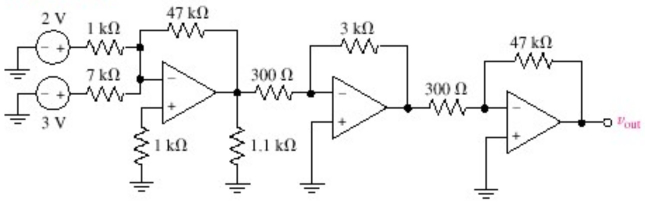
Example: For the cascaded op amp circuit shown in Fig. 6.40, compute the output voltage of each stage.

Figure 6.40



Solution: The output of the first op amp stage may be found by realising that the voltage at the non-inverting input (and hence the voltage at the inverting input) is 0, and writing a single nodal equation at the inverting input:

$$0 = \frac{0 - V_{out}\big|_{stage\,1}}{47} + \frac{0-2}{1} + \frac{0-3}{7}$$

which leads to $V_{out}\big|_{stage\,1} = -114.1V$

This voltage appears at the input of the second op amp stage, which has a gain of 3/ 0.3 = 10.

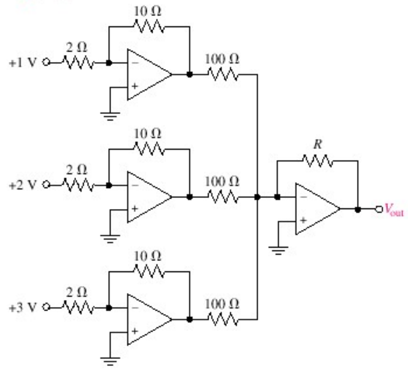
Thus, the output of the second op amp stage is −10(-114.1) = 1141 V.

This voltage appears at the input of the final op amp stage, which has a gain of 47/ 0.3 = 156.7.

Thus, the output of the circuit is −156.7(1141) =−178.8 kV.

Example: Referring to the op amp circuit of Fig. 6.41, what value of R is required to obtain V_{out} =10 V?

Figure 6.41



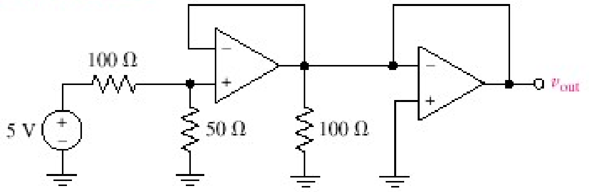
Solution: The output of the top left stage is
$-1(10/2) = -5$ V.
The output of the middle left stage is $-2(10/2) = -10$ V.
The output of the bottom right stage is $-3(10/2) = -15$ V.
These three voltages are the input to a summing amplifier such that

$$V_{out} = -\frac{R}{100}(-5-10-15) = 10V$$

Solving, we find that R = 33.33 Ω.

Example: Compute v_{out} for the two-stage op amp circuit of Fig. 6.42.

Figure 6.42



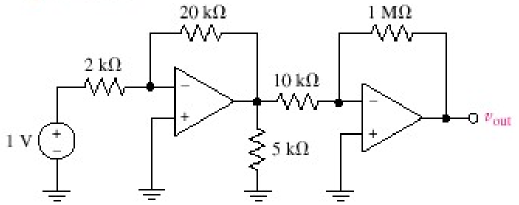
Solution: Stage 1 is configured as a voltage follower: the output voltage will be equal to the input voltage. Using voltage division, the voltage at the non-inverting input (and hence at the inverting input, as well), is

$$5\frac{50}{100+50} = 1.667 \text{ V}$$

The second stage is wired as a voltage follower also, so
$v_{out} = 1.667$ V.

Example: Compute v_{out} for the circuit of Fig. 6.38.

Figure 6.38

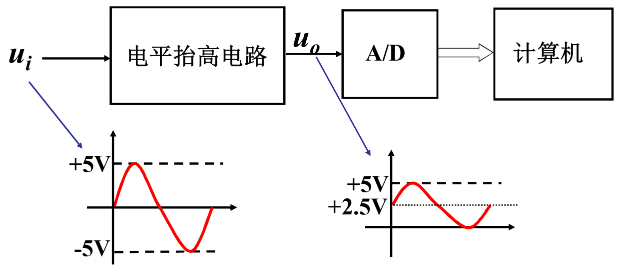


Solution: v_{out} of stage 1 is (1)(-20/ 2) = -10 V.

v_{out} of stage 2 is (-10)(-1000/ 10) = 1000 V

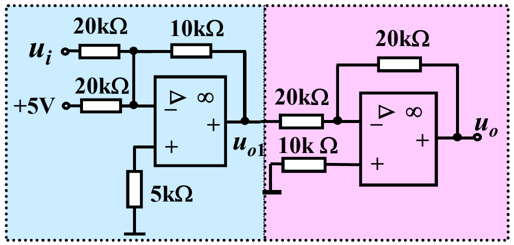
Note: ***in reality, the output voltage will be limited to a value less than that used to power the op amps.***

例：A/D变换器要求其输入电压的幅度为0～+5V，现有信号变化范围为-5V~+5V。试设计一电平抬高电路，将其变化范围变为0~+5V。



$$u_o = 0.5u_i + 2.5 \quad \text{V}$$

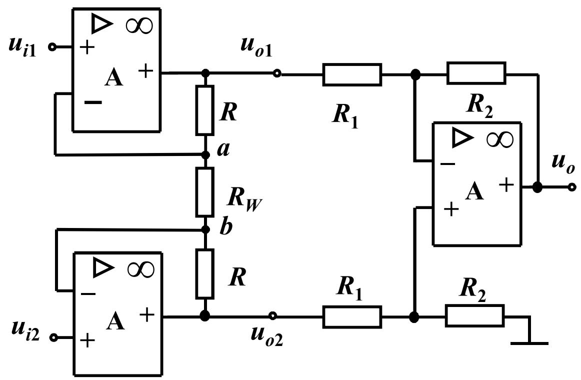
$$u_o = 0.5u_i + 2.5 \quad \text{V}$$
$$= 0.5\,(u_i + 5) \quad \text{V}$$

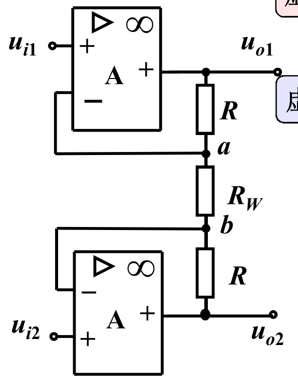


$$u_{o1} = -\frac{10}{20}\times(u_i + 5) = -0.5(u_i + 5)$$

$$u_o = -\frac{20}{20}\times u_{o1} = 0.5(u_i + 5)$$

五、三运放电路





虚短路：

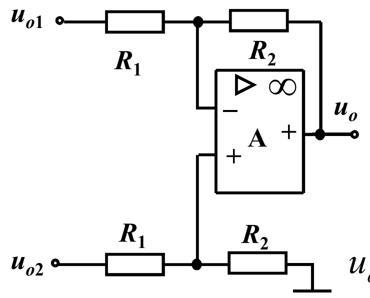
$$u_a = u_{i1} \qquad u_b = u_{i2}$$

虚开路：

$$\frac{u_{o1}-u_{o2}}{2R+R_W} = \frac{u_a-u_b}{R_W}$$

$$= \frac{u_{i1}-u_{i2}}{R_W}$$

$$u_{o2}-u_{o1} = \frac{2R+R_W}{R_W}(u_{i2}-u_{i1})$$

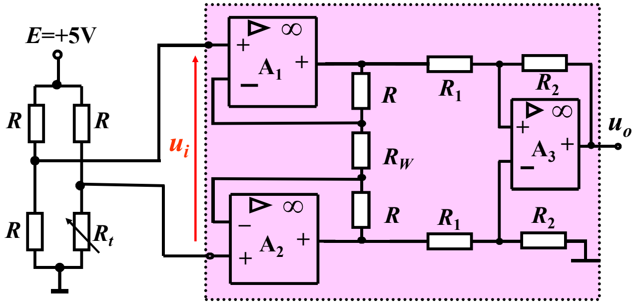


- 三运放电路是差动放大器，放大倍数可变。
- 由于输入均在同相端，此电路的输入电阻高。

$$u_o = \frac{R_2}{R_1}(u_{o2}-u_{o1})$$

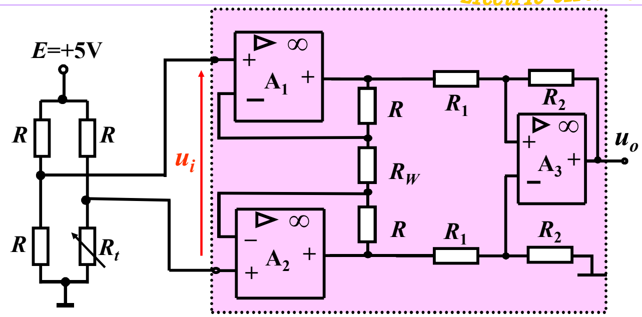
$$u_o = \frac{R_2}{R_1}\cdot\frac{2R+R_W}{R_W}(u_{i2}-u_{i1})$$

例：由三运放放大器组成的温度测量电路。



R_t：热敏电阻

集成化:仪表放大器

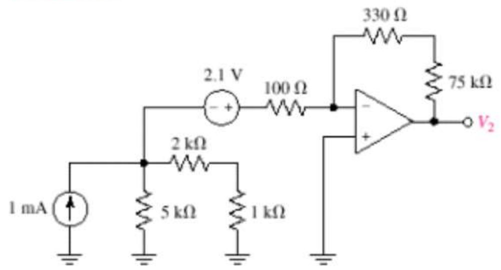


R_t=f (T° C) $\quad u_i = \frac{R_t}{R_t+R}E - \frac{E}{2} = \frac{R_t-R}{2(R_t+R)}E$

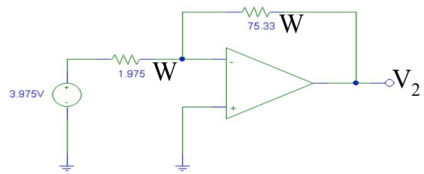
$$u_o = \frac{R_2}{R_1}\times\frac{2R+R_W}{R_W}u_i = \frac{R_2}{R_1}\times\frac{2R+R_W}{R_W}\times\frac{R_t-R}{2(R_t+R)}E$$

Example: For the circuit of Fig. 6.27, calculate the voltage V_2.

Figure 6.27



Solution: A source transformation and some series combinations are well worthwhile prior to launching into the analysis. With 5 kΩ || 3 kΩ = 1.875 kΩ and (1 mA)(1.875 kW) = 1.875 V, we may redraw the circuit as

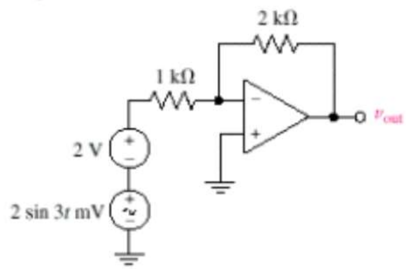


This is now a simple inverting amplifier with gain $-R_f / R_1$ = -75.33/ 1.975 = -38.14.

Thus, V_2 = -38.14(3.975) = -151.6 V.

Example: Find an expression for v_{out} in the circuit of Fig. 6.28, and evaluate it at t = 3 seconds.

Figure 6.28



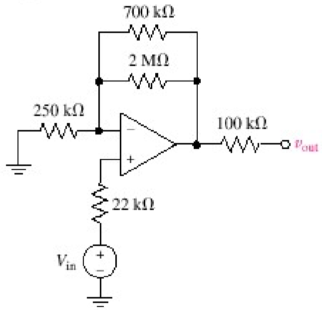
Solution: This is a simple inverting amplifier, so we may write

$$v_{\text{out}} = \frac{-2000}{1000}(2 + 2\sin 3t) = -4(1 + \sin 3t)\,\text{V}$$

$$v_{\text{out}}(t = 3\text{ s}) = -5.648\text{ V.}$$

Example: What value of V_{in} will lead to an output voltage of 18 V in the circuit of Fig.6.29?

Figure 6.29



Solution: We first combine the 2 MW and 700 kW resistors into a 518.5 kW resistor.

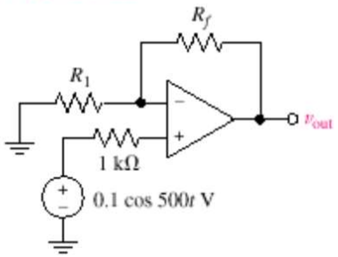
We are left with a simple non-inverting amplifier having a gain of

1 + 518.5/ 250 = 3.074. Thus,

$$v_{\text{out}} = (3.074)\, v_{\text{in}} = 18 \text{ so } v_{\text{in}} = 5.856\text{ V.}$$

Example: Choose R_1 and R_f in Fig. 6.30 to obtain $v_{out} = 23.7 \cos 500t$ volts.

Figure 6.30



Solution:

This is a simple non-inverting amplifier circuit, and so it has a gain of $1 + R_f / R_1$.

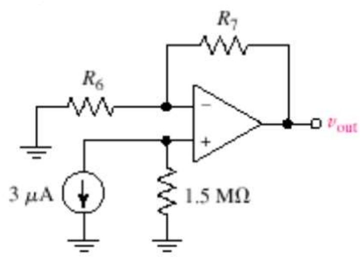
We want v_{out} = 23.7 cos 500*t* V when the input is 0.1 cos 500*t* V, so a gain of 23.7/0.1= 237 is required.

One possible solution of many:

R_f = 236 kW and R_1 = 1 kW.

Example: Derive an expression for v_{out} for the circuit of Fig. 6.31 without using source transformations.

Figure 6.31



Solution: Define a nodal voltage V_- at the inverting input, and a nodal voltage V_+ at the non-inverting input. Then,

At the non-inverting input: $-3\times10^{-6} = \dfrac{V_+}{1.5\times10^6}$

[1] Thus, V_+ = -4.5 V, and we therefore also know that V_- = -4.5 V.

At the inverting input: $0 = \dfrac{V_-}{R_6} + \dfrac{V_- - V_{out}}{R_7}$

[2] Solving and making use of the fact that V_- = -4.5 V,

$$v_{out} = -\frac{R_7}{R_6}(4.5) - 4.5 = -4.5\left(\frac{R_7}{R_6}+1\right) \text{ V}$$