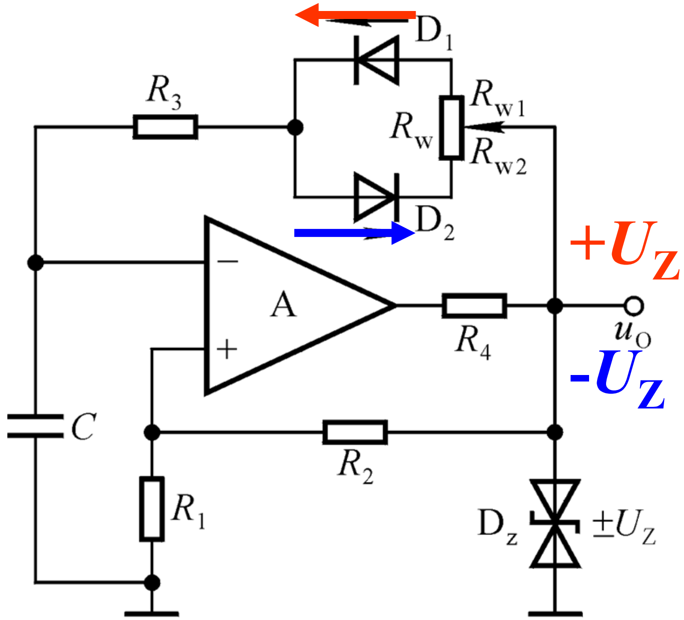
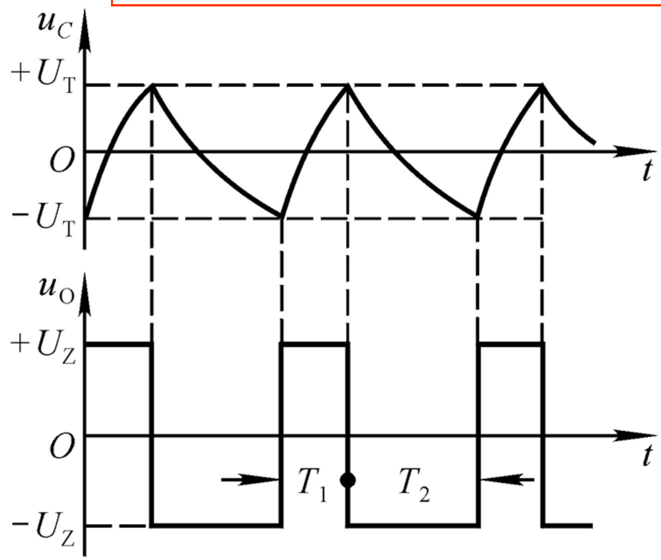
2. 占空比可调的矩形波发生电路

改变电容充放电回路的时间常数

$$占空比q=\frac{T_1}{T}=\frac{R_3+R_{W1}}{2R_3+R_W}$$





$$\tau_{充}\approx(R_3+R_{W1})C$$

$$T_1\approx\tau_{充}\ln(1+\frac{2R_1}{R_2})\qquad T_2\approx\tau_{放}\ln(1+\frac{2R_1}{R_2})$$

$$\tau_{放}\approx(R_3+R_{W2})C$$

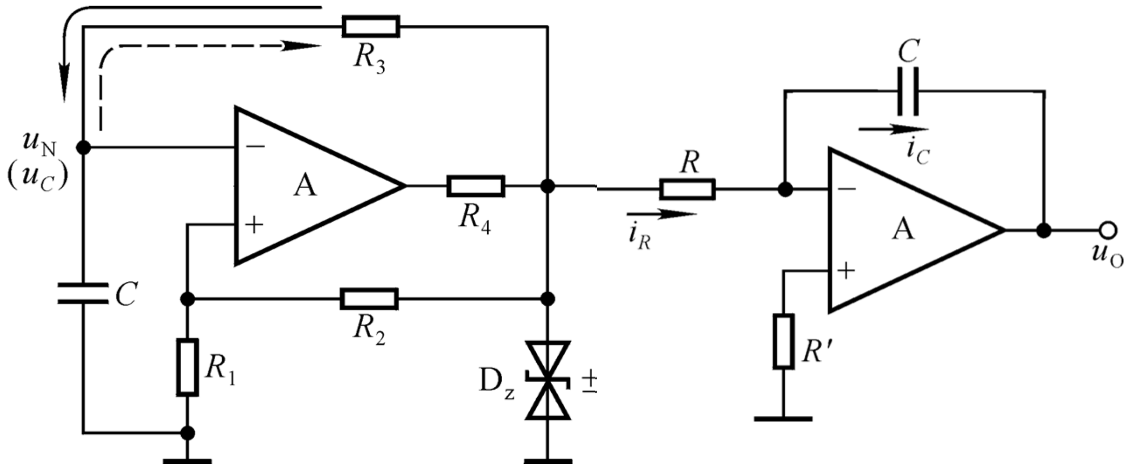
一阶*RC*电路的三要素法

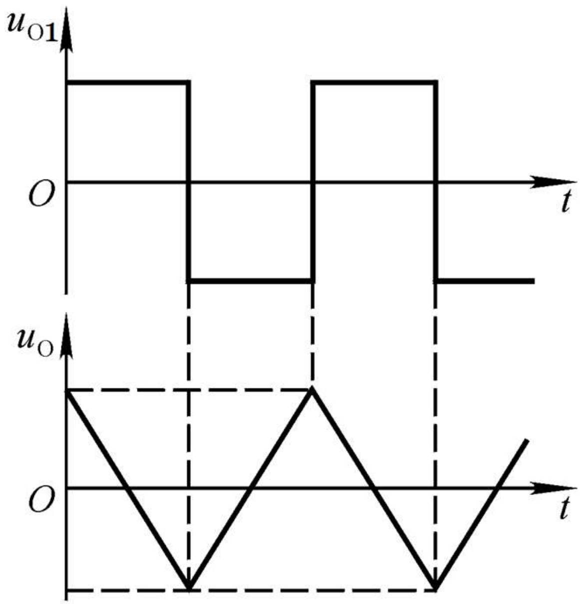
$$T\approx(2R_3+R_W)C\ln(1+\frac{2R_1}{R_2})$$

周期不变，占空比改变

二、三角波发生电路

方波发生电路＋积分电路：三角波幅值随方波周期而变化

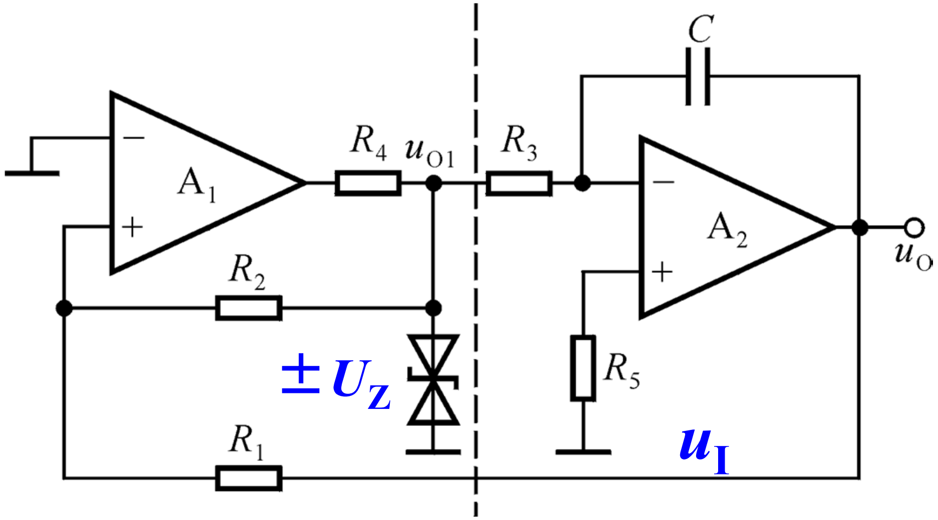


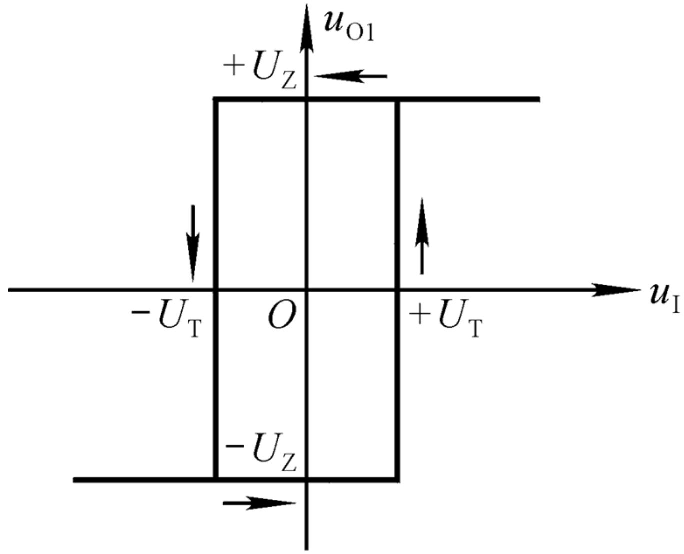


$$u_O = -\frac{1}{RC}\int u_I \mathrm{d}t$$

二、三角波发生电路

1. 基本电路

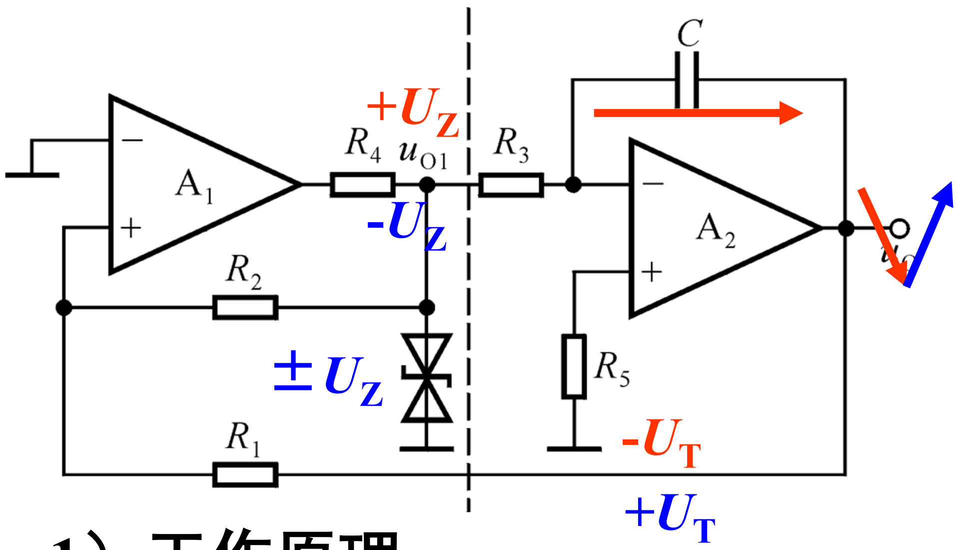


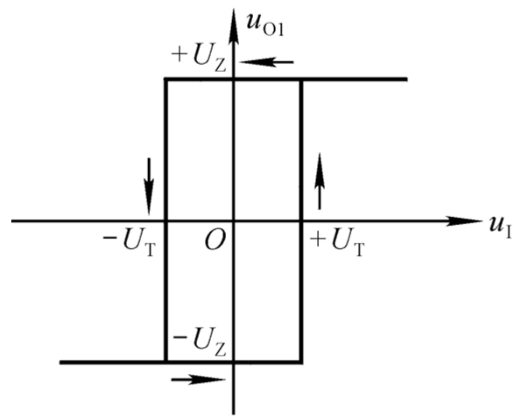


同相滞回比较器＋积分电路

开关＋延迟环节

$$\pm U_T = \pm \frac{R_1}{R_2} U_Z$$





1）工作原理

- 设某一时刻u_{O1}=+U_Z，则阈值为-U_T

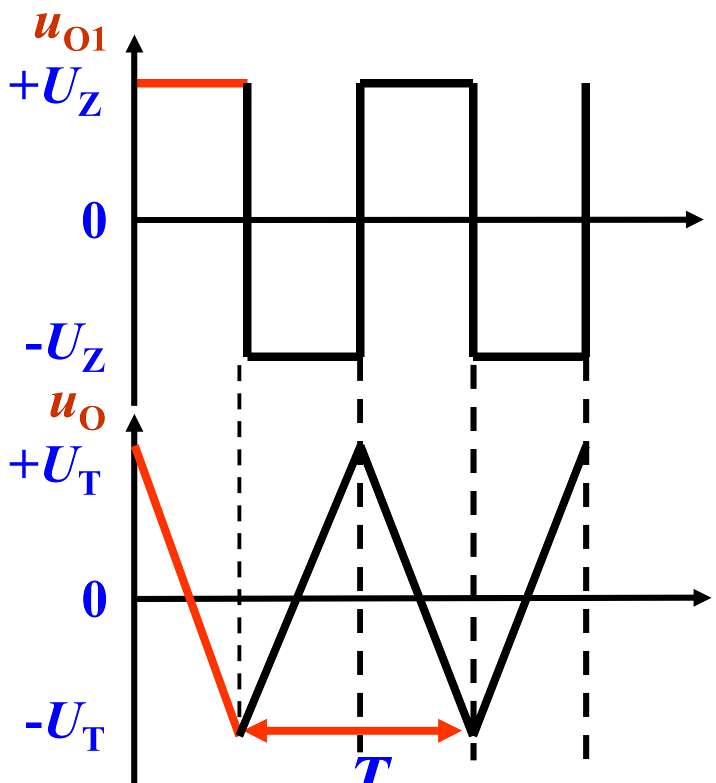
  u_{O1}通过积分电路被积分，u_O↓

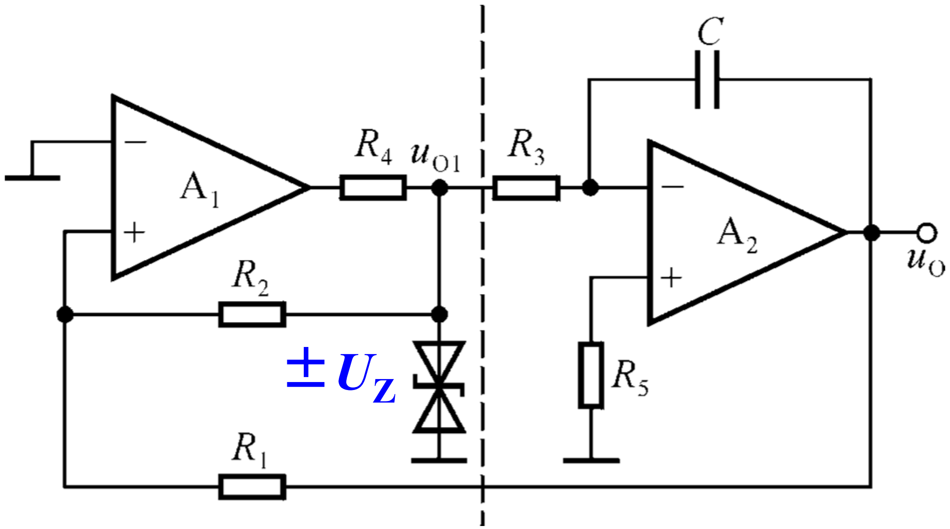
  当u_O = -U_T时，u_{O1}=-U_Z
- u_{O1}=-U_Z，则阈值为+U_T

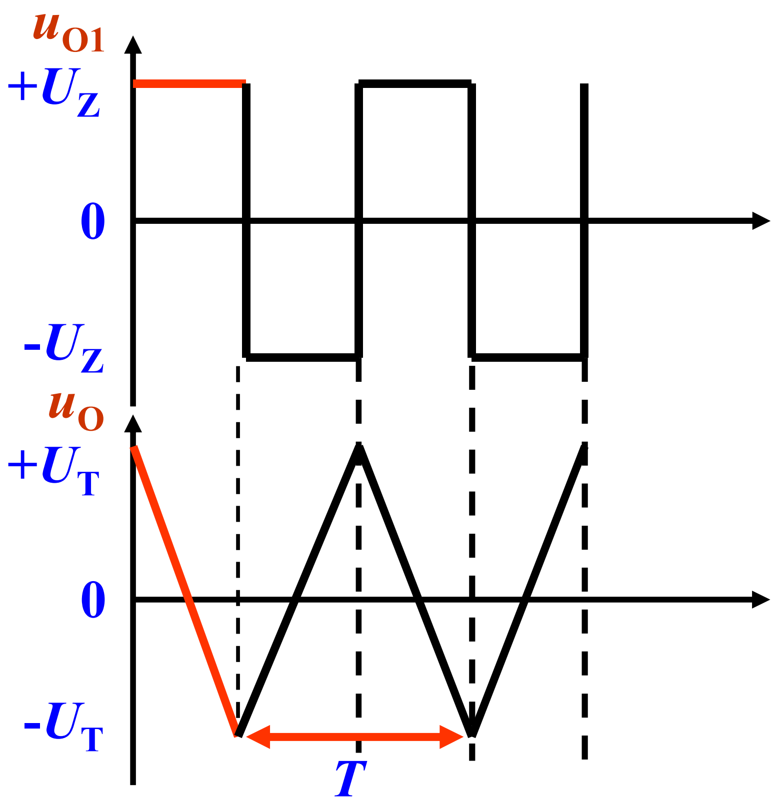
  u_{O1}通过积分电路被积分，u_O↑

  当u_O = +U_T时，u_{O1}=+U_Z

2）波形分析







3）周期分析

$$U_T = -\frac{1}{R_3 C}(-U_Z)\frac{T}{2} - U_T$$

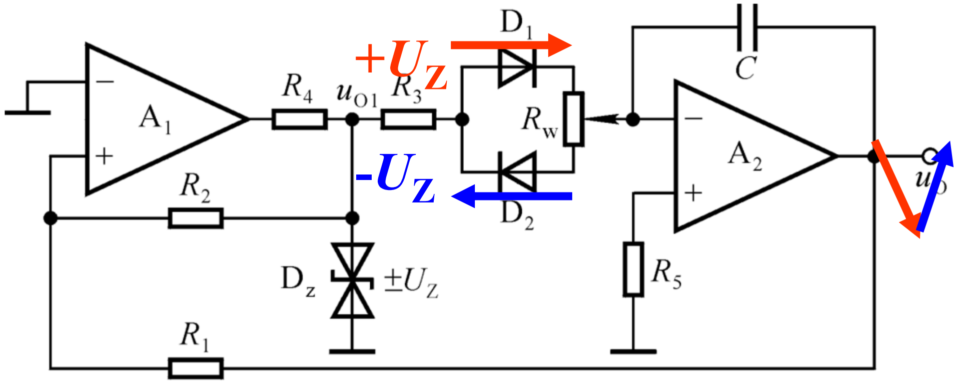
$$\pm U_T = \pm \frac{R_1}{R_2} U_Z \qquad \boxed{T = \frac{4R_1 R_3 C}{R_2}}$$

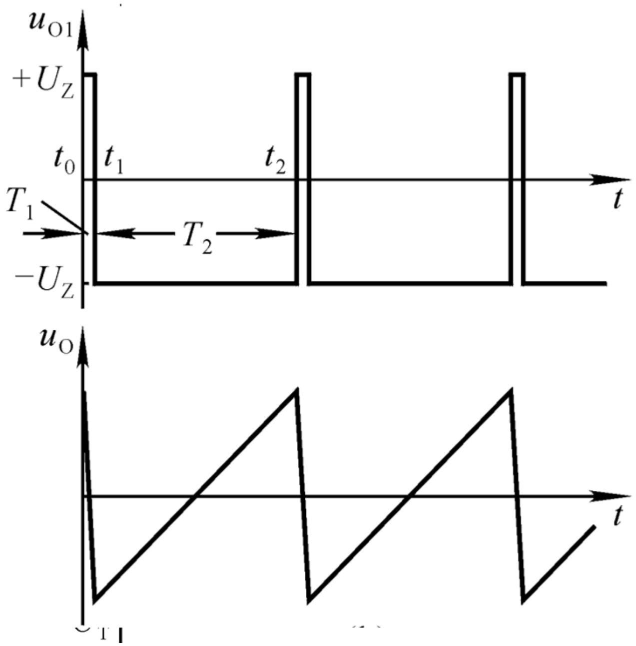
问题讨论：

- 如何调节三角波幅值？如何调节周期？
- 如何使三角波沿纵轴移动？
- 用反相输入滞回比较器能否实现？

2. 锯齿波发生电路

改变电容充放电回路的时间常数





R_W滑动端位于上方

$$\tau_{充} \approx (R_3 + R_{W上})C$$

$$-U_T = -\frac{1}{\tau_{充}} U_Z T_1 + U_T$$

$$T_1 = 2\frac{R_1}{R_2}\tau_{充}$$

$$\tau_{放} \approx (R_3 + R_{W下})C$$

$$T_2 = 2\frac{R_1}{R_2}\tau_{放}$$

$$\boxed{T = T_1 + T_2 = 2\frac{R_1}{R_2}(2R_3 + R_W)C}$$

占空比 $q = \dfrac{T_1}{T} = \dfrac{R_3 + R_{W上}}{2R_3 + R_W}$

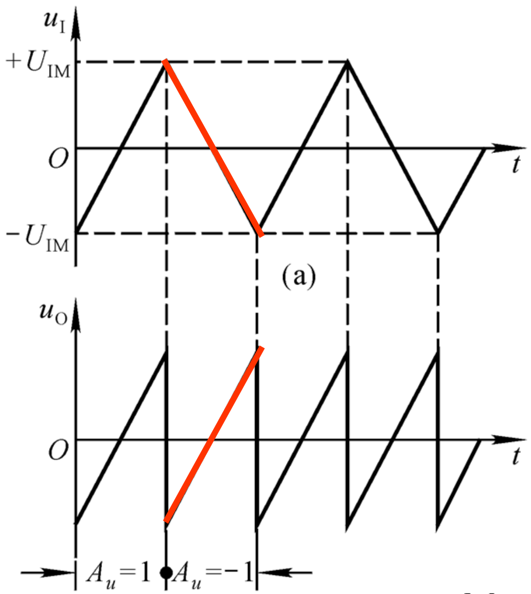
周期不变，占空比改变

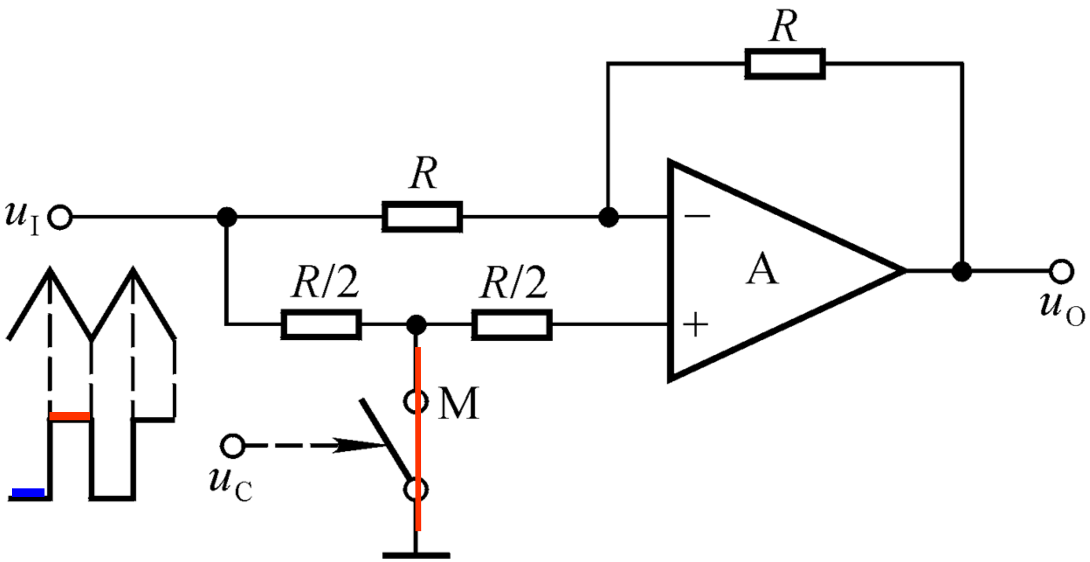
三、波形变换电路

一般周期信号 $\xrightarrow{\text{电压比较器}}$ 方波、矩形波 $\xrightarrow{\text{积分电路}}$ 三角波、锯齿波

三角波 $\xrightarrow{\text{波形变换电路}}$ 锯齿波、正弦波

1. 三角波变锯齿波电路



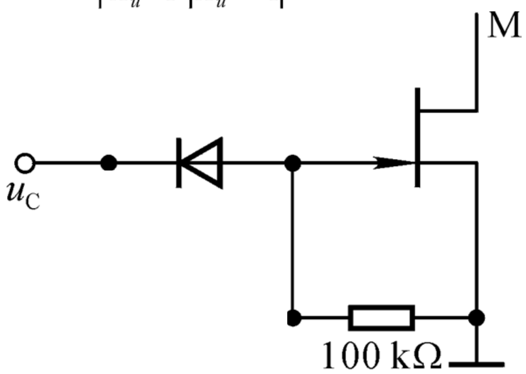


三角波上升沿，开关断开

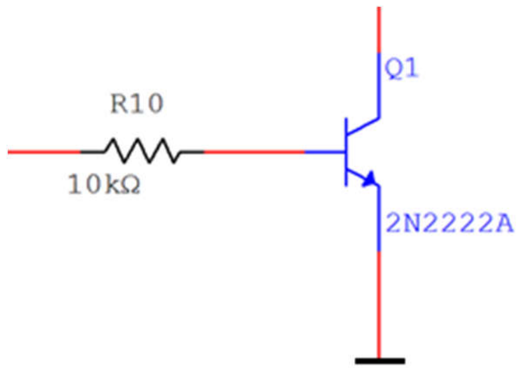
$$\boxed{u_O = u_I}$$

三角波下降沿，开关闭合

$$\boxed{u_O = -u_I}$$



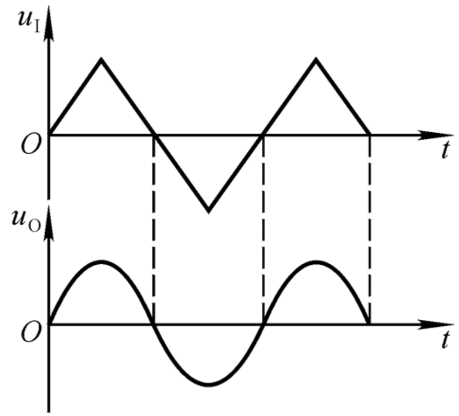
电子开关电路



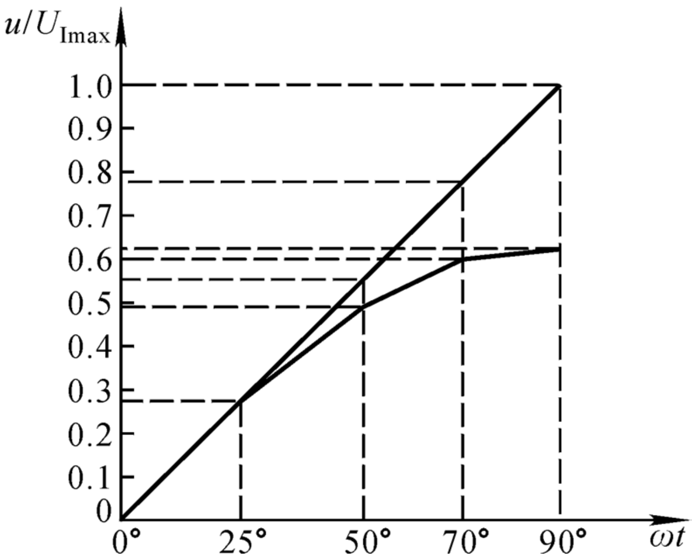
2. 三角波变正弦波电路

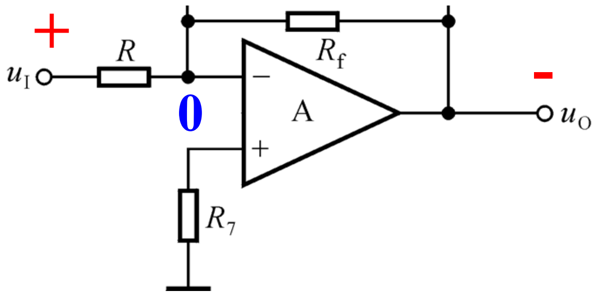
1) 滤波法

(a)



2) 折线法

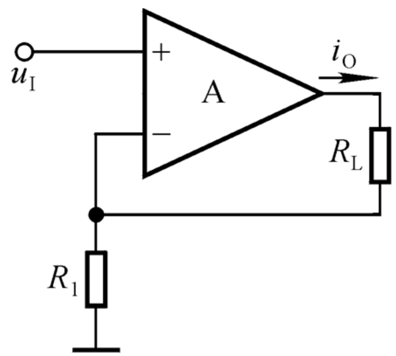




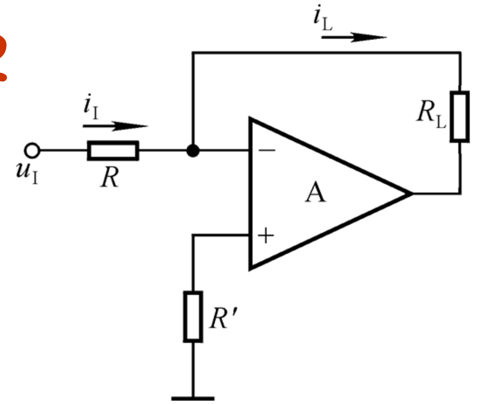
8.3 信号转换电路 (Signal Converter)

一、 u-i 转换电路

电路1



电路2



引入了电流串联负反馈

$$\boxed{i_{\mathrm{O}} = \frac{u_{\mathrm{I}}}{R}, \quad R_{\mathrm{i}} = \infty}$$

R_{i}大

引入了电流并联负反馈

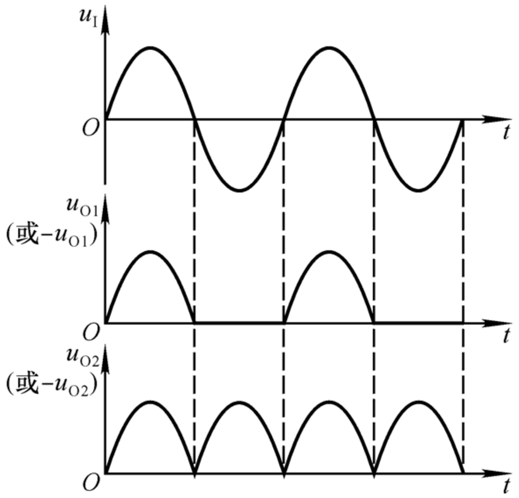
$$\boxed{i_{\mathrm{L}} = -\frac{u_{\mathrm{I}}}{R}, \quad R_{\mathrm{i}} = R}$$

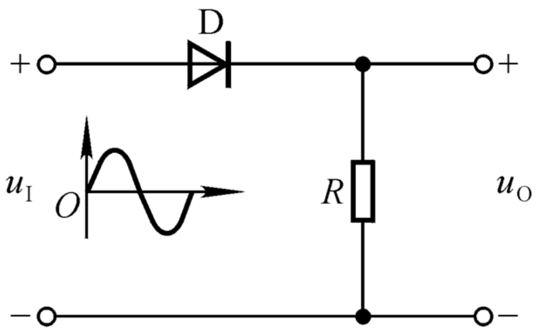
运放$U_{\mathrm{IC}}=0$

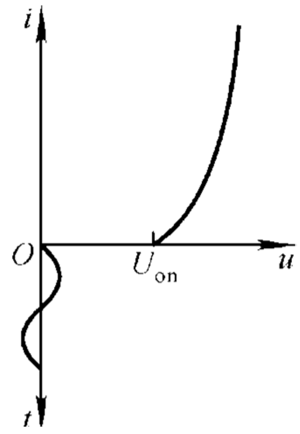
问题：若负载需接地，则上述两电路均不符合要求。

二、精密整流电路

精密整流电路是信号处理电路，实现交流小信号的整流，即将交流小信号转换为直流信号。



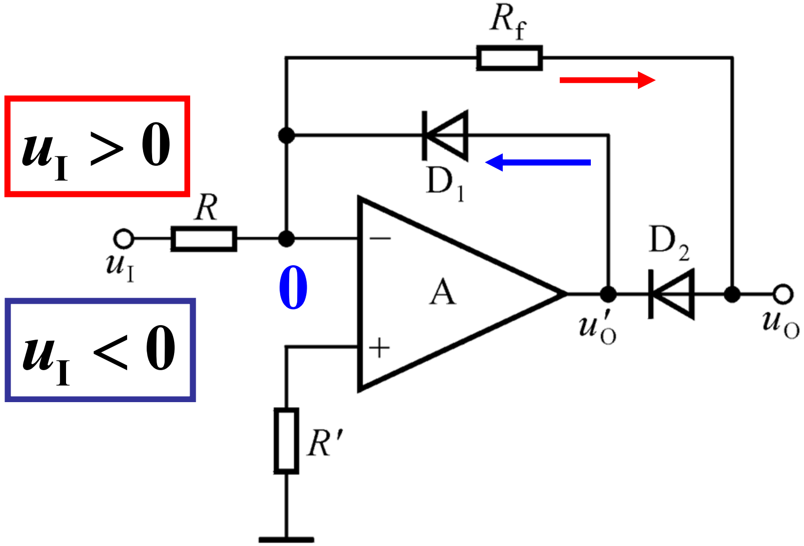




问题：输出信号失真

- 若$u_{Imax}<U_{on}$，则在u_I的整个周期中u_O始终为零；
- 若$u_{Imax}>U_{on}$，则u_O仅在大于U_{on}时近似为u_I，输出失真。

1. 半波精密整流电路

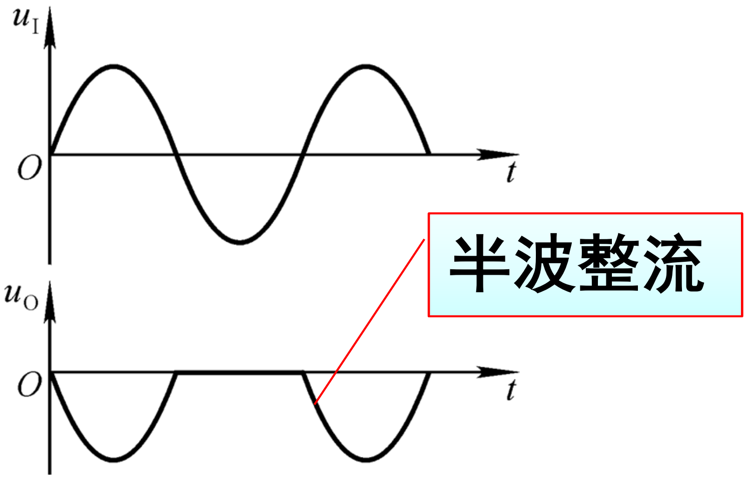


设$R = R_f$

关键是判断二极管工作状态

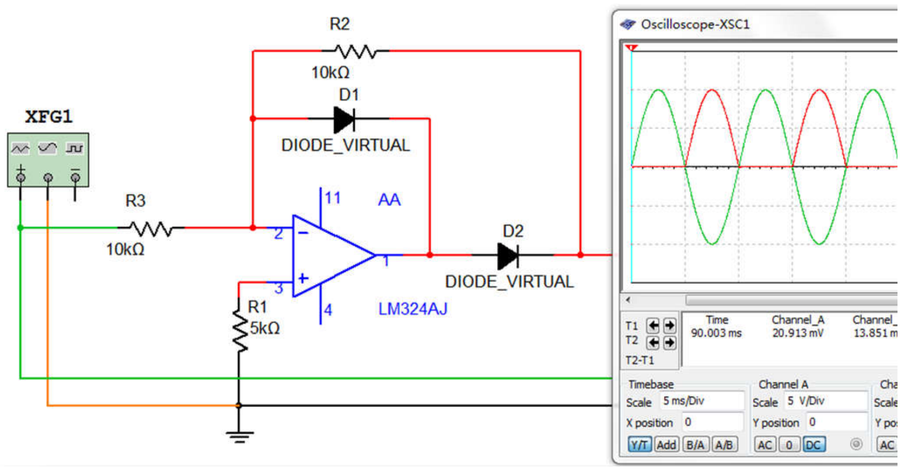
$u_I > 0$时，$u_O' < 0$，D_1截止，D_2导通，$u_O = -u_I$。

$u_I < 0$时，$u_O' > 0$，D_2截止，D_1导通，$u_O = 0$。

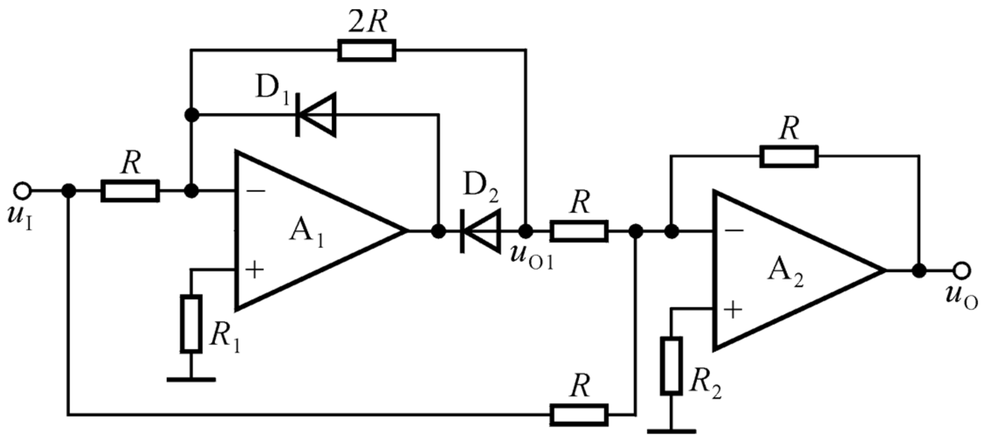


思考：如何得到正半波？

实现全波整流？



2. 全波精密整流电路



思考：如何得到直流电压？

设$R_f = 2R$

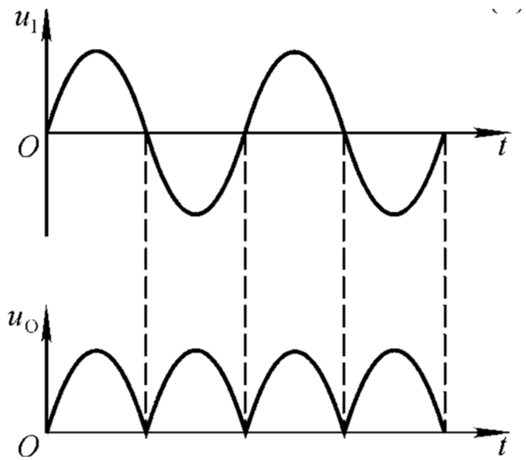
$$\begin{cases} u_{O1} = -2u_I & (u_I > 0) \\ u_{O1} = 0 & (u_I < 0) \end{cases}$$

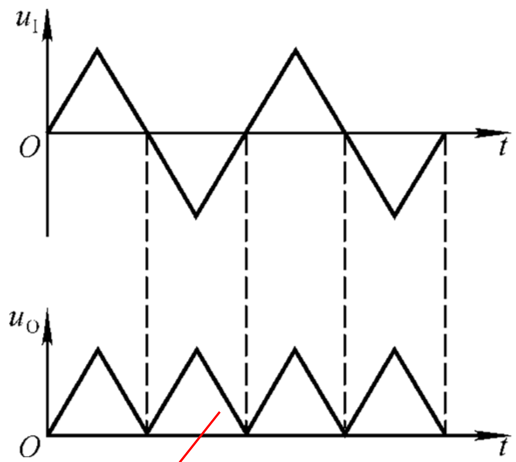
$$u_O = -u_{O1} - u_I$$

$u_I > 0$时， $u_O = u_I$

$u_I < 0$时， $u_O = -u_I$

$$u_O = |u_I|$$

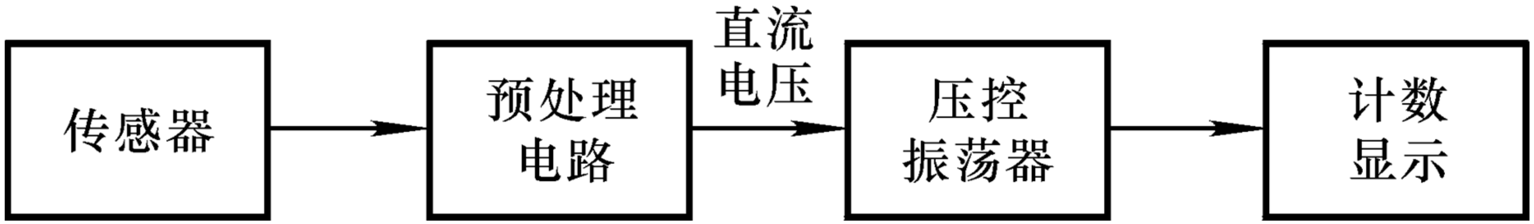




绝对值运算电路

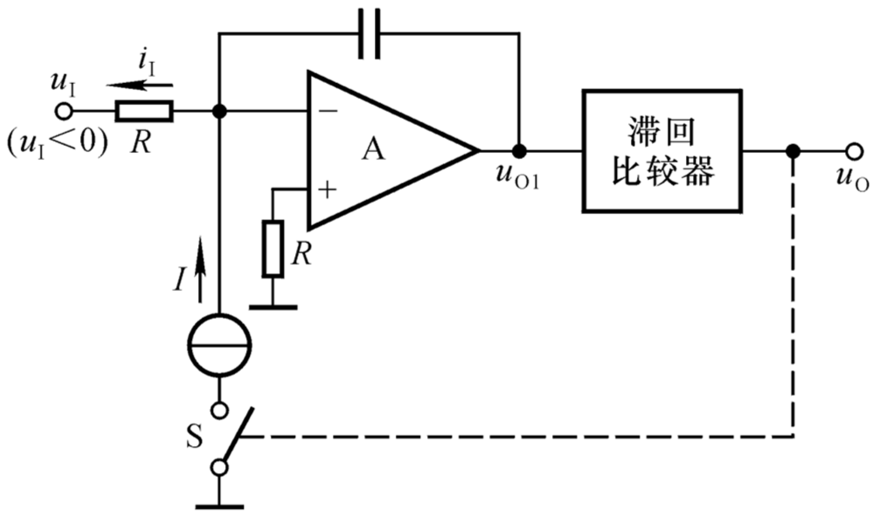
二倍频三角波

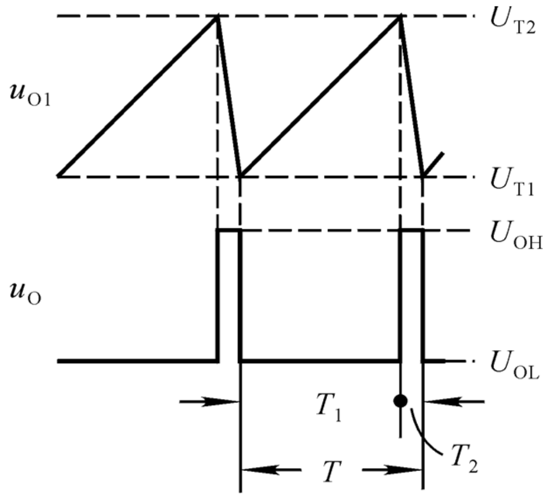
三、电压—频率转换电路



数字式测量仪表

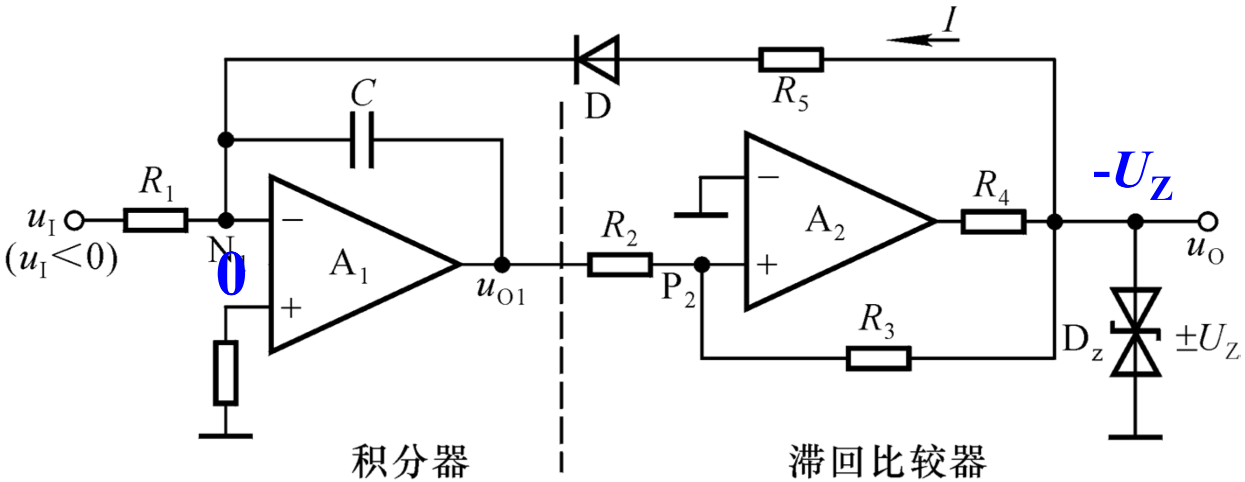
1. 电荷平衡式V-F转换电路





(b)

压控振荡器组成：积分电路、滞回比较器、电子开关



积分电路+同相输入滞回比较器

二极管相当于开关

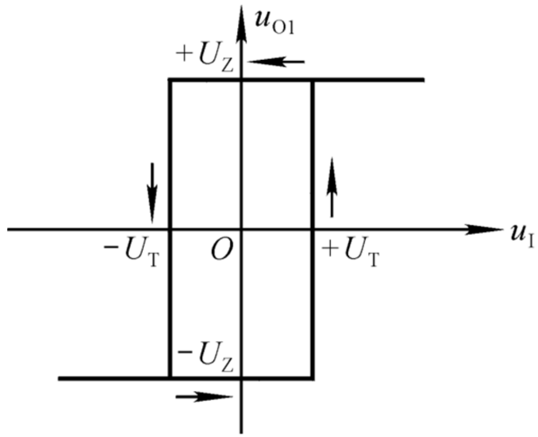
$\boxed{R_5 << R_1}$

- **设初始时刻u_O=-U_Z，则阈值为+U_T**

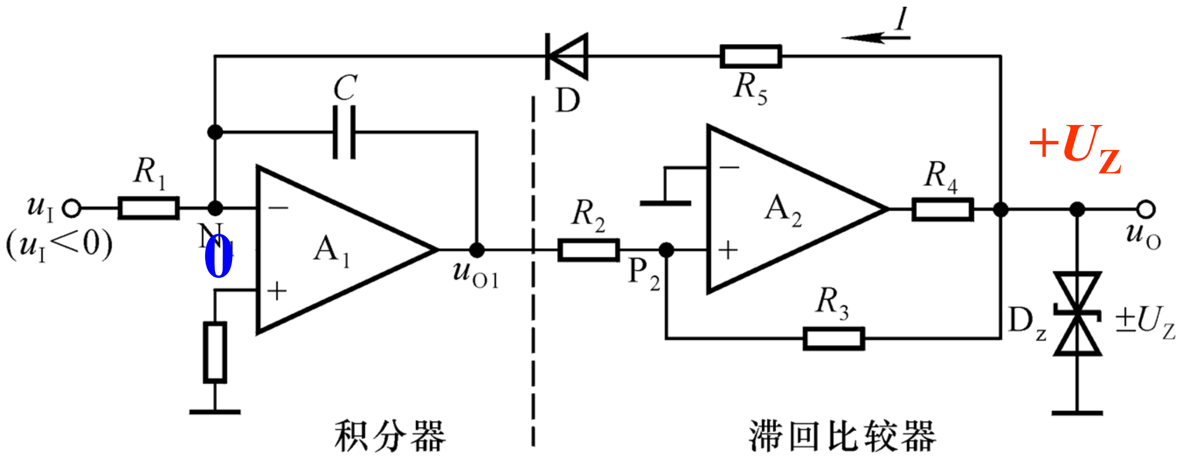
D截止，u_I通过积分电路被积分，u_{O1}↑

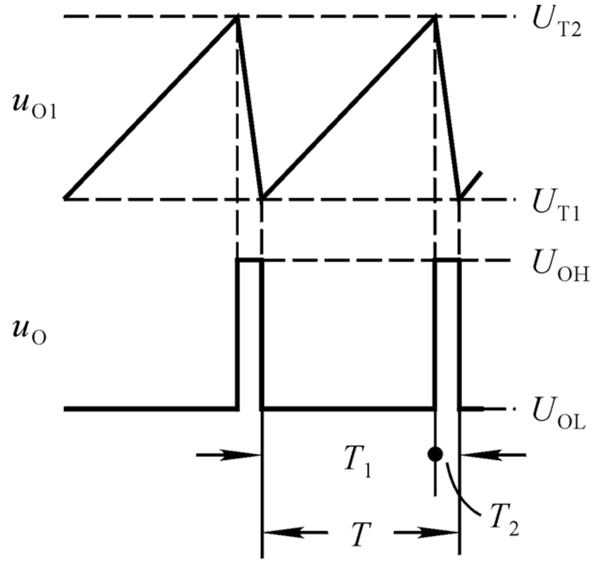
当u_{O1} = +U_T时，u_O=+U_Z

$$u_{O1} = -\frac{1}{R_1 C} u_I (t_1 - t_0) + u_{O1}(t_0)$$



$$\pm U_T = \pm \frac{R_2}{R_3} U_Z$$





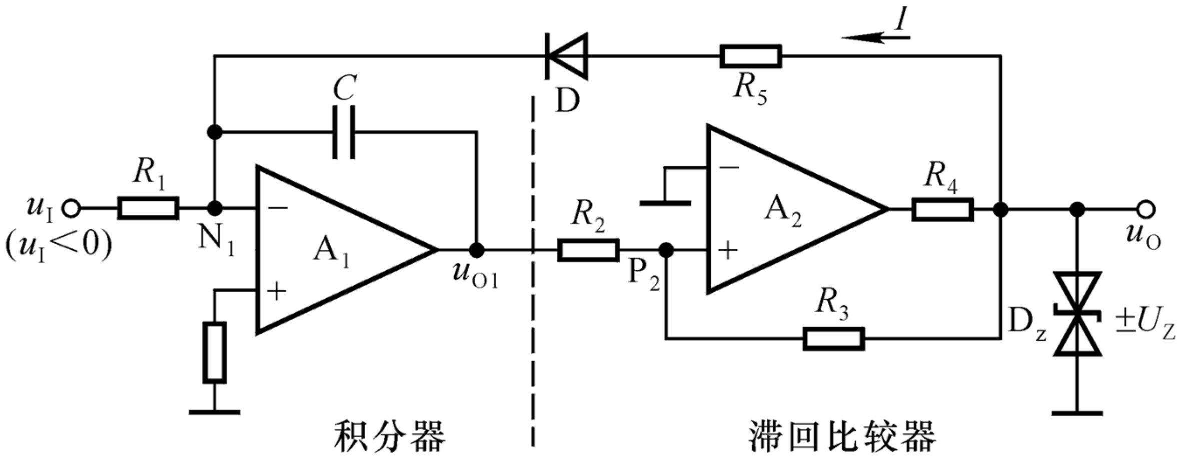
- **$u_O = +U_Z$，则阈值为 $-U_T$**

D导通，u_I与u_O通过积分电路被积分，$u_{O1}\downarrow$

当$u_{O1} = -U_T$时，$u_O = -U_Z$

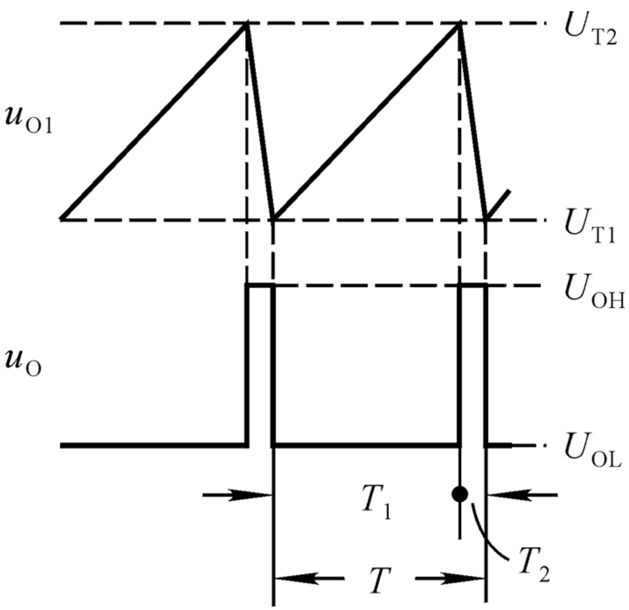
$$u_{O1} = -\frac{1}{R_1 C} u_I (t_2 - t_1) - \frac{1}{R_5 C} U_Z (t_2 - t_1) + u_{O1}(t_1) \qquad R_5 << R_1$$

$$u_{O1} \approx -\frac{1}{R_5 C} U_Z (t_2 - t_1) + u_{O1}(t_1)$$



问题1：u_I>0，电路如何设计？

问题2：如何提高精度？



$$+U_T = -\frac{1}{R_1 C} u_I T_1 - U_T$$

$$\boxed{\pm U_T = \pm \frac{R_2}{R_3} U_Z}$$

$$T \approx T_1 = \frac{2R_1R_2C}{R_3} \cdot \frac{U_Z}{u_I}$$

$$\boxed{f \approx \frac{R_3}{2R_1R_2C} \cdot \frac{u_I}{U_Z}}$$