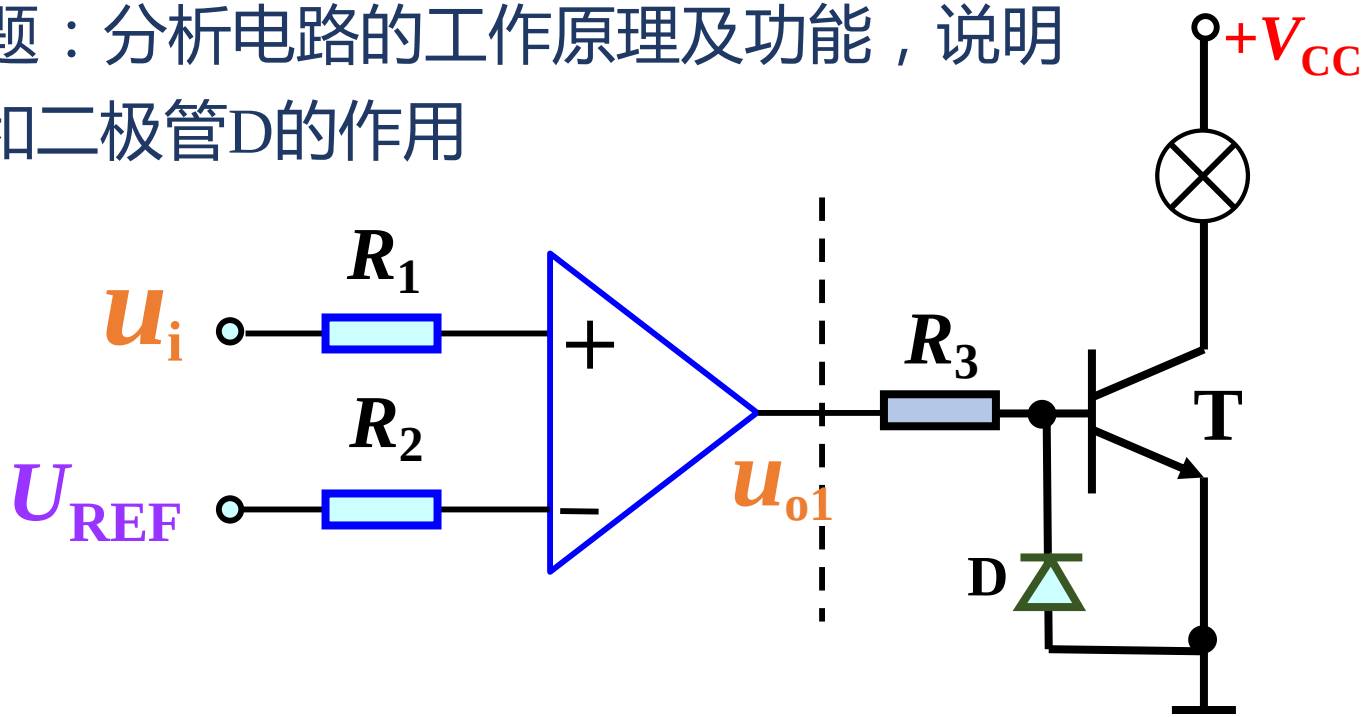
7.2.2 单限比较器

例题：分析电路的工作原理及功能，说明R_3和二极管D的作用



$u_i < U_{REF}$　$u_{o1}=0$　D导通，T截止，灯不亮

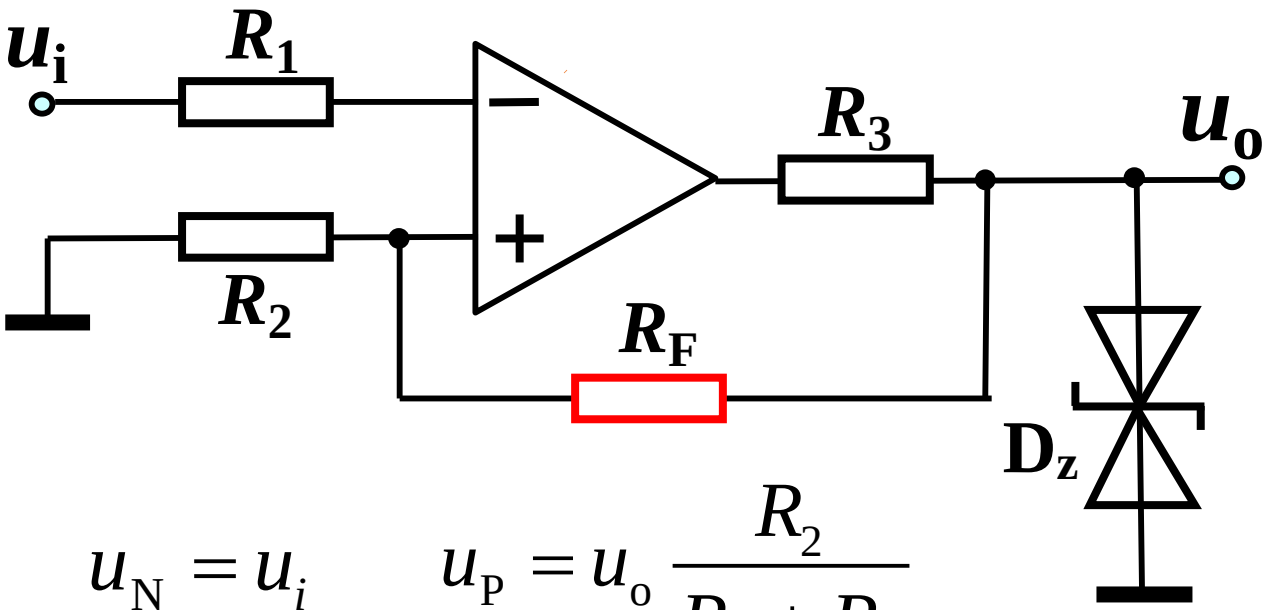
$u_i > U_{REF}$　$u_{o1}=1$　D截止，T饱和，灯亮

报警电路

D是保护二极管，把三极管发射结反向电压限制在U_D，从而保护三极管不被反向击穿。

电阻R_3决定了三极管基极的驱动电流，$I_B=(U_{OM}-U_{BE})/R_3$，I_B的大小是三极管能进入饱和状态的关键因素。

7.2.3 滞回比较器



$$u_N = u_i \qquad u_P = u_o \frac{R_2}{R_F + R_2}$$

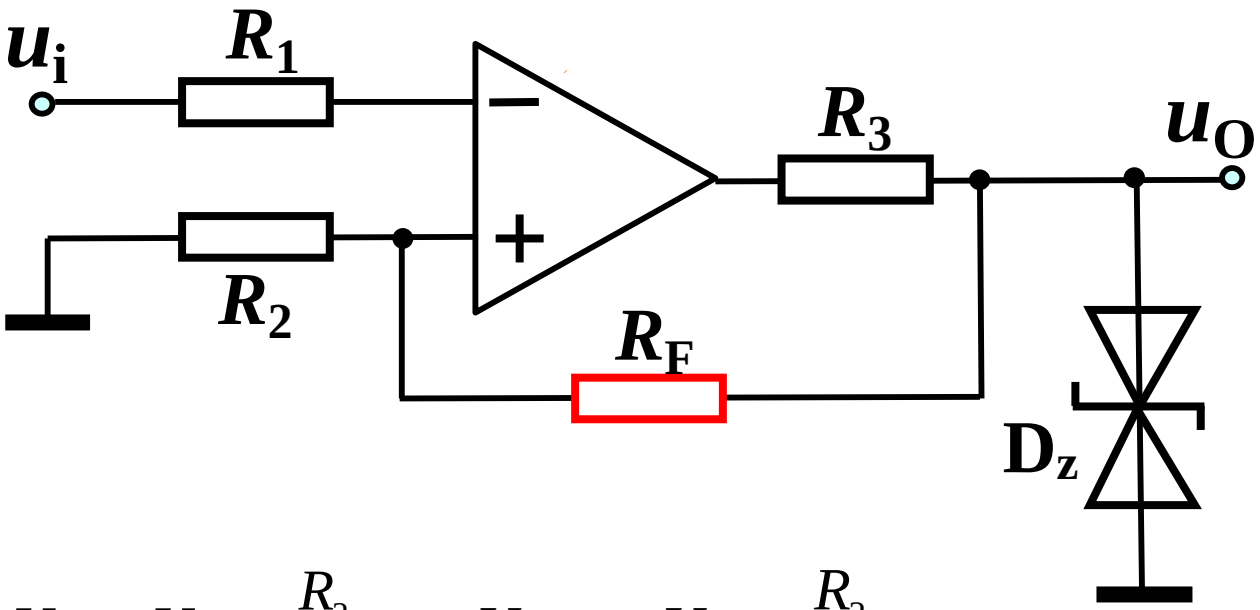
$$u_N = u_P$$

$$\Rightarrow \quad U_T = u_o \cdot \frac{R_2}{R_F + R_2}$$

$$u_O = \pm U_Z$$

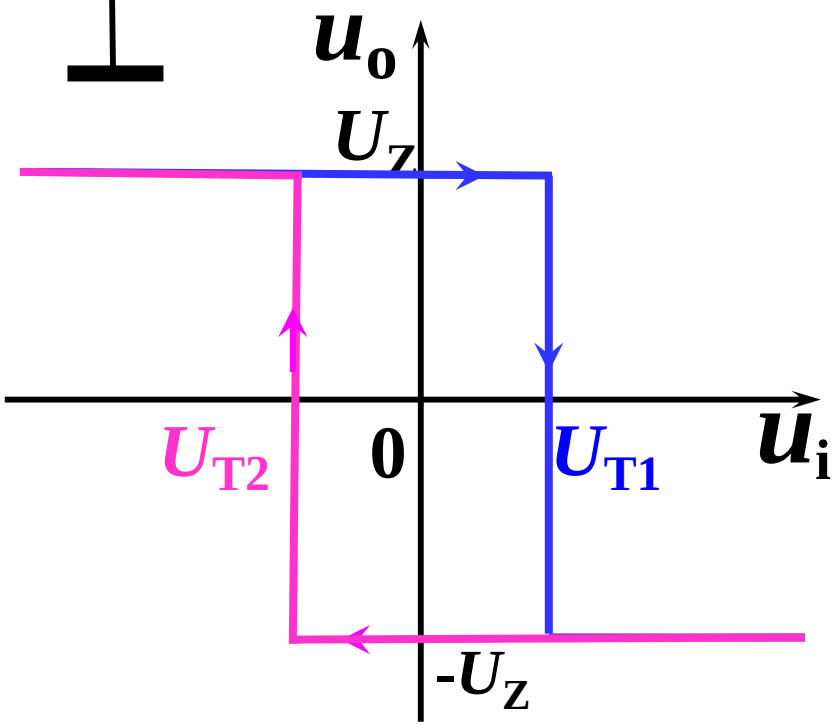
$$\Rightarrow \begin{cases} U_{T1} = U_Z \dfrac{R_2}{R_F + R_2} & (u_O = +U_Z) \\ U_{T2} = -U_Z \dfrac{R_2}{R_F + R_2} & (u_O = -U_Z) \end{cases}$$

7.2.3 滞回比较器

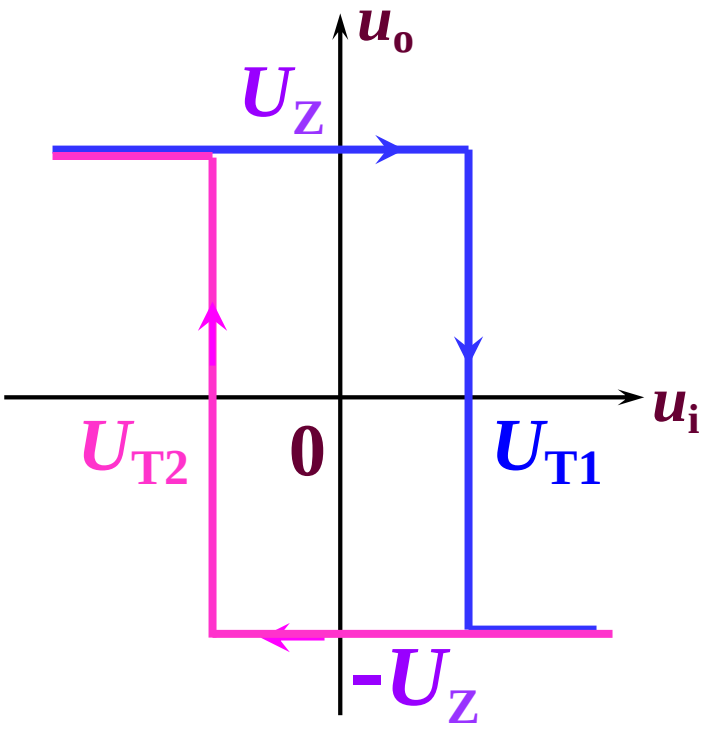


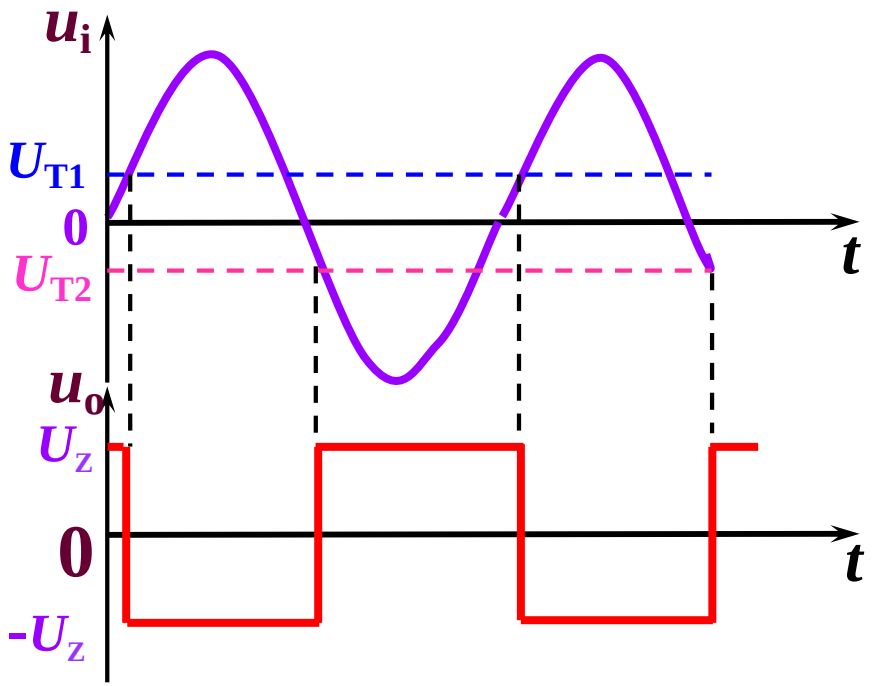
$$U_{T1} = U_Z \frac{R_2}{R_F + R_2} \qquad U_{T2} = -U_Z \frac{R_2}{R_F + R_2}$$

从$-U_Z$跃变为$+U_Z$和从$+U_Z$跃变为$-U_Z$的阈值电压不同，即$-U_T < u_i < +U_T$时的输出u_O，由u_i的变化方向决定。

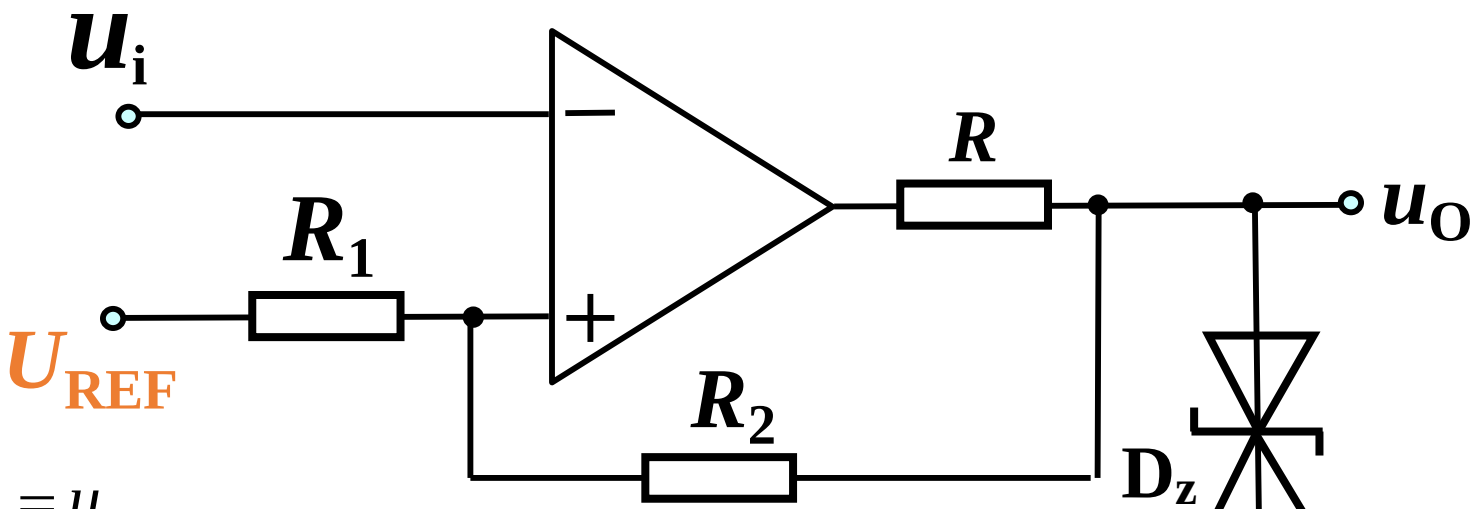


7.2.3 滞回比较器





7.2.3 滞回比较器

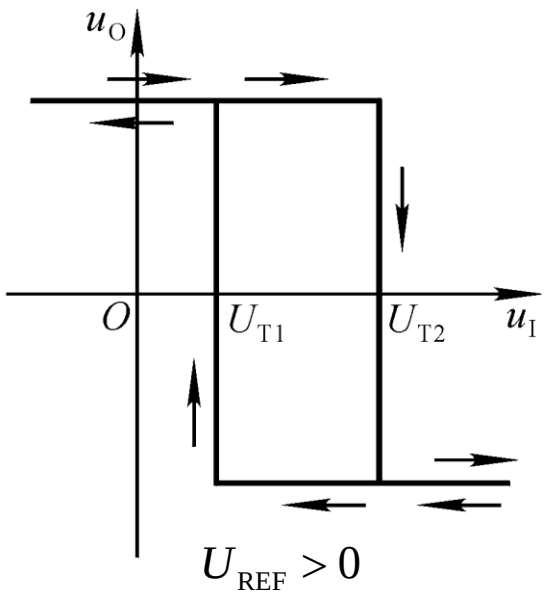


$$u_N = u_i$$

$$u_P = \frac{R_2}{R_1 + R_2} \cdot U_{REF} \pm \frac{R_1}{R_1 + R_2} \cdot U_Z$$

$$U_{T1} = \frac{R_2}{R_1 + R_2} \cdot U_{REF} - \frac{R_1}{R_1 + R_2} \cdot U_Z$$

$$U_{T2} = \frac{R_2}{R_1 + R_2} \cdot U_{REF} + \frac{R_1}{R_1 + R_2} \cdot U_Z$$

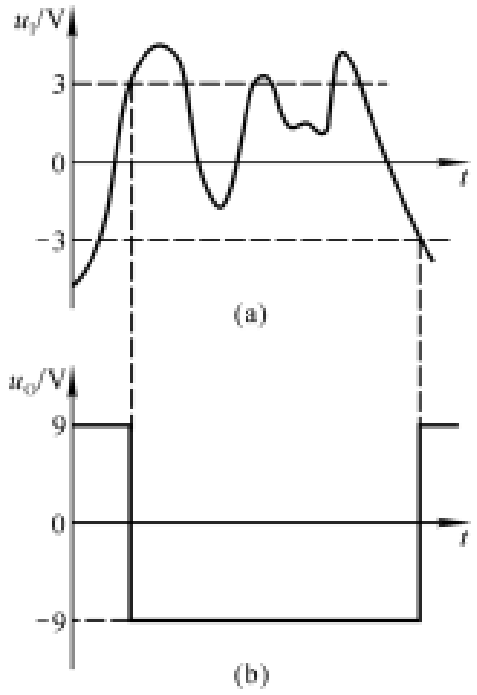


7.2.3 滞回比较器

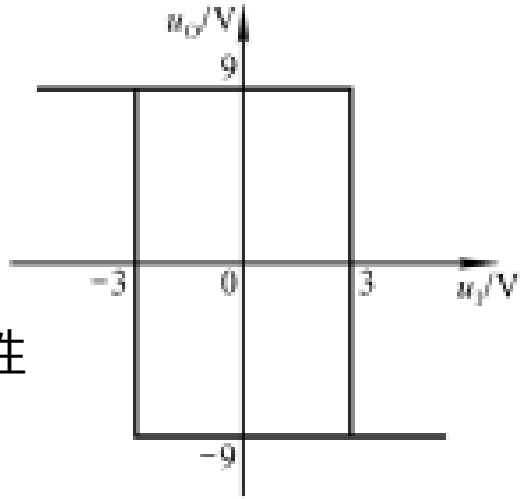
例：测得某电路输入电压u_I和输出电压u_o的波形如图所示，

（1）判断该电路是哪种电压比较器，并求解电压传输特性

（2）若要使U_{T1}=2V，U_{T2}=-4V，可以在电路中采取什么措施



解：（1）滞回比较器

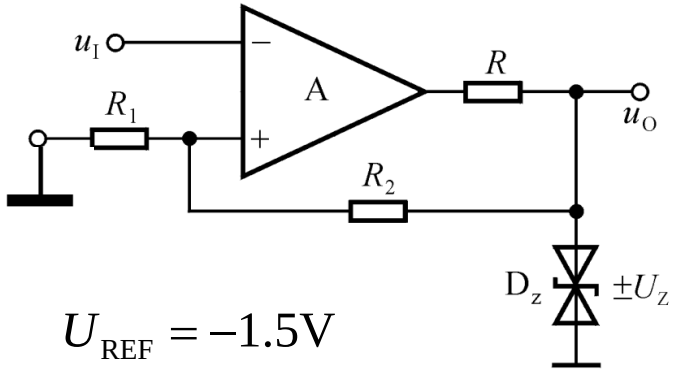


电压传输特性

（2）

$$U_{T1}=\frac{R_2}{R_1+R_2}\cdot U_{REF}-\frac{R_1}{R_1+R_2}\cdot U_Z$$

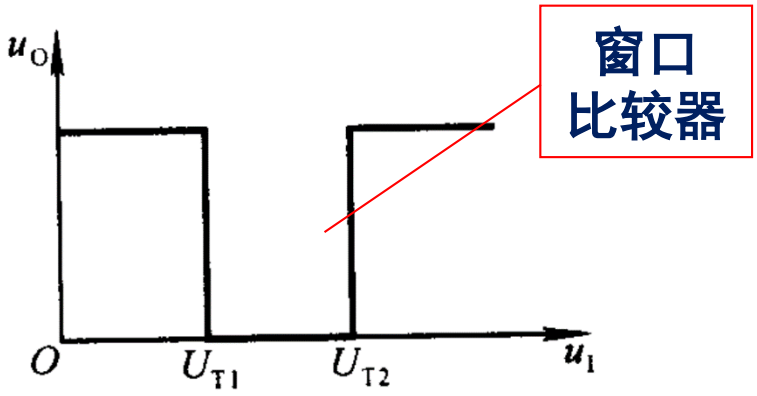
$$U_{T2}=\frac{R_2}{R_1+R_2}\cdot U_{REF}+\frac{R_1}{R_1+R_2}\cdot U_Z$$

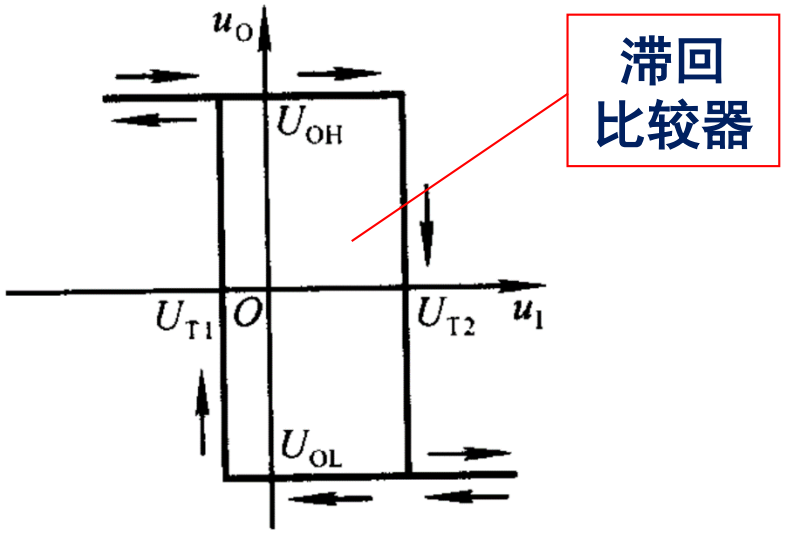


$U_{REF}=-1.5\text{V}$

7.2.4 窗口比较器

- 基本概念：有两个不相等的电压阈值，u_i从零开始增大且经过阈值U_{T1}时u_O从高电平U_{OH}变化为低电平U_{OL}，u_i继续增大且经过阈值U_{T2}时u_O从低电平U_{OL}变化为高电平U_{OH}。

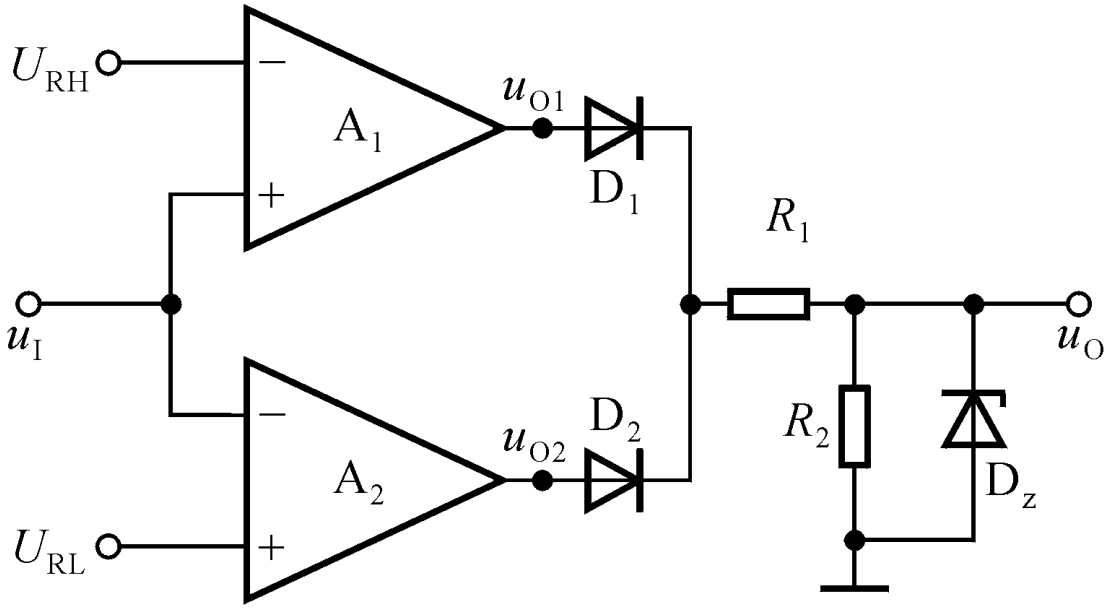




输入电压u_i从小到大过程中使输出电压u_i产生两次跃变。

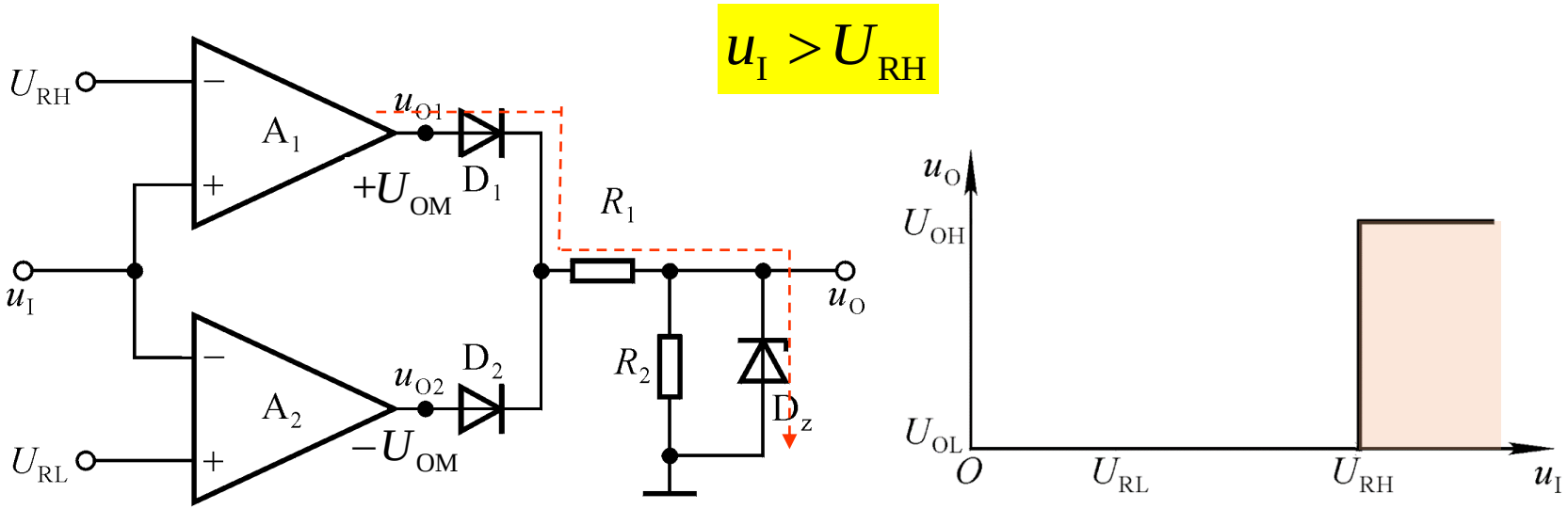
7.2.4 窗口比较器

电路形式：运放工作在开环状态，外加参考电压U_{RL}和U_{RH}且$U_{RL}<U_{RH}$，且R_1、R_2和D_Z构成限幅电路。



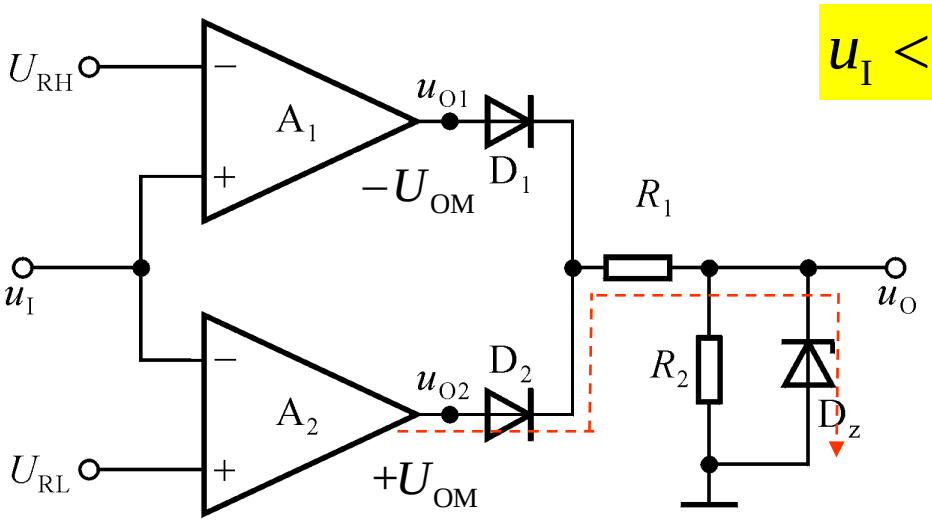
7.2.4 窗口比较器

当$u_I > U_{RH}$时（ u_I必然大于U_{RL} ），运放A_1的输出为$u_{O1}=+U_{OM}$，使得D_1导通、D_2截止，D_Z工作在稳压状态，比较器的输出为$u_O = U_Z$。

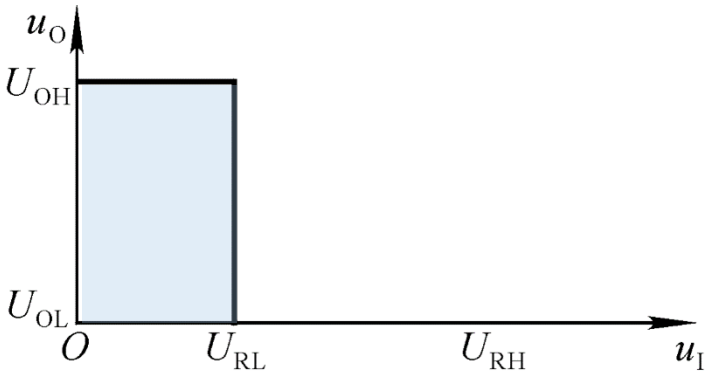


7.2.4 窗口比较器

当$u_I < U_{RL}$时（ u_I必然小于U_{RH} ），运放A_2的输出为$u_{O2}=+U_{OM}$，使得D_1截止、D_2导通，D_Z工作在稳压状态，比较器的输出为$u_O = U_Z$。

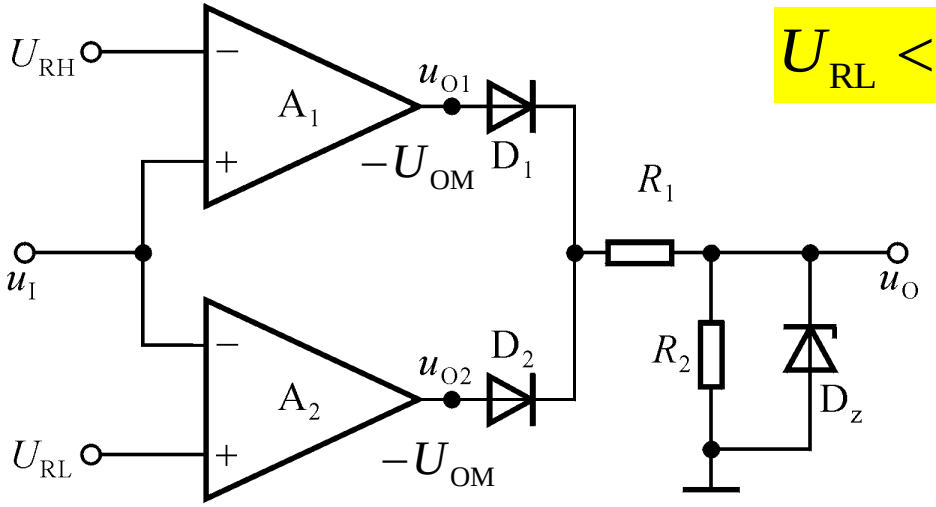


$u_I < U_{RL}$

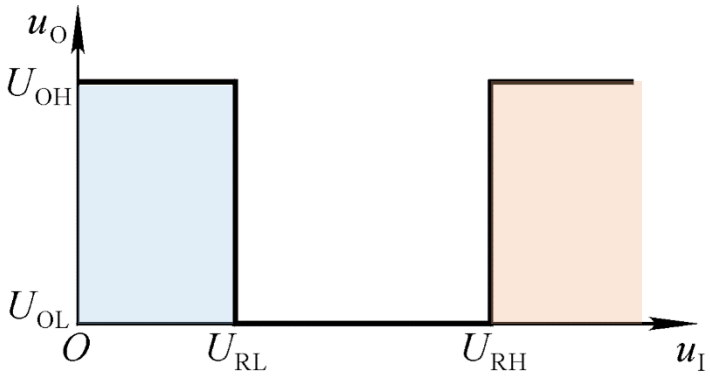


7.2.4 窗口比较器

当$U_{RL} < u_I < U_{RH}$时，运放A_1和A_2的输出为$u_{O1} = u_{O2} = -U_{OM}$，使得$D_1$和$D_2$均截止，比较器的输出为$u_O = 0$。

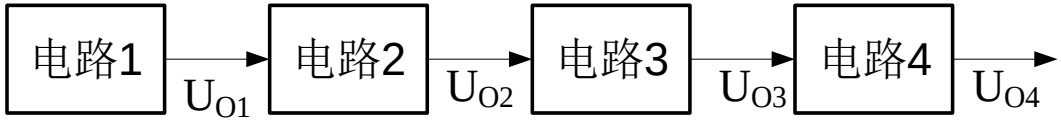


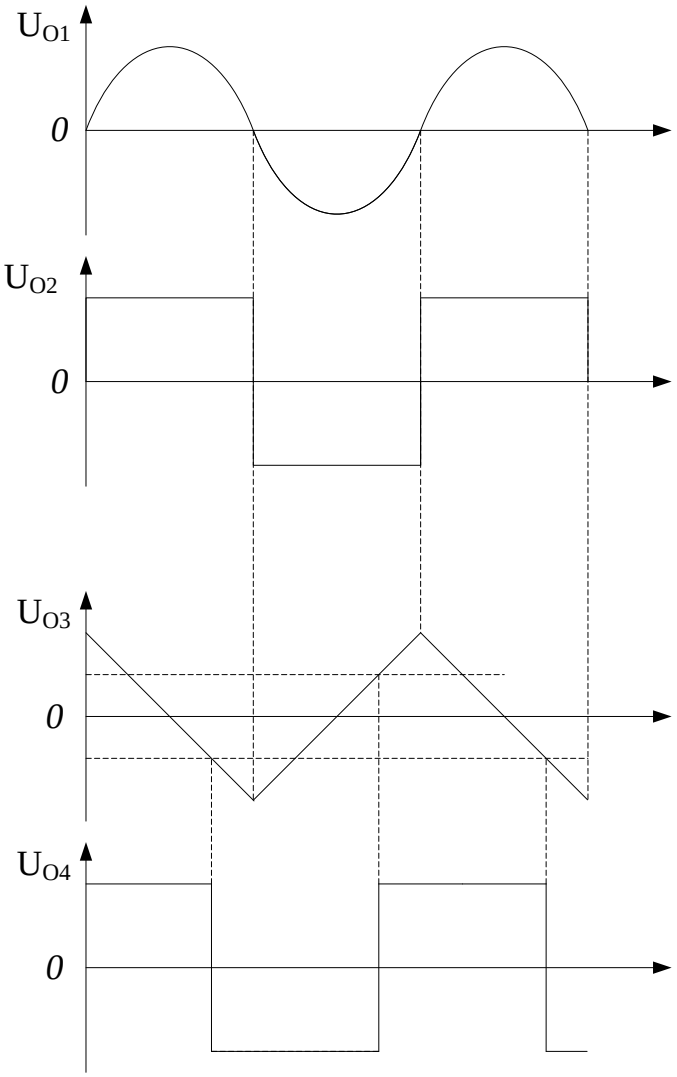
$U_{RL} < u_I < U_{RH}$



7.2.4 窗口比较器

例：已知方框图各点的波形，填写各电路名称





（1）正弦波振荡电路。

（2）同相输入的过零比较器

（3）反向输入的积分运算电路

（4）同相输入滞回比较器

电压比较器的分析方法

- 阈值电压

$$u_{\mathrm{p}} = u_{\mathrm{N}}$$

- 输出电压

输出端不接D_Z时，　$u_O = \pm U_{OM}$

输出端接D_Z限幅时，　$u_O = \pm U_Z$

- 跃变方向决定于输入电压作用于同相输入端还是反相输入端

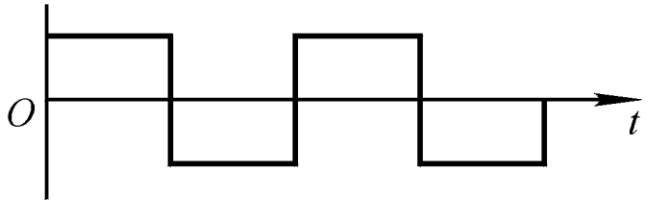
作业

7.13

7.16

7.3.1 矩形波发生器

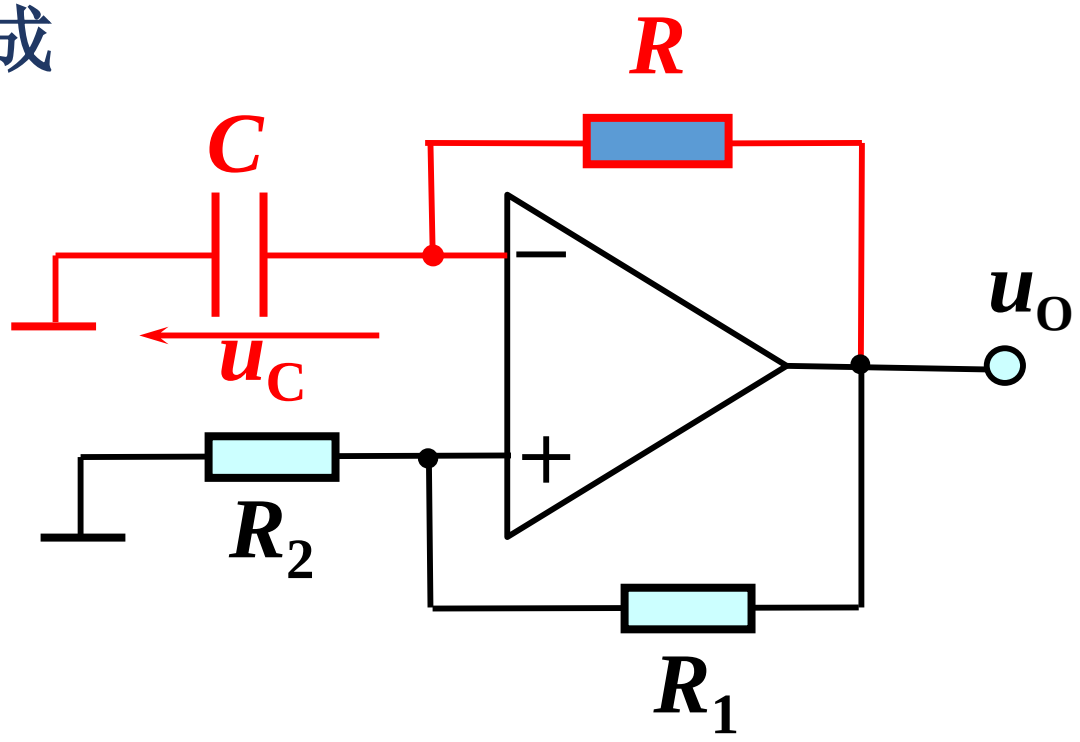
基本组成分析



- 电压比较器：输出只有高电平和低电平两种情况，即两个暂态
- 反馈网络：因需自控两种状态转换，在输出为某一暂态时能够孕育出翻转成另一暂态的条件，故应引入反馈。
- 延迟环节：要使两个暂态均维持一定的时间，可以采用*RC*环节实现，进而决定着振荡频率 。

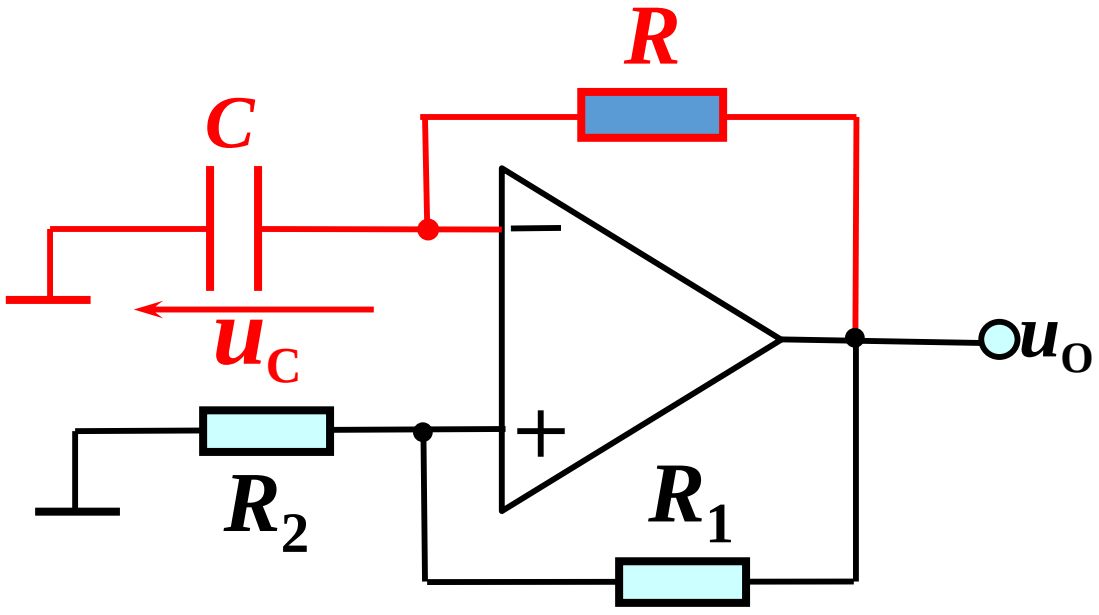
7.3.1 矩形波发生器

1. 电路的组成



滞回比较器 + *RC*电路；*RC*回路作为延迟环节，电容*C*上电压作为滞回比较器输入； 通过*RC*电路的充电和放电实现输出状态的自动转换。

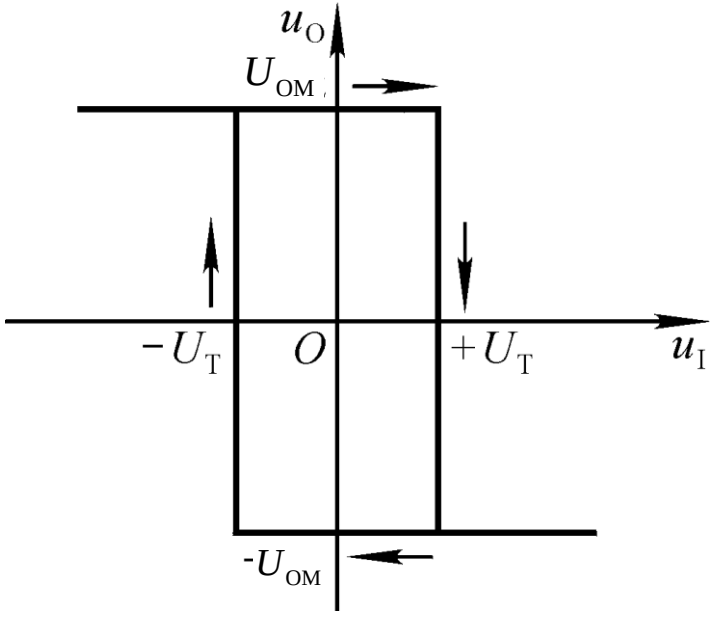
7.3.1 矩形波发生器



$$u_P = \frac{R_2}{R_2 + R_1} \cdot u_O$$

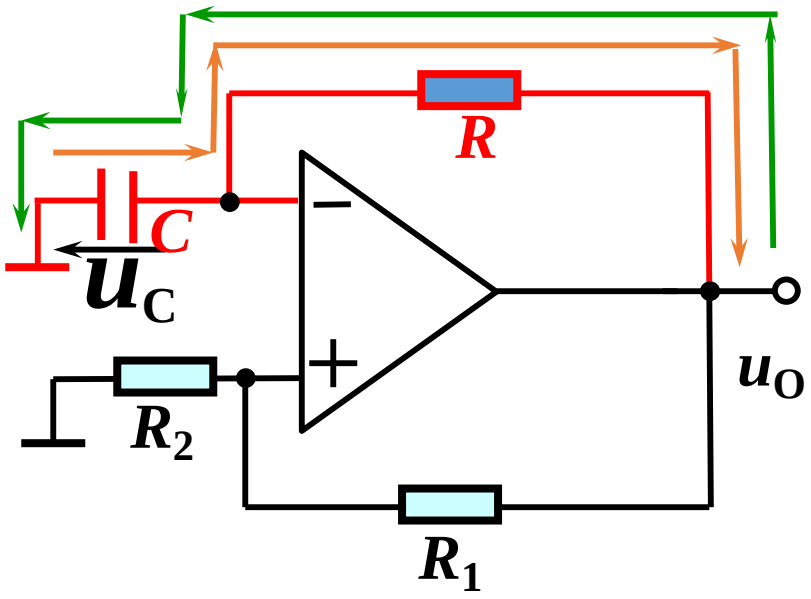
$$u_N = u_C$$

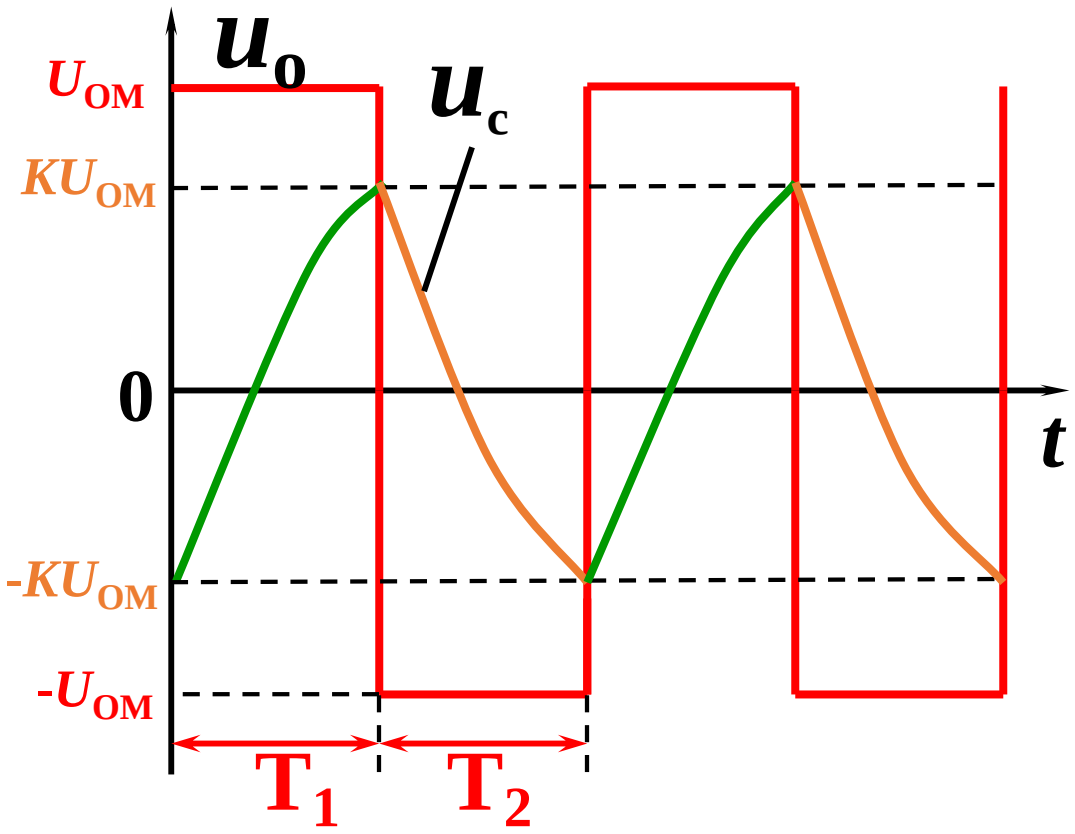
$$u_T = \pm \frac{R_2}{R_2 + R_1} \cdot U_{OM} = \pm K U_{OM}$$



7.3.1 矩形波发生器

2. 工作原理





设初始时 $u_o=U_{OM}$

$u_p= KU_{OM}$

C充电，u_C↑

至$U_C=KU_{OM}$

$u_o=-U_{OM}$

$u_P=-KU_{OM}$

C放电，u_C↓

至$U_C=-KU_{OM}$

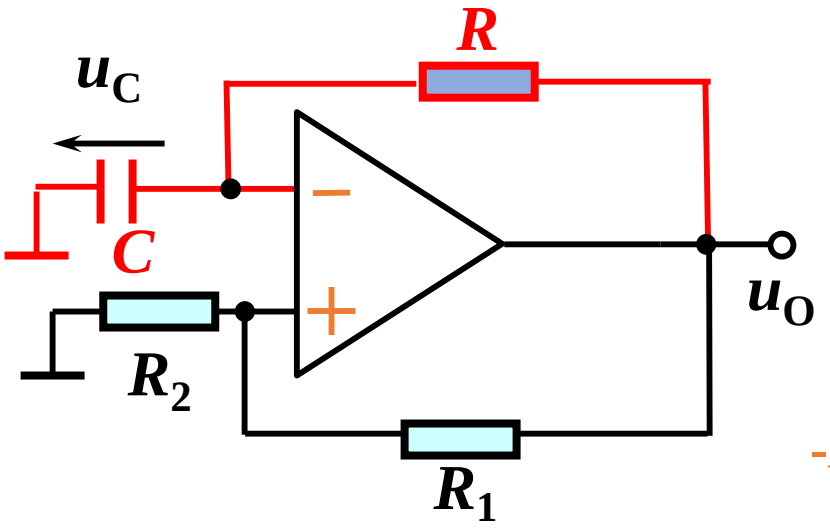
$u_o=U_{OM}$

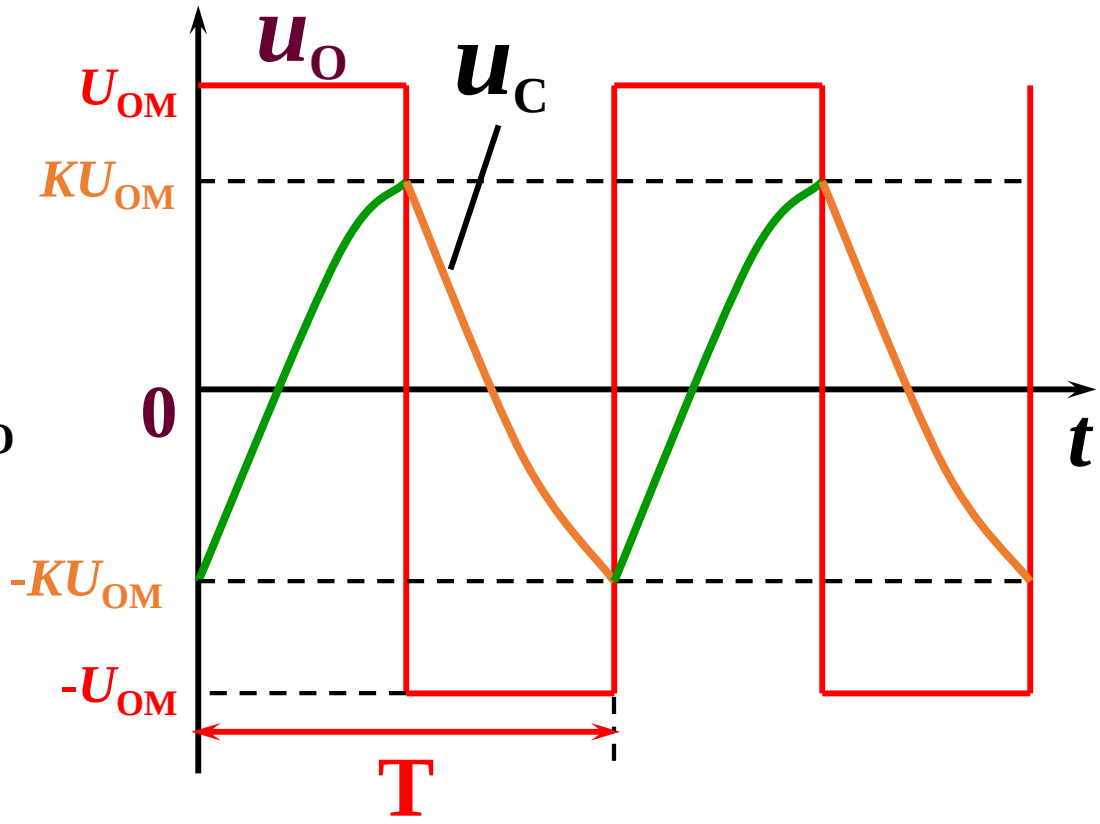
……

7.3.1 矩形波发生器

北京航空航天大學 BEIHANG UNIVERSITY

3. 主要参数



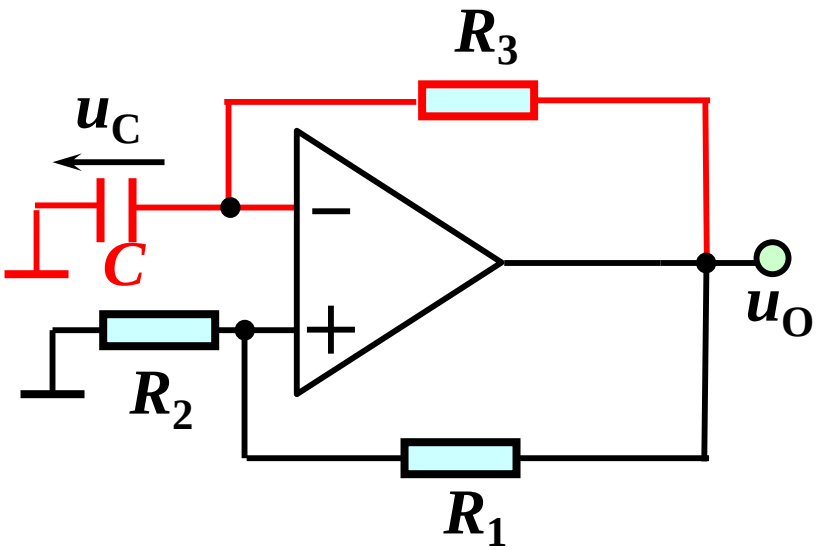


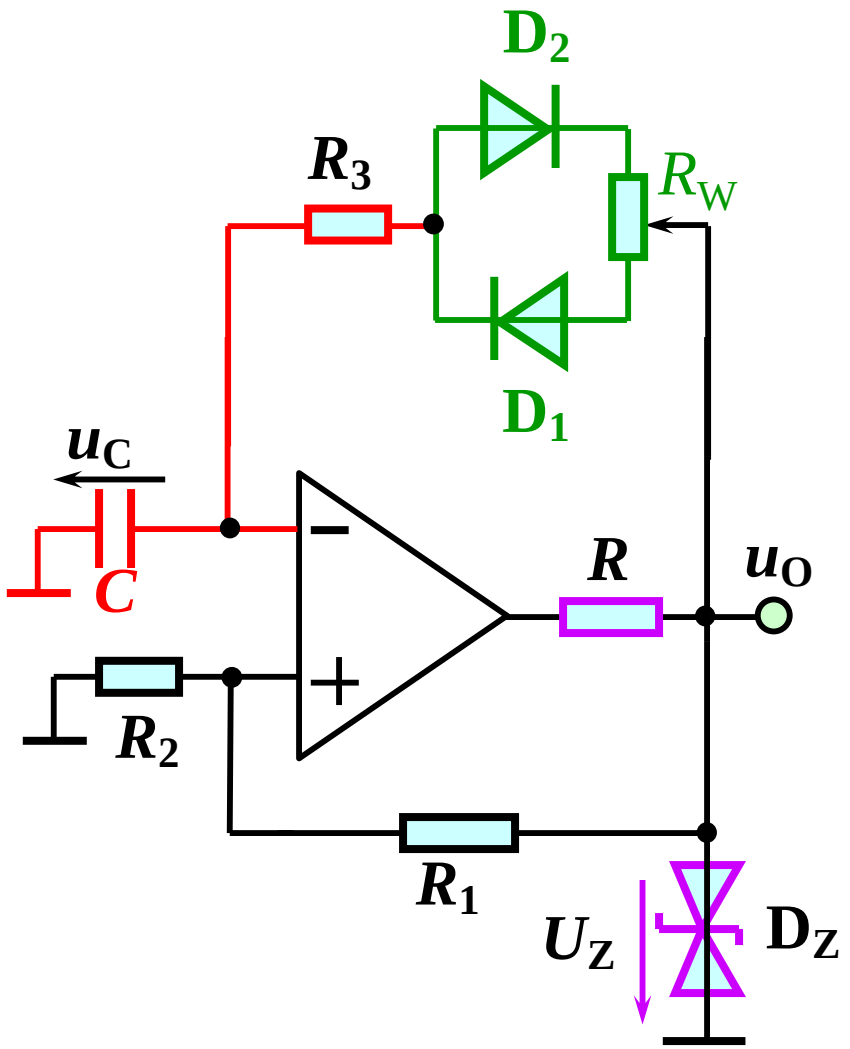
$$f(t) = f(\infty) + [f(0_+) - f(\infty)]e^{-t/\tau}$$

幅度 ： $U_{om}=U_{OM}$　　周期 ： $T=2RC\ln(1+\frac{2R_2}{R_1})$

7.3.1 矩形波发生器

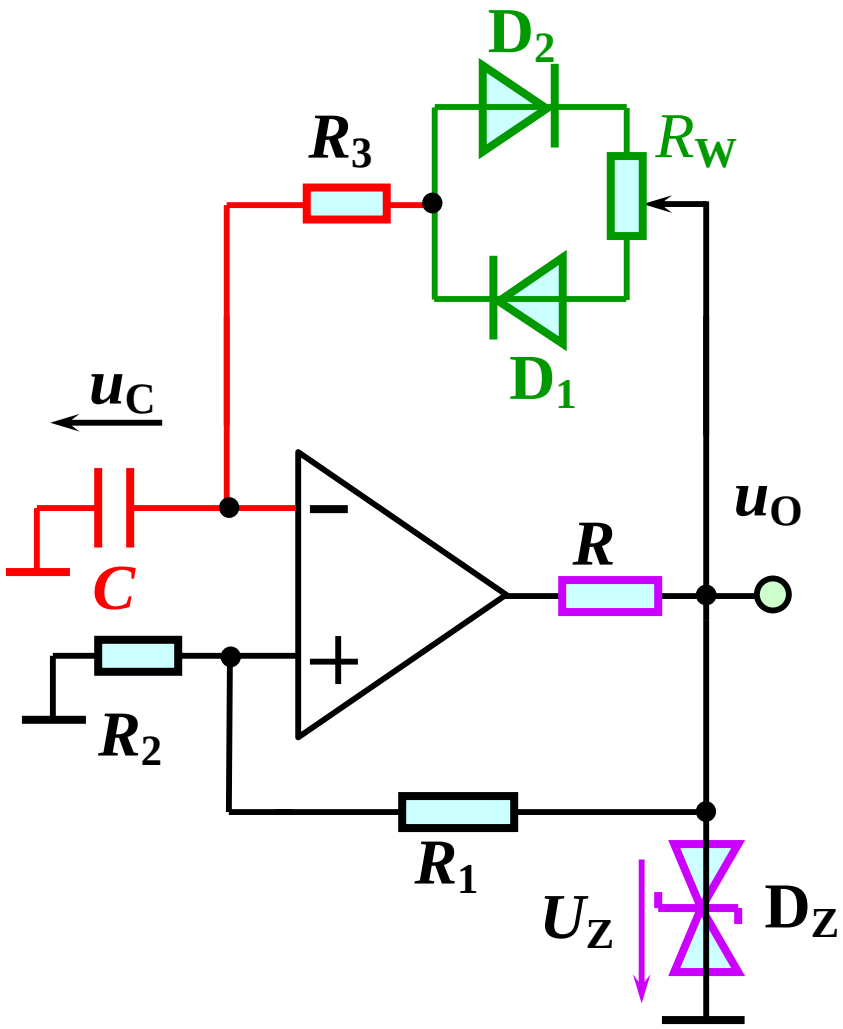
4. 占空比可调电路

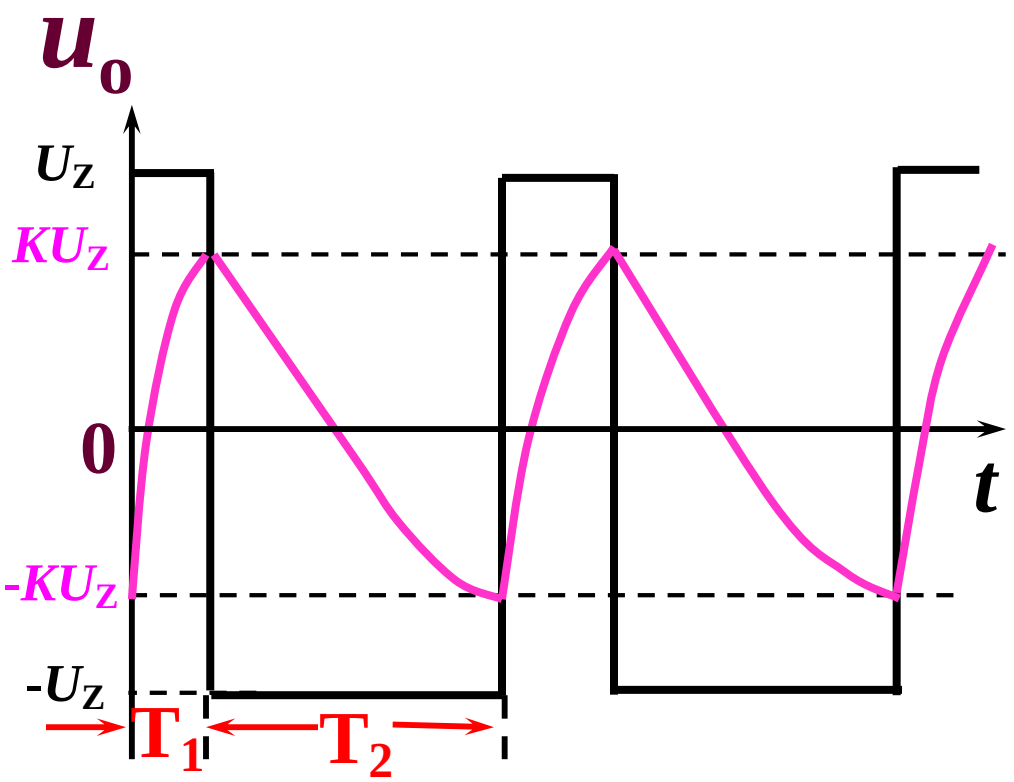




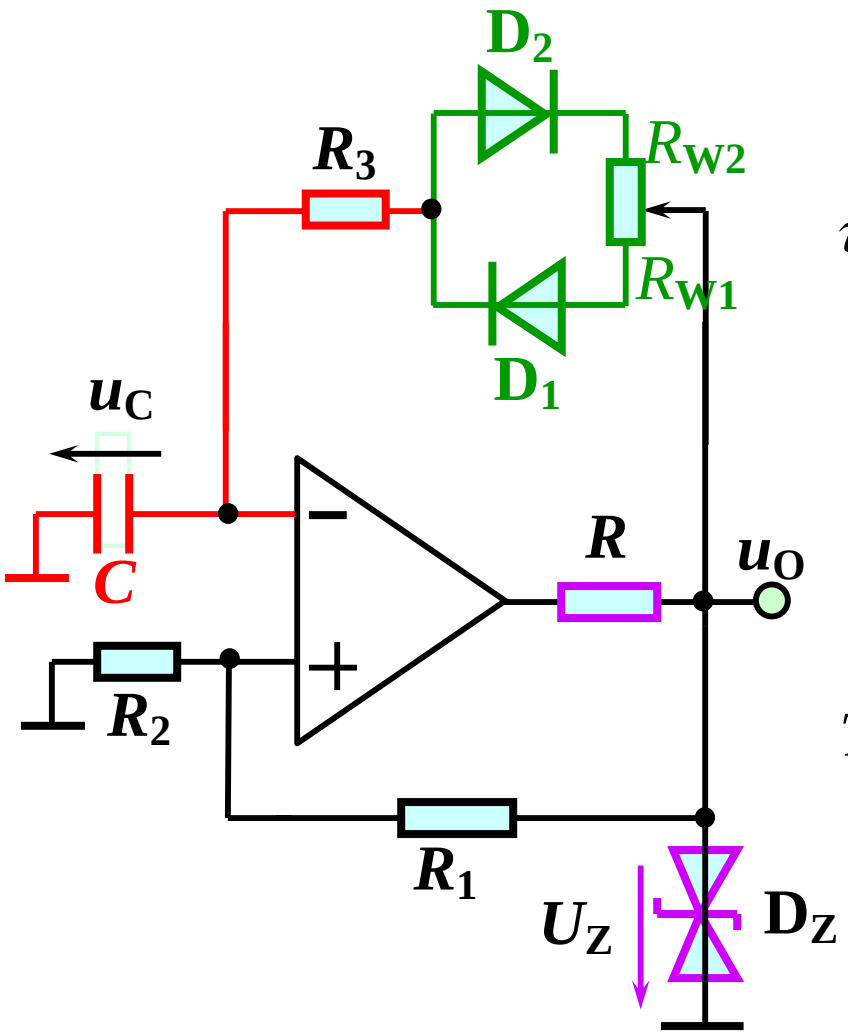
实现正向充电和反向充电的时间常数可调，则占空比就可调；利用二极管单向导电性引导充电和放电电流流经不同通路。

7.3.1 矩形波发生器





7.3.1 矩形波发生器



- 计算占空比

充电阶段：

$$\tau_1 = (R_3 + R_{W1})C \qquad T_1 = \tau_1 \ln\left(1 + \frac{2R_2}{R_1}\right)$$

放电阶段：

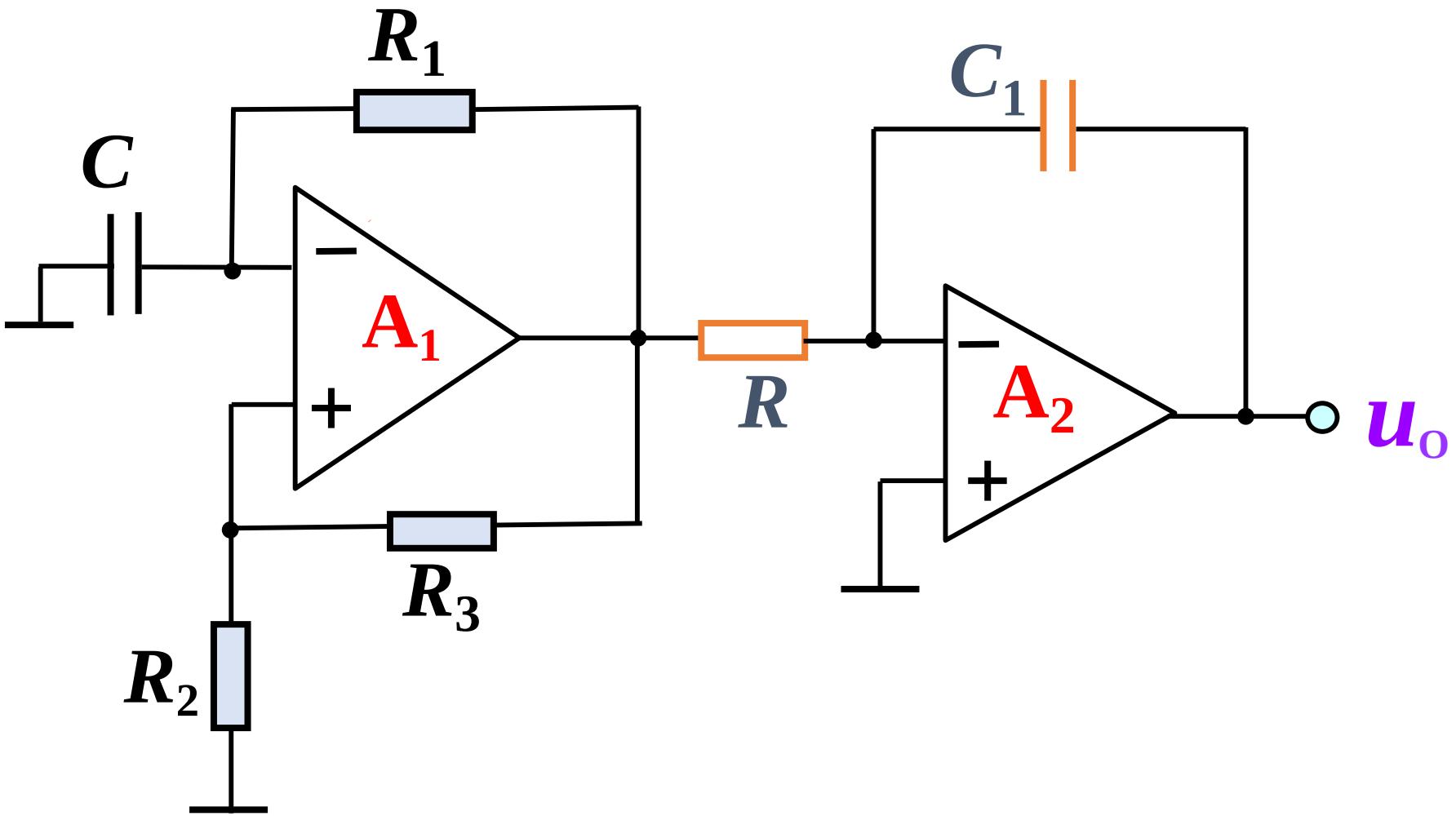
$$\tau_2 = (R_3 + R_{W2})C \qquad T_2 = \tau_2 \ln\left(1 + \frac{2R_2}{R_1}\right)$$

振荡周期

$$T = T_1 + T_2 = (R_W + 2R_3)C \cdot \ln\left(1 + \frac{2R_2}{R_1}\right)$$

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

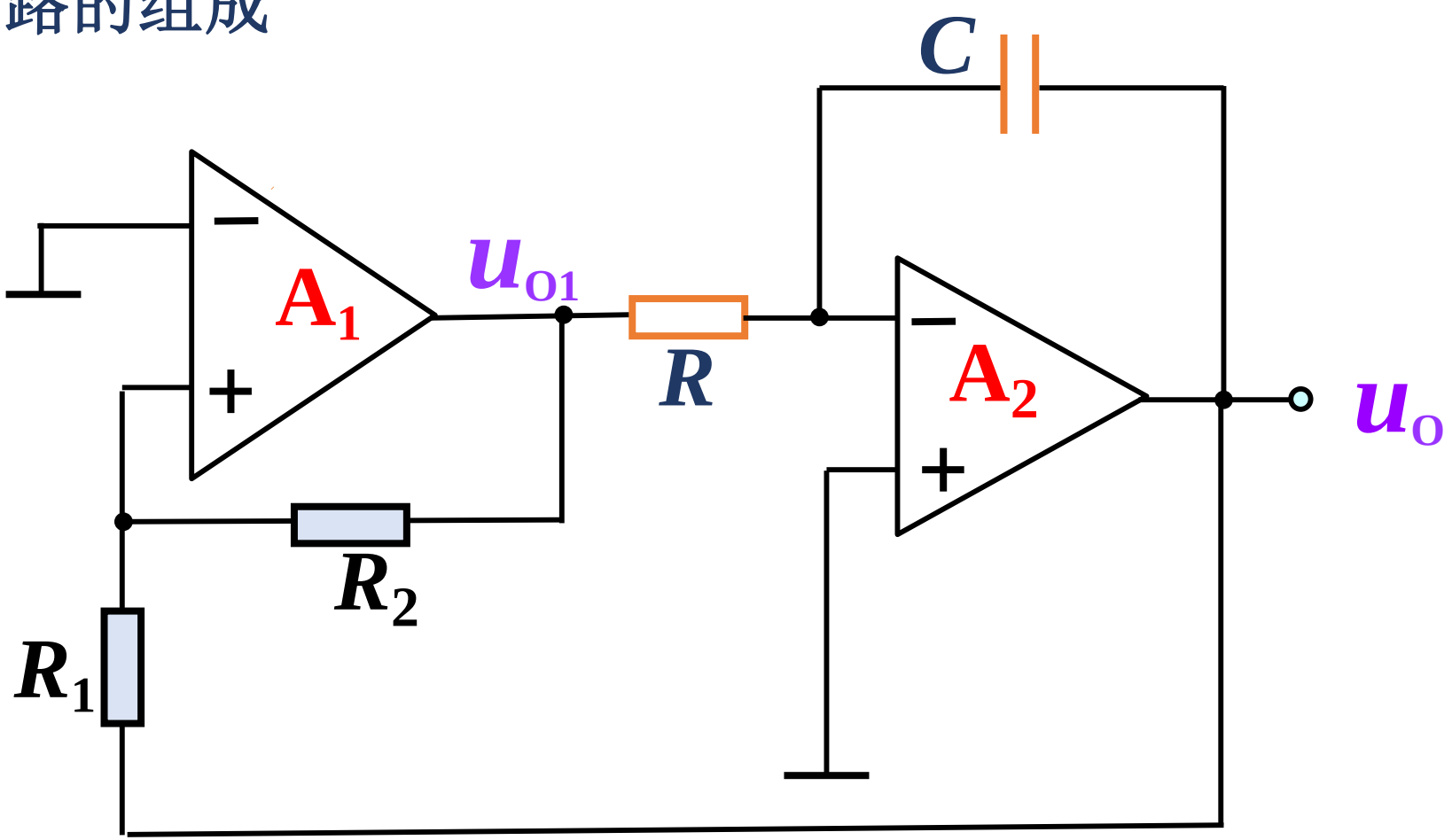
7.3.2 三角波发生器



积分运算电路将方波变为三角波

7.3.2 三角波发生器

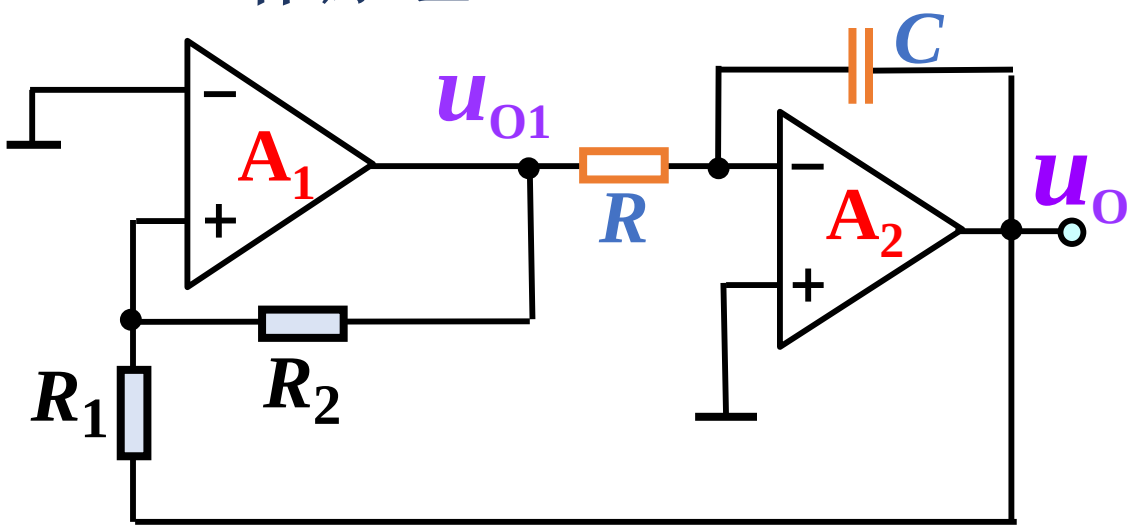
1. 电路的组成



三角波发生器由 { A_1— 滞回电压比较器；A_2 — 反相积分电路 } 组成

7.3.2 三角波发生器

2. 工作原理

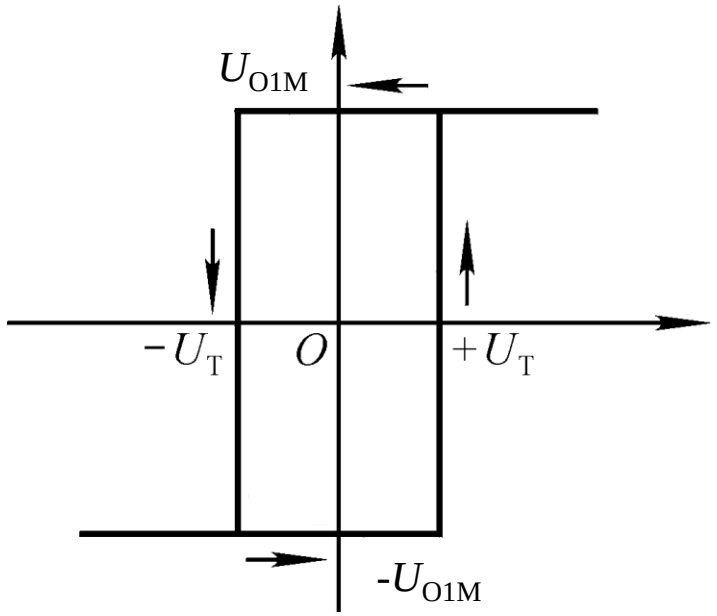


$$u_{N1}=0$$

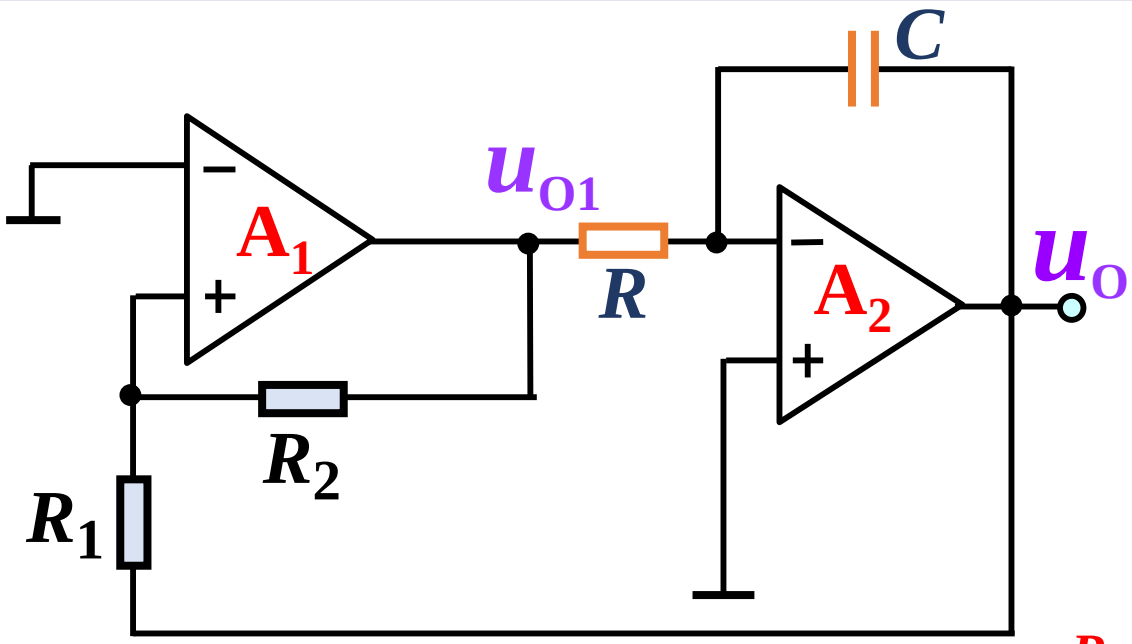
$$u_{P1}=\frac{R_1}{R_1+R_2}u_{o1}+\frac{R_2}{R_1+R_2}u_o$$

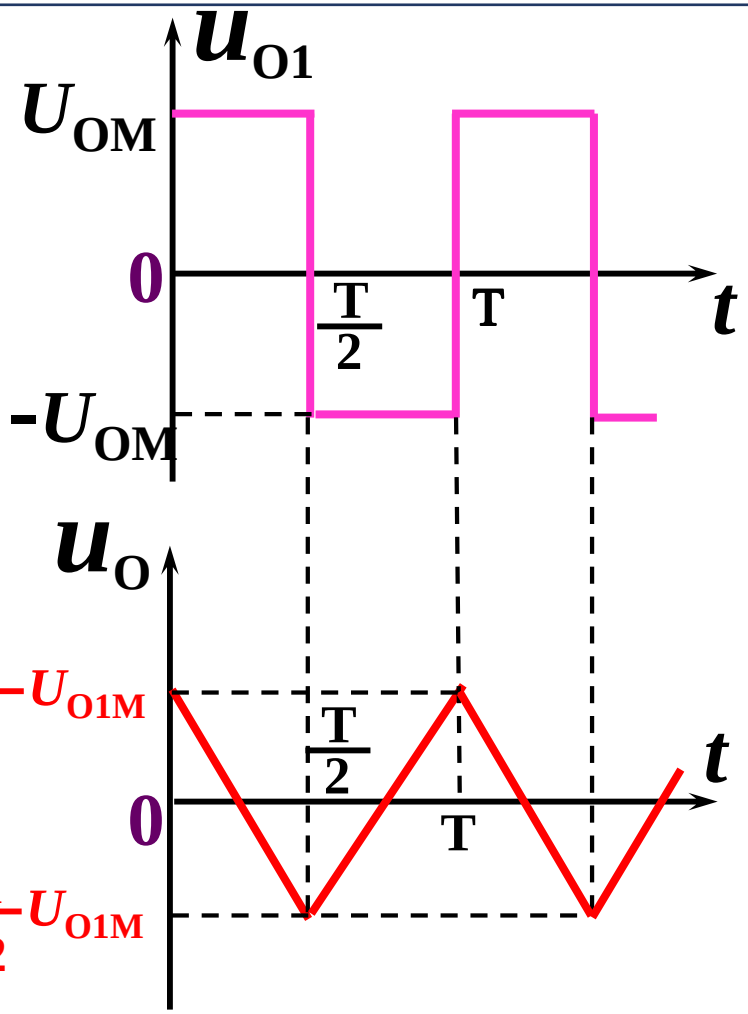
$$u_o=-\frac{R_1}{R_2}u_{o1}$$

$$u_T=\pm\frac{R_1}{R_2}U_{O1M}$$



7.3.2 三角波发生器





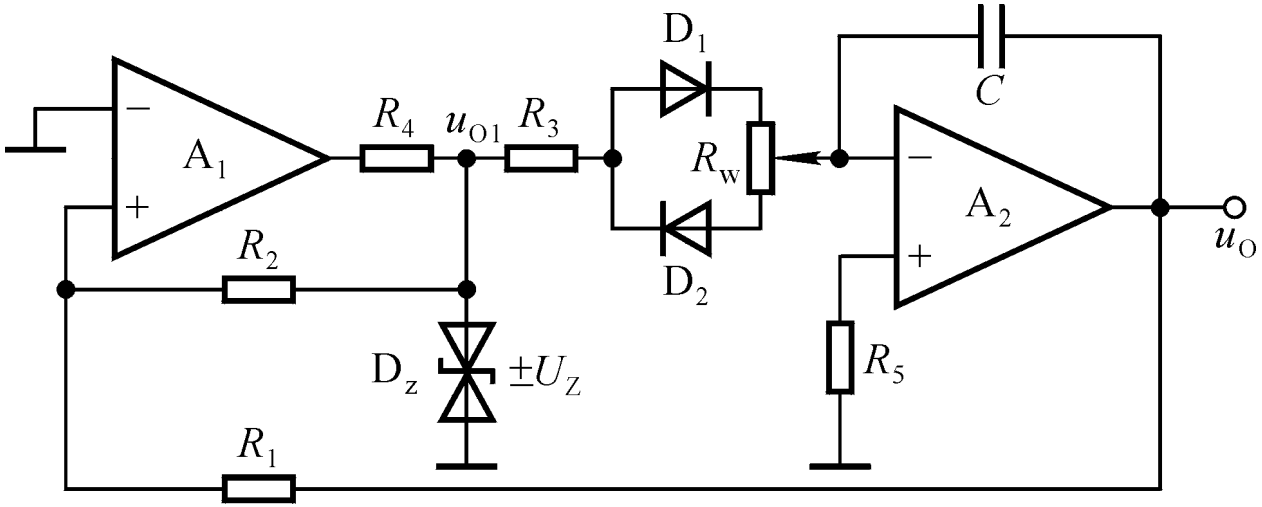
$$u_o = -\frac{1}{RC}\int_{t_0}^{t_1} u_{o1}dt + u_o(t_0)$$

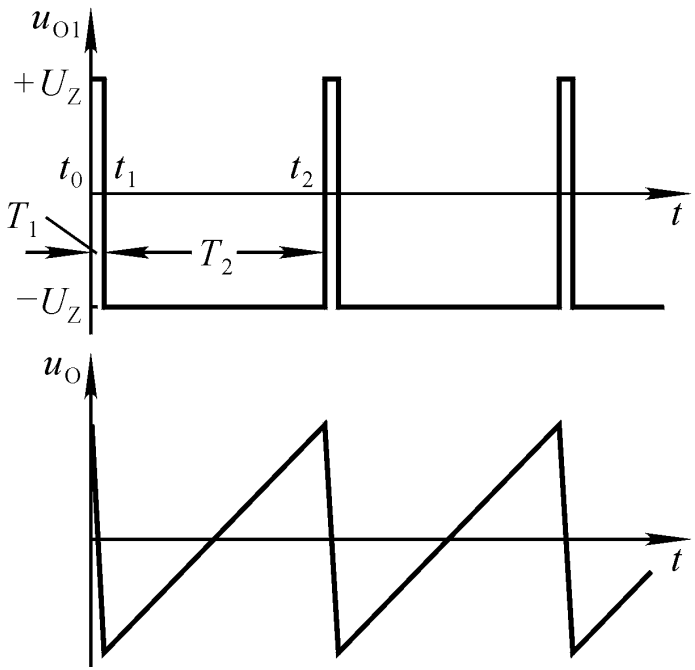
$$u_O = -\frac{1}{RC}u_{O1}(t_1 - t_0) + u_O(t_0)$$

$$u_T = u_o = \pm\frac{R_1}{R_2}u_{O1M}$$

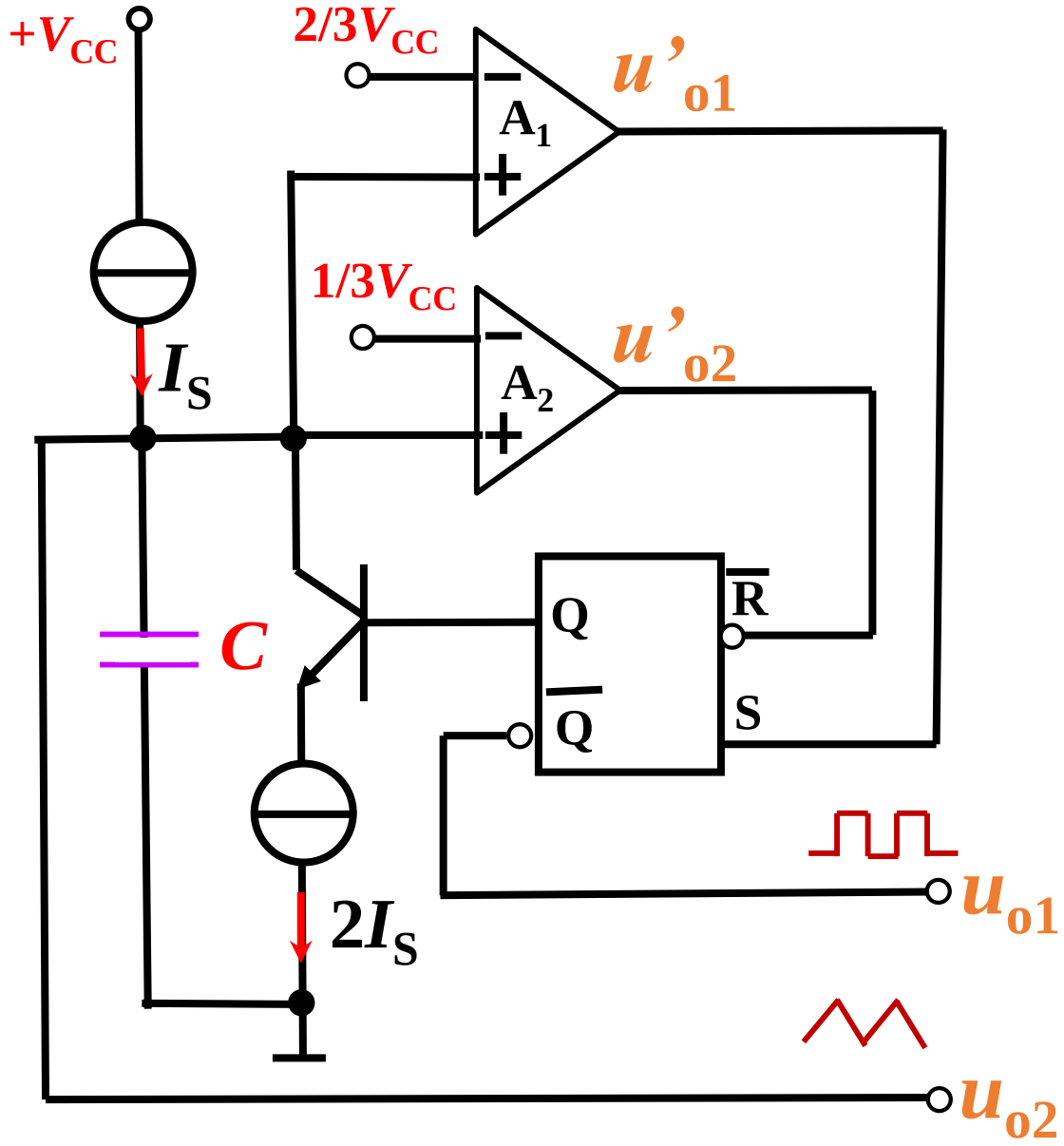
$$T = \frac{4R_1RC}{R_2} \qquad f = \frac{R_2}{4R_1RC}$$

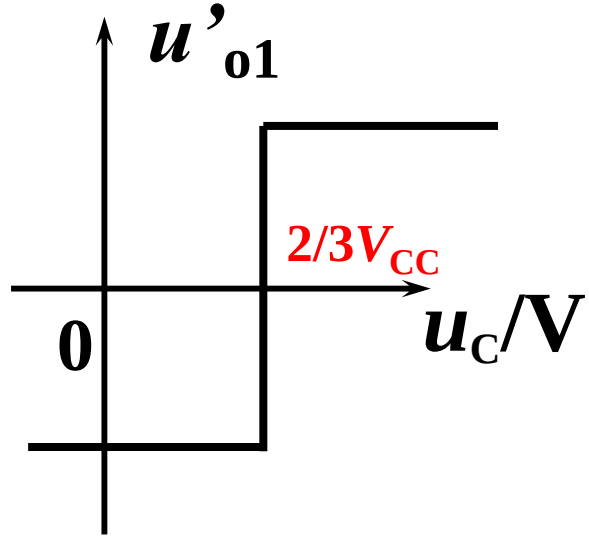
7.3.3 锯齿波发生器

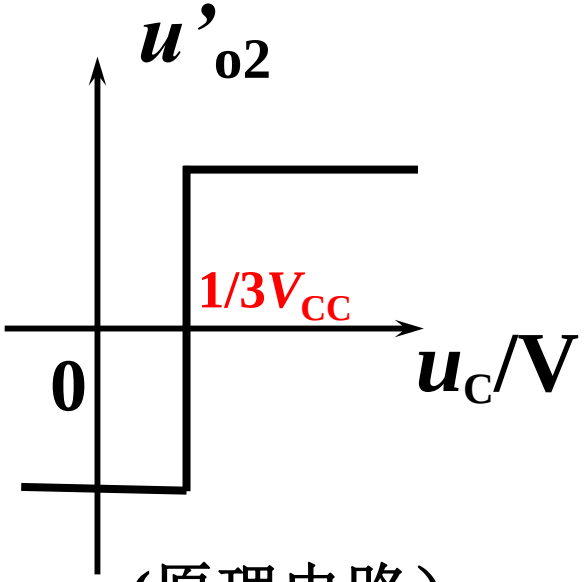

A1
A2
R4
uO1
R3
D1
D2
Rw
C
R2
R1
Dz
±UZ
R5
uO


uO1
+UZ
t0
t1
t2
T1
T2
t
−UZ
uO
t

7.3.5 函数发生器

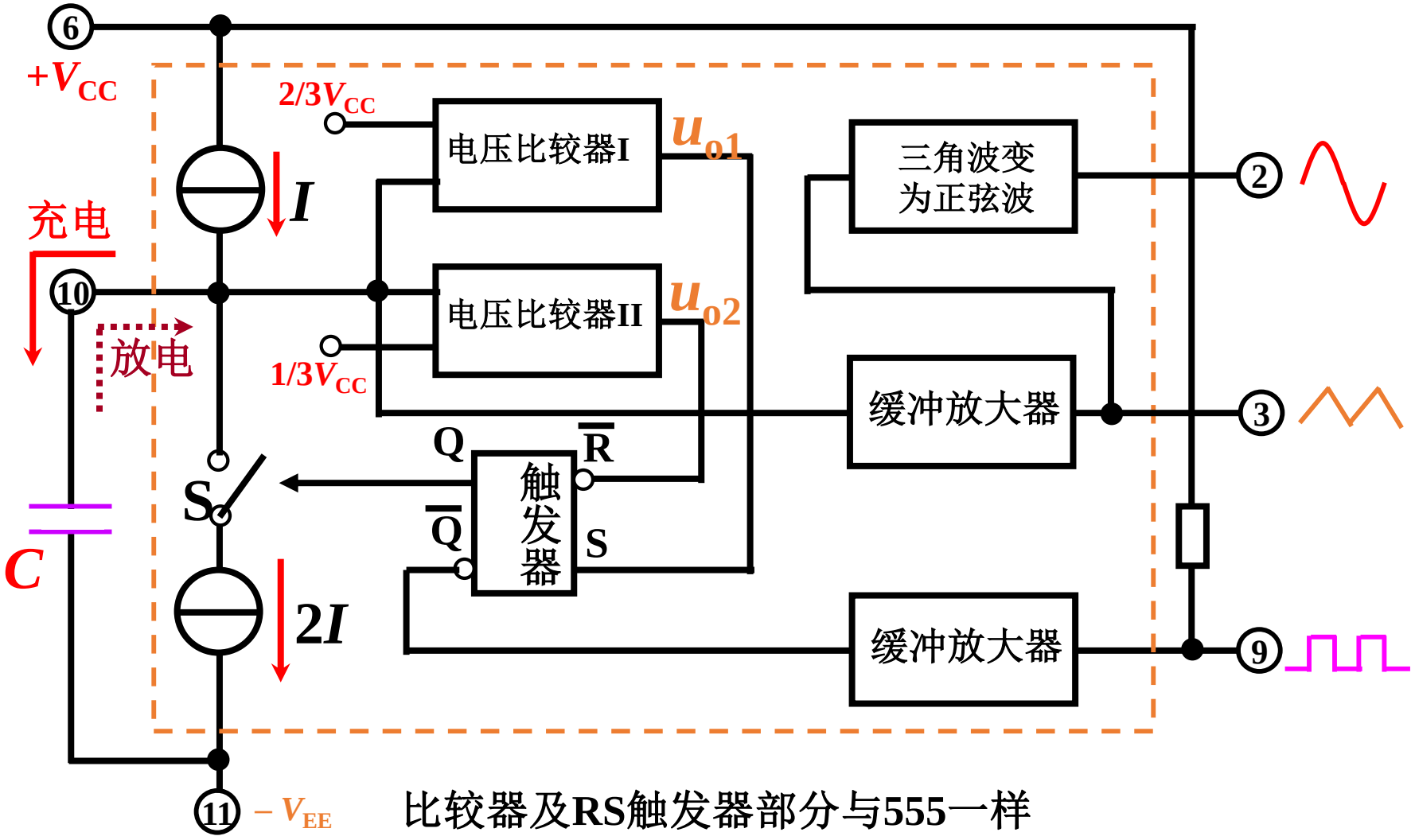






(原理电路)

7.3.5 函数发生器



比较器及RS触发器部分与555一样

作业
7.20