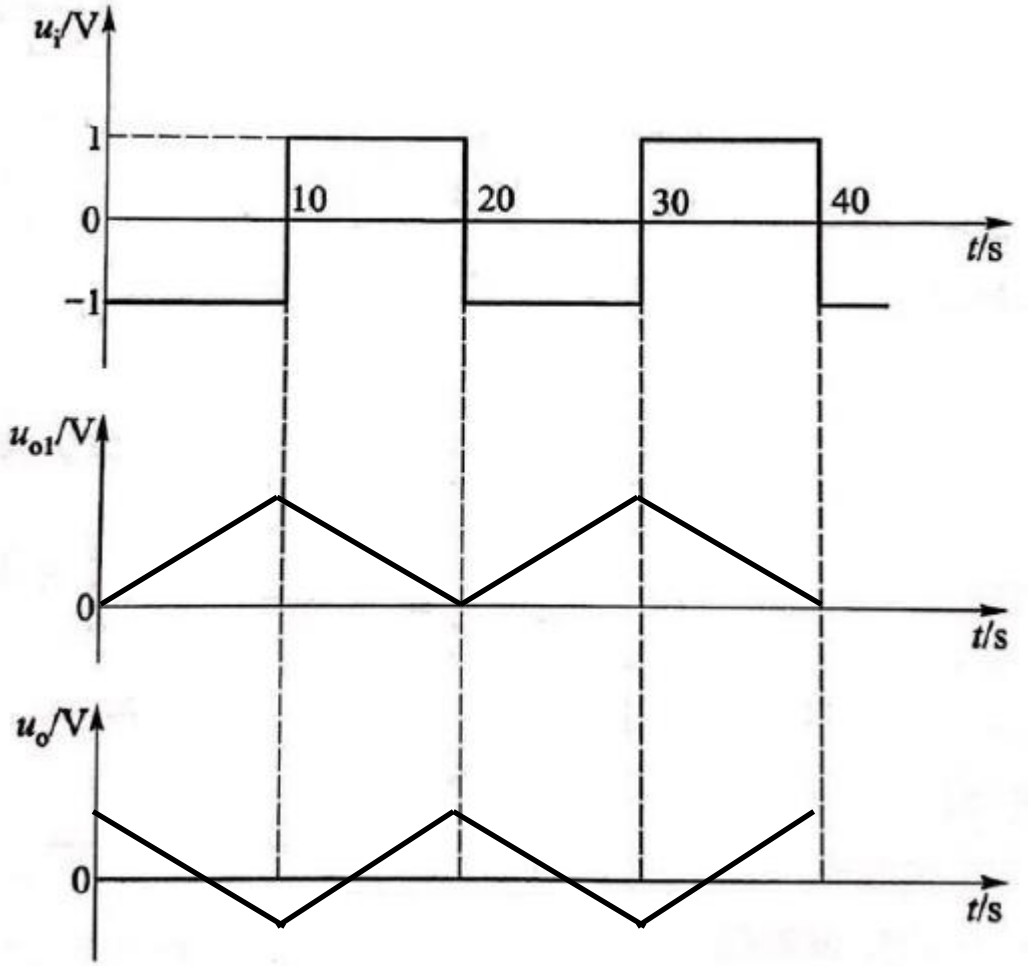
6-3 波形转换电路如图6-3（a）所示。若输入电压波形如图6-3（b）所示，试对应画出输出电压*uo的波形。设t=0时，电容两端的电压为0。*



(a)

$$u_{o1} = -\frac{1}{RC}\int_{t_0}^{t} u_i(t)dt + u_i(t_0) = -0.1\int_{t_0}^{t} u_i(t)dt + u_i(t_0)$$

$$u_o = -u_{o1} + 0.5$$


u_i/V
1
0
−1
10
20
30
40
t/s
u_{o1}/V
0
t/s
u_o/V
0
t/s

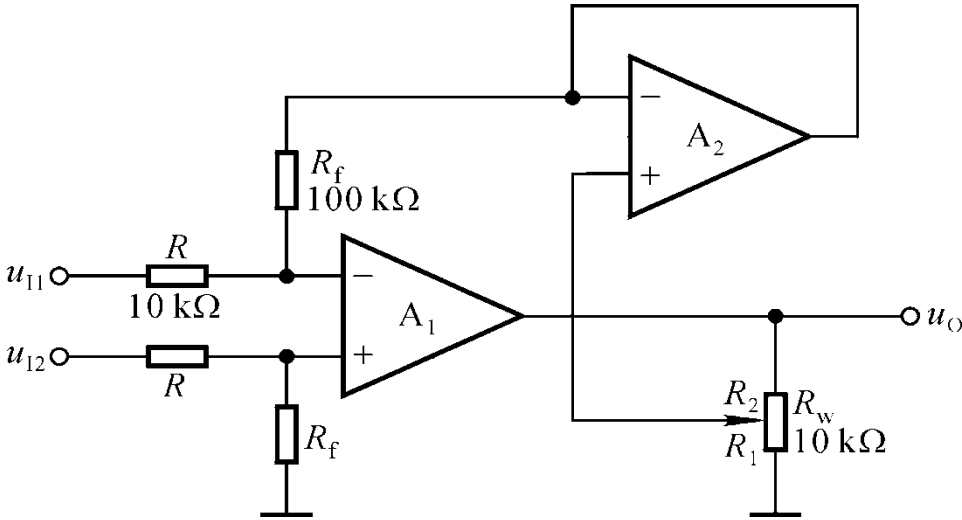
6-4 电路如图6-4所示，已知u_O的最大幅值为±14V。

1）写出u_O与u_{I1}、u_{I2}的运算关系式；

2）当R_W的滑动端在最上端时，若u_{I1}＝10mV，u_{I2}＝20mV，则u_O＝？

3）当输入电压最大值u_{I1max}＝10mV，u_{I2max}＝20mV，最小值均为0V，则为了保证集成运放工作在线性区，R_2的最大值为多少？

解答：



解：(1) A_2同相输入端电位

$$u_{P2} = u_{N2} = \frac{R_f}{R}(u_{I2} - u_{I1}) = 10(u_{I2} - u_{I1})$$

输出电压 $$u_O = (1 + \frac{R_2}{R_1}) \cdot u_{P2} = 10(1 + \frac{R_2}{R_1})(u_{I2} - u_{I1})$$

或 $$u_O = 10\frac{R_W}{R_1}(u_{I2} - u_{I1})$$

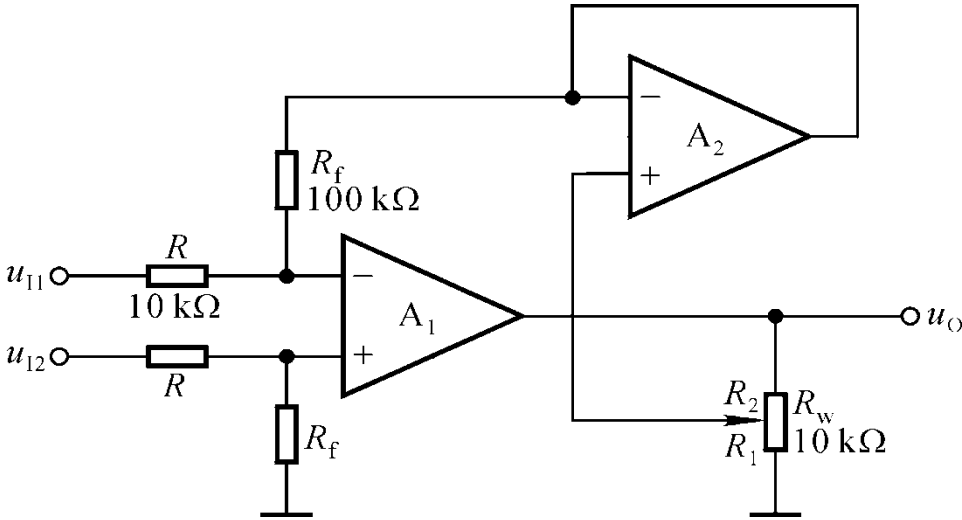
6-4 电路如图6-2所示，已知u_O的最大幅值为±14V。

1）写出u_O与u_{I1}、u_{I2}的运算关系式；

2）当R_W的滑动端在最上端时，若u_{I1}=10mV，u_{I2}=20mV，则u_O=？

3）当输入电压最大值u_{I1max}=10mV，u_{I2max}=20mV，最小值均为0V，则为了保证集成运放工作在线性区，R_2的最大值为多少？

解答：



(2) 将 $u_{I1}=10mV$， $u_{I2}=20mV$ 代入上式，得 $u_O=100mV$ 。

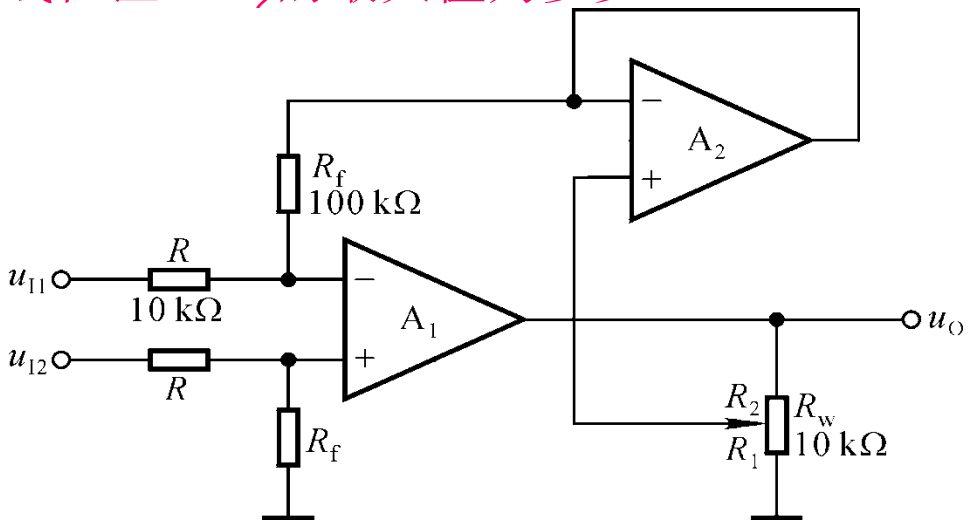
6-4 电路如图6-2所示，已知u_O的最大幅值为±14V。

1）写出u_O与u_{I1}、u_{I2}的运算关系式；

2）当R_W的滑动端在最上端时，若u_{I1}=10mV，u_{I2}=20mV，则u_O=？

3）当输入电压最大值u_{I1max}=10mV，u_{I2max} =20mV，最小值均为0V，则为了保证集成运放工作在线性区，R_2的最大值为多少？

解答：



(3) 根据题目所给参数，$(u_{I2}-u_{I1})$的最大值为 $20mV$ 。若 R_1 为最小值，则为保证集成运放工作在线性区，$(u_{I2}-u_{I1})$=$20mV$时集成运放的输出电压应为$+14V$ ，

写成表达式为 $$u_O=10\cdot\frac{R_W}{R_{1\min}}\cdot(u_{I2}-u_{I1})=10\cdot\frac{10}{R_{1\min}}\cdot 20=14$$

故 $R_{1\min}\approx 143\Omega$

$$R_{2\max}=R_W-R_{1\min}=(10-0.143)k\Omega\approx 9.86k\Omega$$

6-5 阻抗变换电路如图6-5所示，求输入阻抗*Zi*的表达式

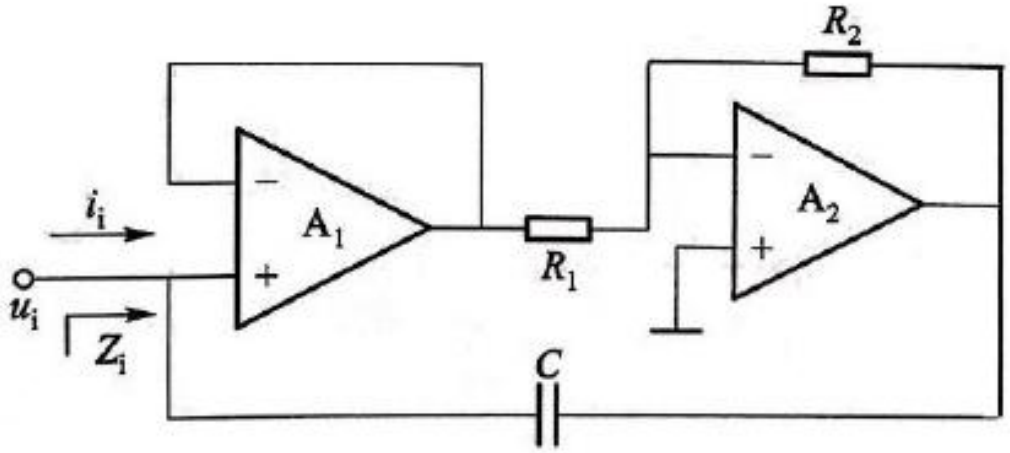


图 6-5

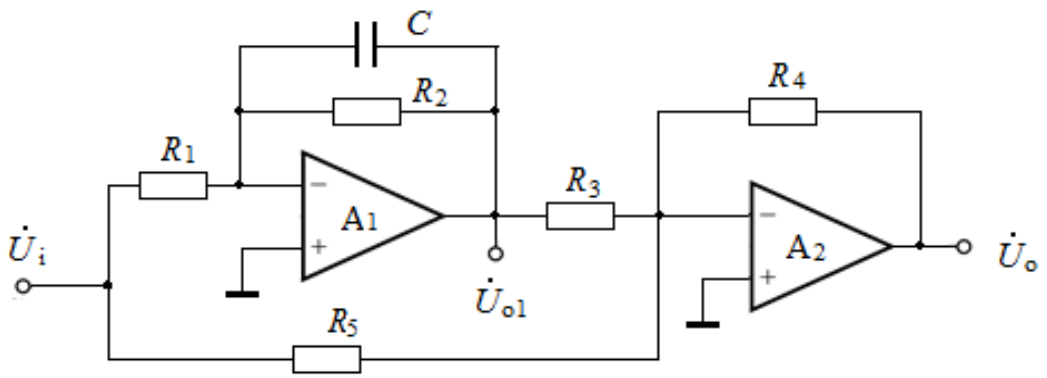
$$i_i = \frac{u_i - u_o}{1/\ jwC} = jwC(u_i + \frac{R_2}{R_1}u_i)$$

$$Z_i = \frac{u_i}{i_i} = \frac{1}{jwC(1+\frac{R_2}{R_1})}$$

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。

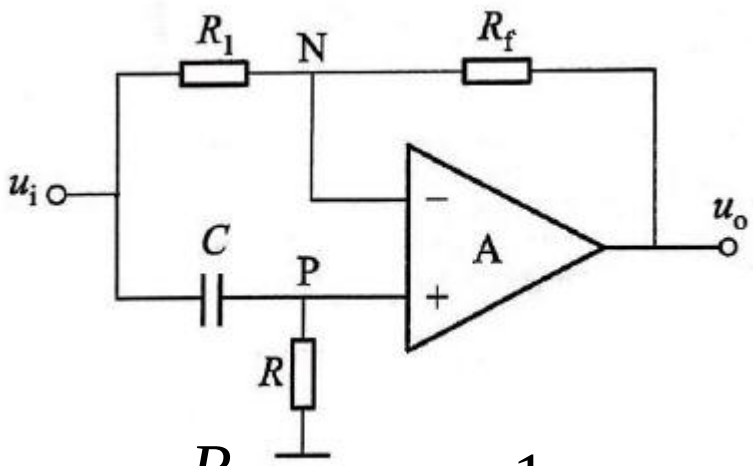
6-7

一阶全通滤波电路电路如图6-7所示。

1）写出电路的频率特性表达式。

2）分别求出幅频响应和相频响应，说明当ω由0→∞时，相角ψ的变化范围

$$\psi : -180^\circ \to 0^\circ$$



$$u_p = \frac{j\omega RC}{1+j\omega RC}u_i$$

$$u_o = -\frac{R_f}{R_1}u_i + (1+\frac{R_f}{R_1})u_p = -\frac{R_f}{R_1}u_i + (1+\frac{R_f}{R_1})(1-\frac{1}{1+j\omega RC})u_i$$

$$= (\frac{j\omega RC - \frac{R_f}{R_1}}{1+j\omega RC})u_i \qquad A_u = \frac{j\omega RC - \frac{R_f}{R_1}}{1+j\omega RC} = \frac{j\omega RC - 1}{j\omega RC + 1}$$