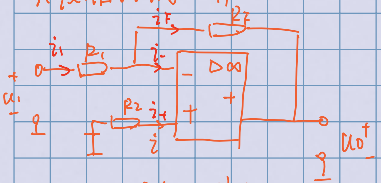
1.

集成运放电路在"饱和区"无"虚短"功能.
在线性区有虚短虚断.

16.2.1 比例运算

1.反相比例运算



①有平衡电阻

$R_2 = R_1 // R_F$

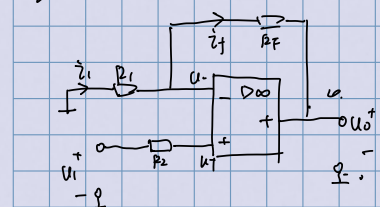
2.电压放大倍数

$i_+ = i_- = 0$　$i_1 = i_F$

$\therefore i_1 = \frac{u_i}{R_1}$　$i_F = \frac{-V_o}{R_F}$

$\therefore A_u = \frac{V_o}{u_i} = -\frac{R_F}{R_1}$

2.同相比例运算



平衡电阻 $R_2 = R_1 // R_F$

② 电压放大倍数.　同相输入放大比例为正数

虚断: $i_1 = i_f$

短: 且 $u_+ = u_- = u_i$

$i_f = \frac{u_o - u_i}{R_F}$　$i_1 = \frac{u_i}{R_1}$

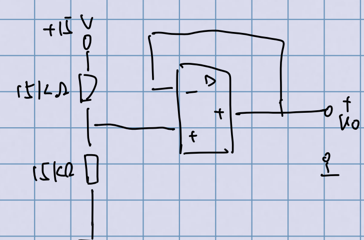
$\frac{u_o - u_i}{R_F} = \frac{u_i}{R_1} \Rightarrow$

$R_1 u_o - R_1 u_i = u_i R_F$

$R_1 u_o = u_i (R_F + R_1)$

$A_u = 1 + \frac{R_F}{R_1}$

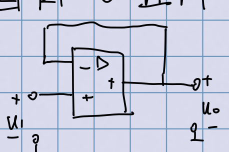
eg: 求 U_o



$u_o = 7.5V$

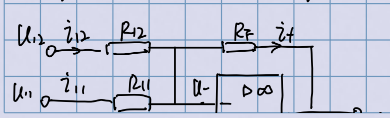
③ 电压跟随器.

当 $R_1 = \infty$ 且 $R_F = 0$ 时, 可得 $A_u = 1$, 得到下图



16.2.2 加法运算

1.反相加法运算



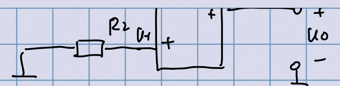
分析: $U_o = -[U_{i1} + U_{i2})$

平衡电阻 $R_2 = R_{11} // R_{12} // R_F$

电路特点

(1) 输入 R 低

(2) 共模 V 低



(3) 当改变某一路输入R时，对其他路无影响

虚短: $u_+=u_-=0$

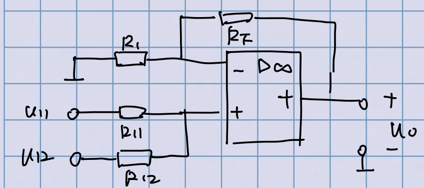
$i_{12}+i_{11}=i_f$

∵ $i_{12}=\frac{u_{i2}}{R_{12}}$ $i_{11}=\frac{u_{i1}}{R_{11}}$ $i_f=\frac{-u_o}{R_F}$

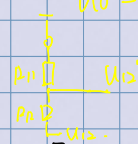
∴ $i_{12}+i_{11}=i_f \Rightarrow \frac{u_{i2}}{R_{12}}+\frac{u_{i1}}{R_{11}}=\frac{-u_o}{R_F}$

$\Rightarrow u_o=-R_F\left(\frac{u_{i2}}{R_{12}}+\frac{u_{i1}}{R_{11}}\right)$

2. 同相加法运算电路



$u_o=\left(1+\frac{R_F}{R_1}\right)\left(\frac{R_{12}}{R_{11}+R_{12}}u_{i1}+\frac{R_{11}}{R_{11}+R_{12}}u_{i2}\right)$



→同相比例

$u_o''=\left(1+\frac{R_F}{R_1}\right)\cdot u_+''$

$u_+'=u_{i1}\cdot\frac{R_{11}}{R_{12}+R_{11}}$

分析: 根据叠加原理

u_{i2}作用时: $u_o''=\left(1+\frac{R_F}{R_1}\right)\cdot\frac{R_{11}}{R_{12}+R_{11}}u_{i2}$

$u_o'=\left(1+\frac{R_F}{R_1}\right)\cdot\frac{R_{12}}{R_{11}+R_{12}}u_{i1}$

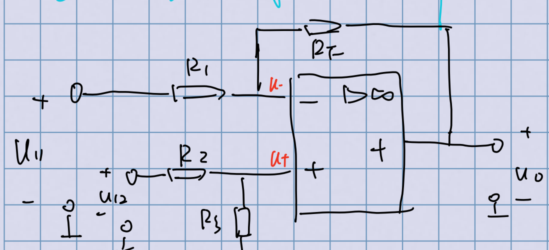
电路特点

(1) 输入R高

(2) 共模V高

(3) 改变某一路对其他有影响

16.2.3 减法运算



其中: $R_2//R_3=R_1//R_F$

分析: $u_+=\frac{R_3}{R_2+R_3}u_{i2}$

$u_-=u_{i1}-i_1R_1$

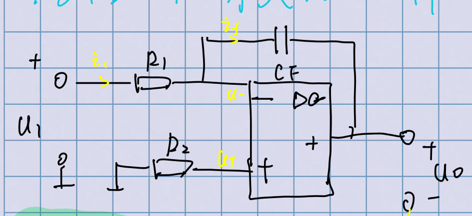
$=u_{i1}-\frac{u_{i1}-u_o}{R_1+R_F}R_1$

∵ $u_+=u_-$

$u_o=\left(1+\frac{R_F}{R_1}\right)\frac{R_3}{R_2+R_3}u_{i2}-\frac{R_F}{R_1}u_{i1}$

(同相加法 - 比例减法) ← 叠加原理

16.2.4 积分运算



分析: $i_1=i_F$

$i_1=\frac{u_i}{R_1}$ $i_F=C\frac{du_c}{dt}$

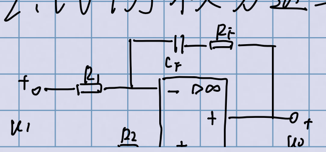
$\frac{u_i}{R_1}=C\frac{du_c}{dt}=-C\frac{du_o}{dt}$

$u_o=-\frac{1}{R_1C_F}\int u_i\,dt$

$C=\frac{Q}{U}$

↓

2. 比例积分运算电路



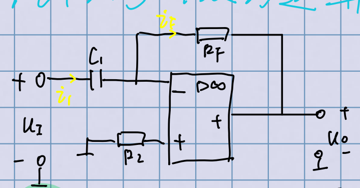
分析: $u_o=-(R_Fi_f+u_c)$

$=-\left(R_Fi_1+\frac{1}{C_F}\int i_1dt\right)$

$= -(\frac{R_F}{R_1}u_1 + \frac{1}{R_1C_F}\int u_1 dt)$

$$u_o = -(\frac{R_F}{R_1}u_1 + \frac{1}{R_1C_F}\int u_1 dt)$$

16.2.5 微分运算



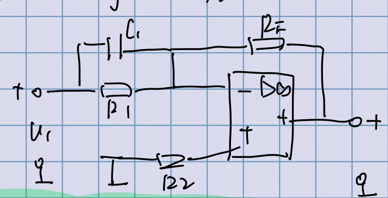
分析: $i_1 = i_F$

$C_1\frac{du_1}{dt} = -\frac{u_o}{R_F}$

$u_o = -R_FC_1\frac{du_1}{dt}$

$$u_o = -R_FC_1\frac{du_1}{dt}$$

2. 比例微分电路



分析: $u_o = -i_FR_F$

$i_F = i_C + i_R$

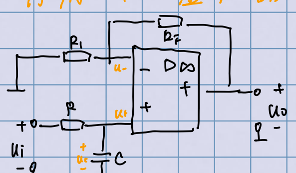
$= \frac{u_1}{R_1} + C_1\frac{du}{dt}$

$$u_o = -(\frac{R_F}{R_1}u_1 + R_FC_1\frac{du_1}{dt})$$

16.3 运算放大器在信号处理方面

16.3.1 有源滤波器

有源低通滤波器



分析: $u_+ = u_C = \frac{-j\frac{1}{wC}}{R-j\frac{1}{wC}}u_i = \frac{1}{1+jwRC}U_i$

$u_o = (1+\frac{R_F}{R_1})u_+$ ($w_0 = \frac{1}{RC}$ 截止角频率)

$\frac{u_o}{u_i} = \frac{1+\frac{R_F}{R_1}}{1+jwRC} = \frac{1+\frac{R_F}{R_1}}{1+j\frac{w}{w_0}}$

若w为变量

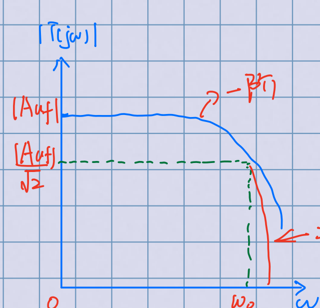
则 $\frac{u_o}{u_i} = \frac{A_{uf}}{1+\frac{j}{w_0}\cdot w} = T(jw)$

其模为 $|T(jw)| = \frac{|A_{uf}|}{\sqrt{1+(\frac{w}{w_0})^2}}$

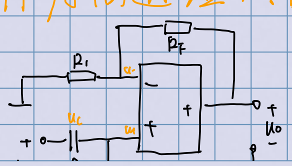
当 $w=0$ 时 $|T(jw)| = |A_{uf}|$

当 $w=w_0$ 时 $|T(jw)| = \frac{|A_{uf}|}{\sqrt{2}}$

当 $w=\infty$ 时 $|T(jw)| = 0$

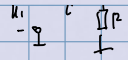


有源高通滤波器



分析: $u_+ = \frac{R}{R-j\frac{1}{wC}}U_i$

$u_o = (1+\frac{R_F}{R_1})u_+$



$$\dot{T}(j\omega)=\frac{U_o}{U_i}=\frac{1+\frac{R_F}{R_1}}{1+\frac{1}{j\omega RC}}=\frac{A_{uf}}{1-j\frac{\omega_0}{\omega}}$$

当 $\omega=0$ 时 $|\dot{T}(j\omega)|=0$

当 $\omega=\omega_0$ 时 $|\dot{T}(j\omega)|=\frac{|A_{uf}|}{\sqrt{2}}$

当 $\omega=\infty$ 时 $|\dot{T}(j\omega)|=A_{uf}$