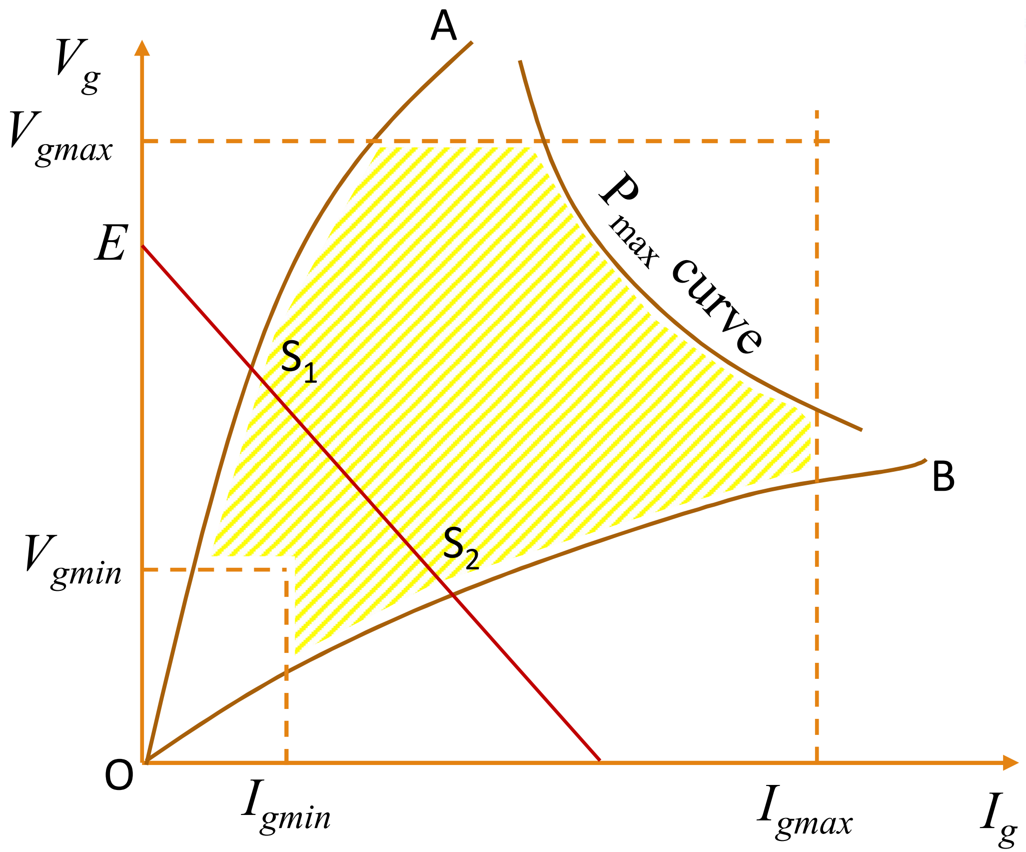
Power Electronics

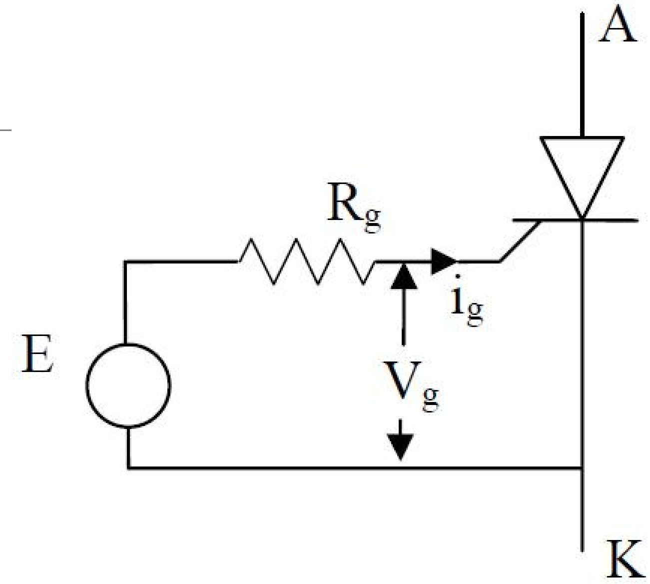
TRIGGERING CIRCUITS

2018

Dr. Francis M. Fernandez

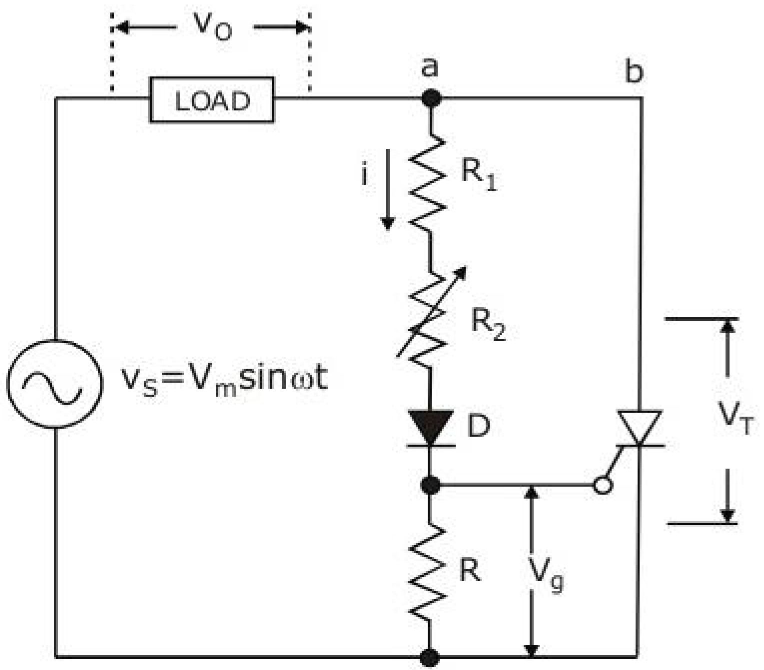
Gate Characteristics





OA and OB represent the spread of characteristics for the thyristor of same rating

R - Triggering Circuit



- R_1 is the gate current limiting resistance
- R_2 is used to vary the gate current and hence firing angle

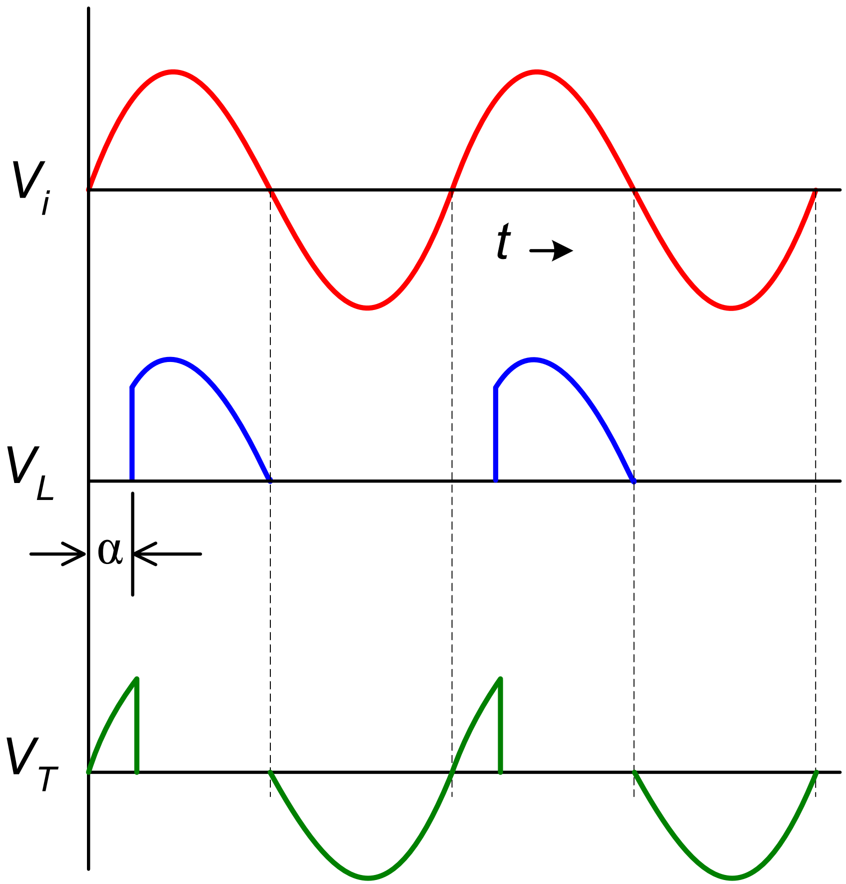
$$I_{g\max} = \frac{V_m}{R_1} \Rightarrow R_1 \geq \frac{V_m}{I_{g\max}}$$

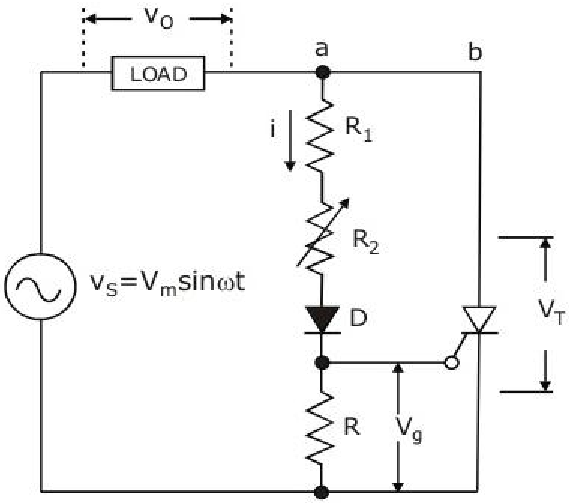
- R limits the voltage at Gate terminal

$$R \leq \frac{V_{g\max} R_1}{V_m - V_{g\max}}$$

- Diode D prevents build-up of negative voltage at Gate terminal

R-Trig Waveforms

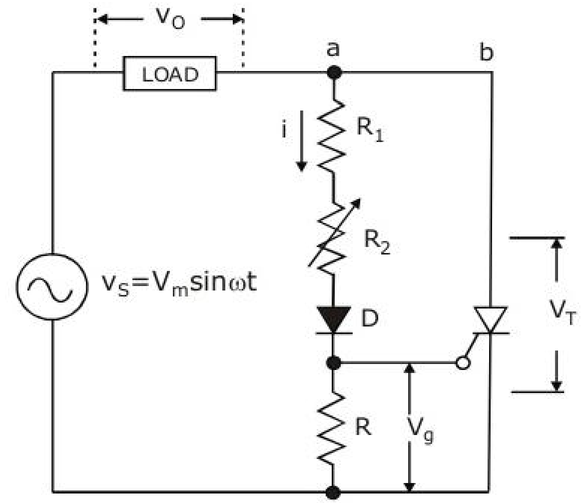


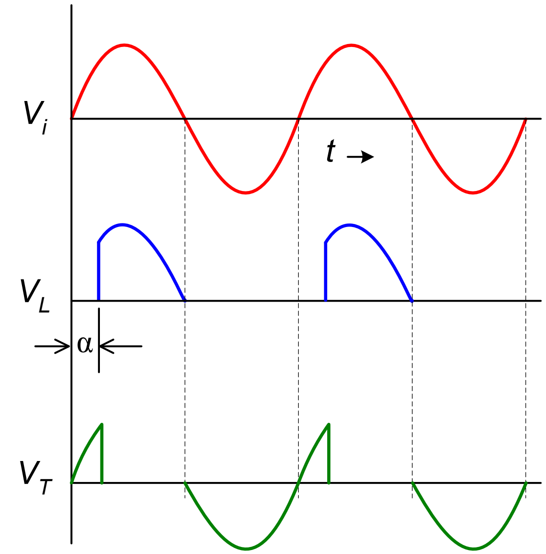


- The phase angle at which the SCR starts conducting is called **firing angle, α**

Features of R-Trig Circuit

- Simple circuit
- Disadvantages:
  - Performance depends on temperature and SCR characteristics
  - Minimum phase angle is typically 2-4 degrees only (not zero degree)
  - Maximum phase angle is only 90 degrees





Problem

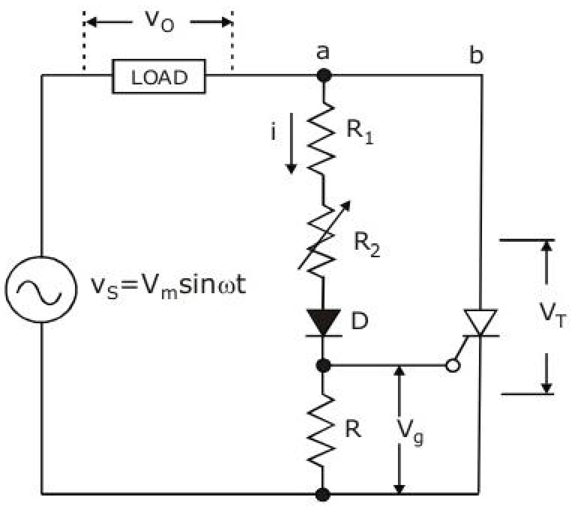
Design an R-triggering circuit for a half wave controlled rectifier circuit for 24 V ac supply. The SCR to be used has the following data.

$I_{gmin} = 0.1$ mA, $I_{gmax} = 12$ mA, $V_{gmin} = 0.6$V, $V_{gmax} = 1.5$ V

<u>Solution:</u>

$V_m = 24\sqrt{2}$

$$R_1 \geq \frac{V_m}{I_{g\max}} = \frac{24\sqrt{2}}{12\times10^{-3}} = 2.8\ k\Omega \simeq 3.3\ k\Omega$$



$$R \leq \frac{V_{gmax} R_1}{V_m - V_{gmax}} = \frac{1.5 \times 3.3 \times 10^3}{24\sqrt{2} - 1.5} = 145.8\,\Omega \simeq 120\,\Omega$$

For finding R2 ➡ $\frac{V_{gmin}}{V_m - V_{gmin}} = \frac{R}{R_1 + R_2}$

$$R_2 = \frac{(V_m - V_{gmin})R}{V_{gmin}} - R_1 = \frac{(24\sqrt{2} - 0.6) \times 120}{0.6} - 3.3 \times 10^3 = 3.37\ k\Omega$$

Select 4.7 k Potentiometer for R_2

(Drop across diode D is neglected)

Problem

In a resistance firing circuit for SCR, the following parameters are applicable

$I_{gt(min)} = 0.5$ mA,

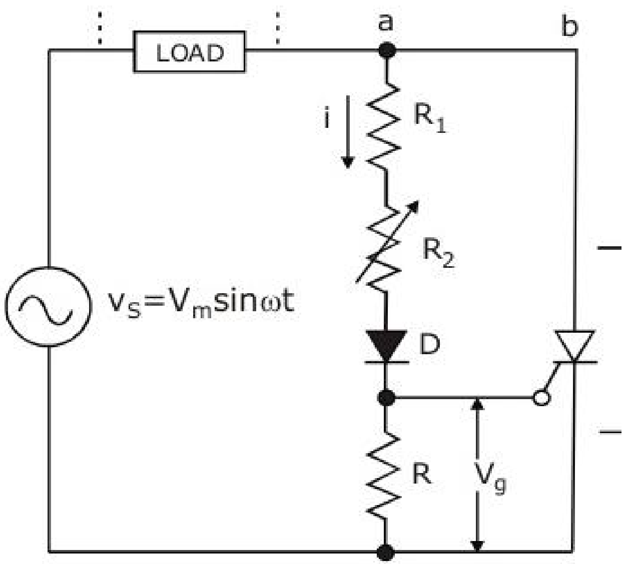
$V_{gt(min)} = 0.7$V,

Supply voltage = 48 V, 50Hz

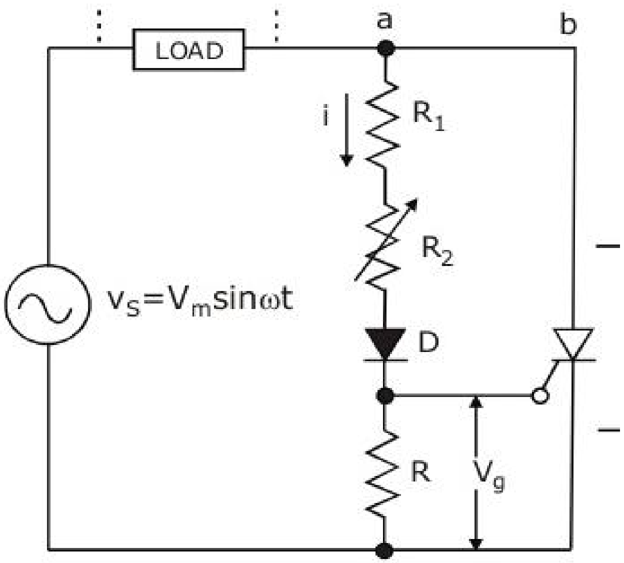
Resistance in gate current path = 70 kΩ.

a) Find the firing angle for the above condition

b) What is the resistance for which firing angle is 90 degrees



Solution



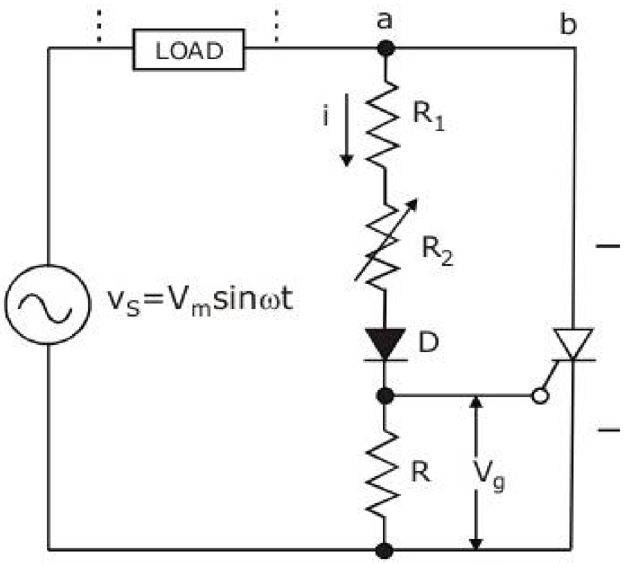
a)

$$e_t = I_g \cdot (R_1 + R_2) + V_D + V_g$$
$$= 0.5\times10^{-3}\times70\times10^{3} + 0.6 + 0.7$$
$$= 36.3 \text{ V}$$

$$e_t = V_m \sin\omega t$$
$$36.3 = \sqrt{2}\times48\sin\omega t$$
$$\sin\omega t = \frac{36.3}{\sqrt{2}\times48} = 0.535$$
$$\omega t = \sin^{-1}\omega t = 32.3°$$

Firing angle = 32.3 degrees

Solution



b)

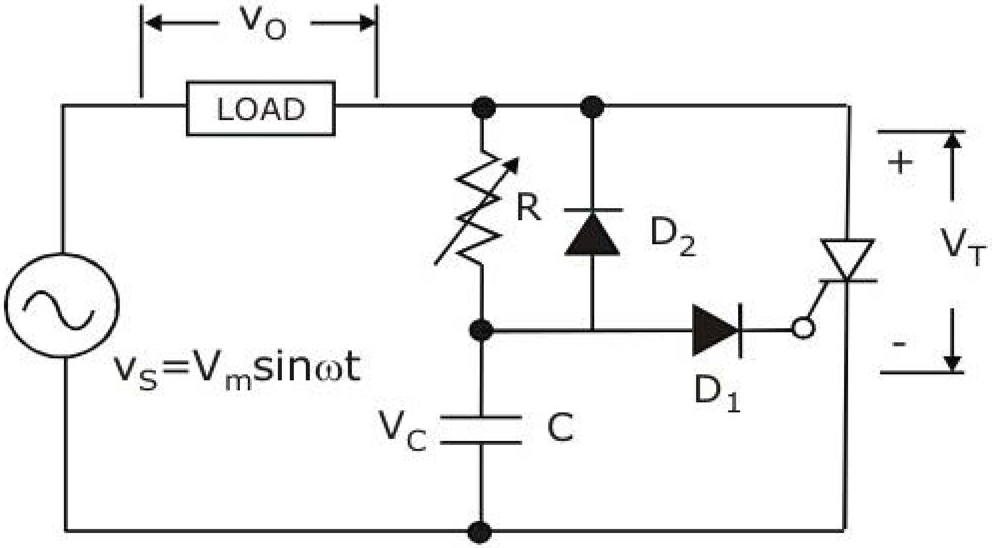
$$e_t = I_g \cdot (R_1 + R_2) + V_D + V_g$$

$$\sqrt{2} \times 48 = 0.5 \times 10^{-3} \times R + 0.6 + 0.7$$

$$66.6 = 0.5 \times 10^{-3} \times R$$

$$R = \frac{66.6}{0.5 \times 10^{-3}} = 133\ \text{k}\Omega$$

RC Triggering Circuit



Advantage over R-triggering Circuit:

Controls upto 180 degrees

$$RC \geq \frac{1.3\,T}{2}$$

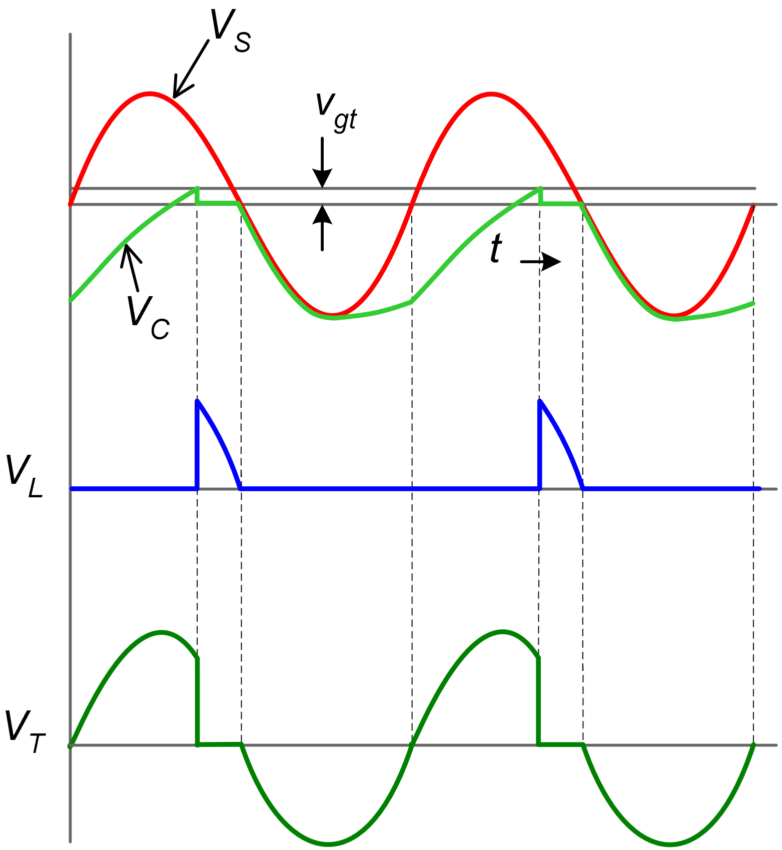
To ensure minimum gate current

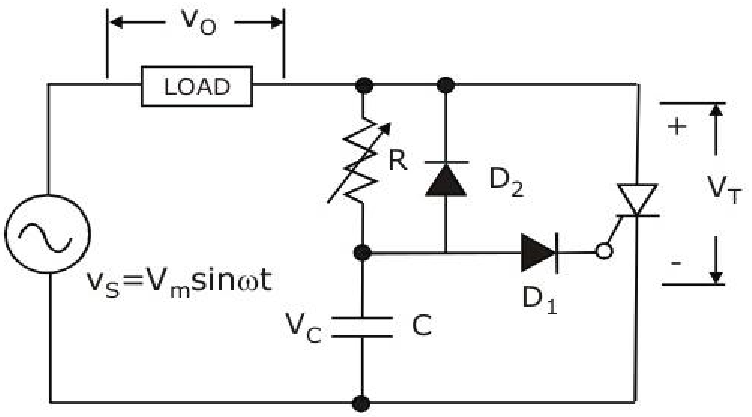
$$v_s \geq R\,I_{g\min} + V_{g\min} + V_{D_1}$$

$$R \leq \frac{v_s - V_{g\min} - V_{D_1}}{I_{g\min}}$$

- Capacitor charges during the negative half cycle through D_2
- When SCR is turned on, capacitor C is suddenly discharged through D_2
- D_1 protects the SCR during negative half cycle

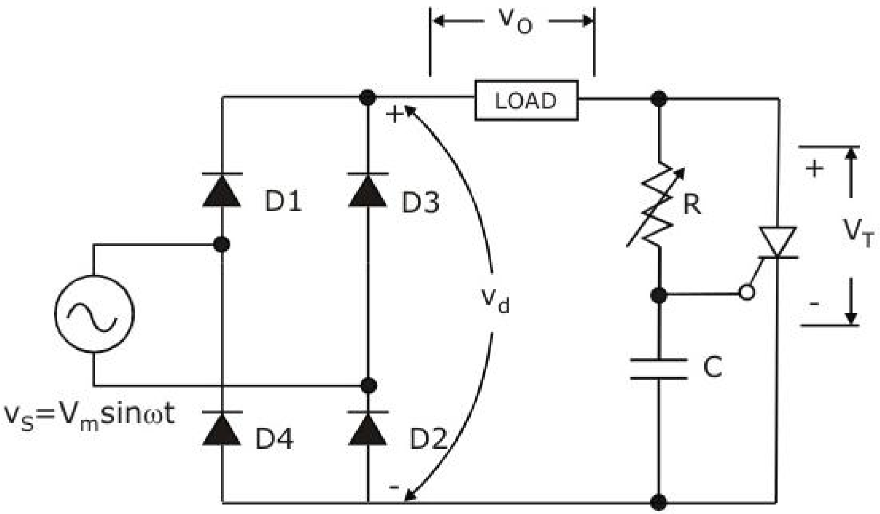
RC Trig Waveforms

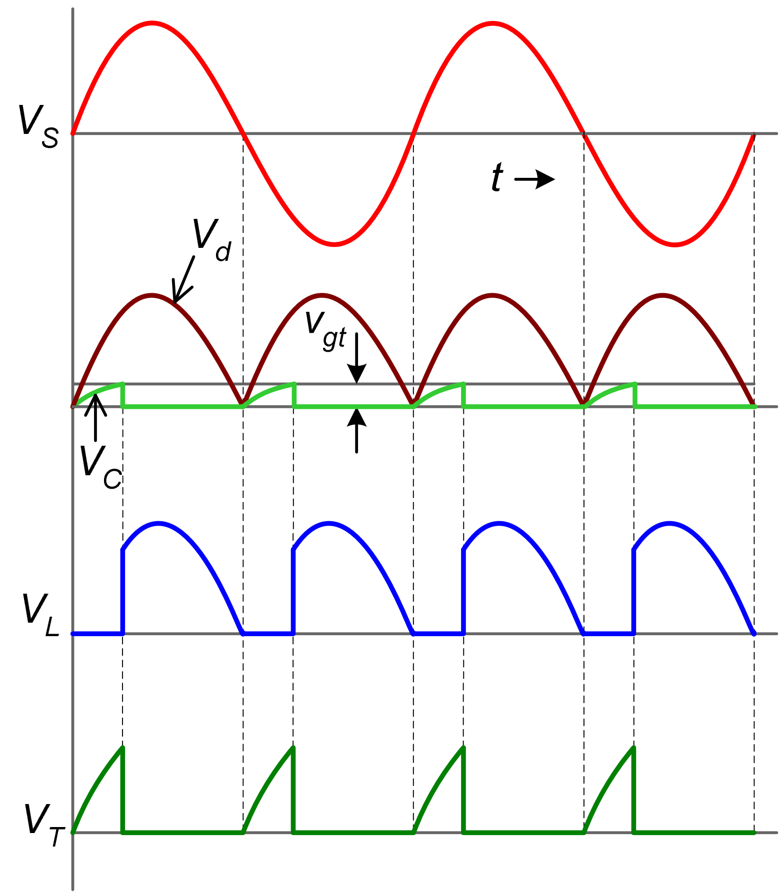




$$RC \geq \frac{1.3\,T}{2}$$

RC Full wave trigger circuit

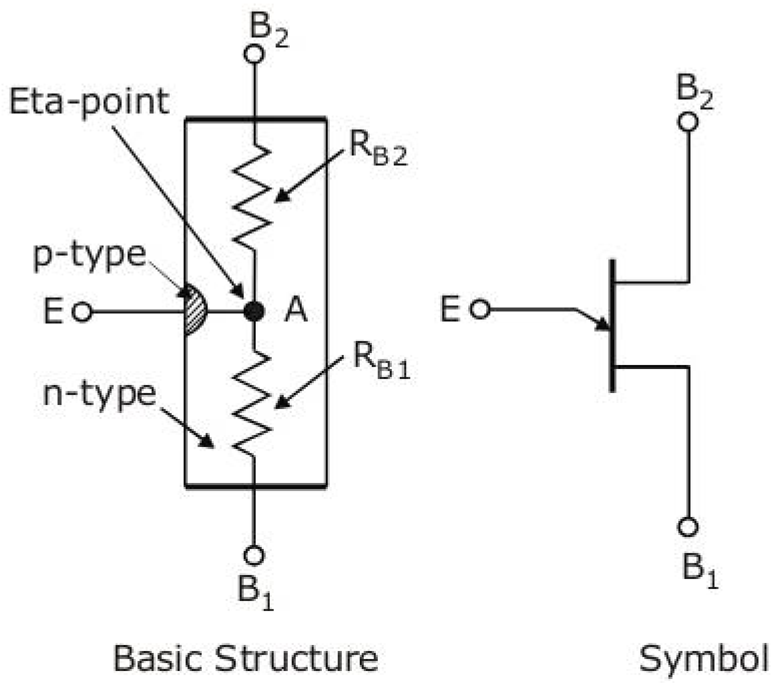




- Initial Capacitor voltage in each half cycle is almost zero

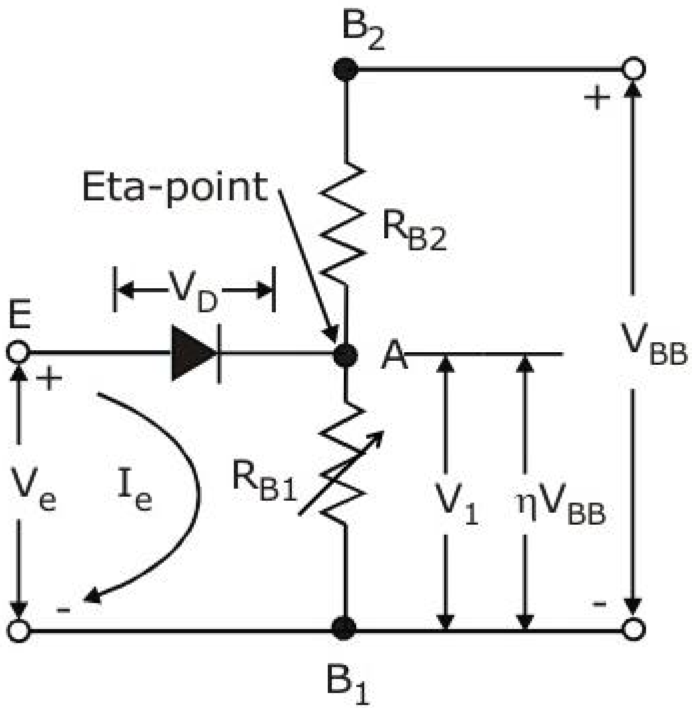
$$RC \geq \frac{50\,T}{2} \qquad R \leq \frac{v_s - V_{g\,min}}{I_{g\,min}}$$

Unijunction Transistor (UJT)



- Has a lightly doped n-type silicon layer to which a heavily doped p-type emitter is embedded
- The inter-base resistance is in the range of 5 – 10 kΩ
- This device cannot ‘amplify’

UJT Equivalent Circuit



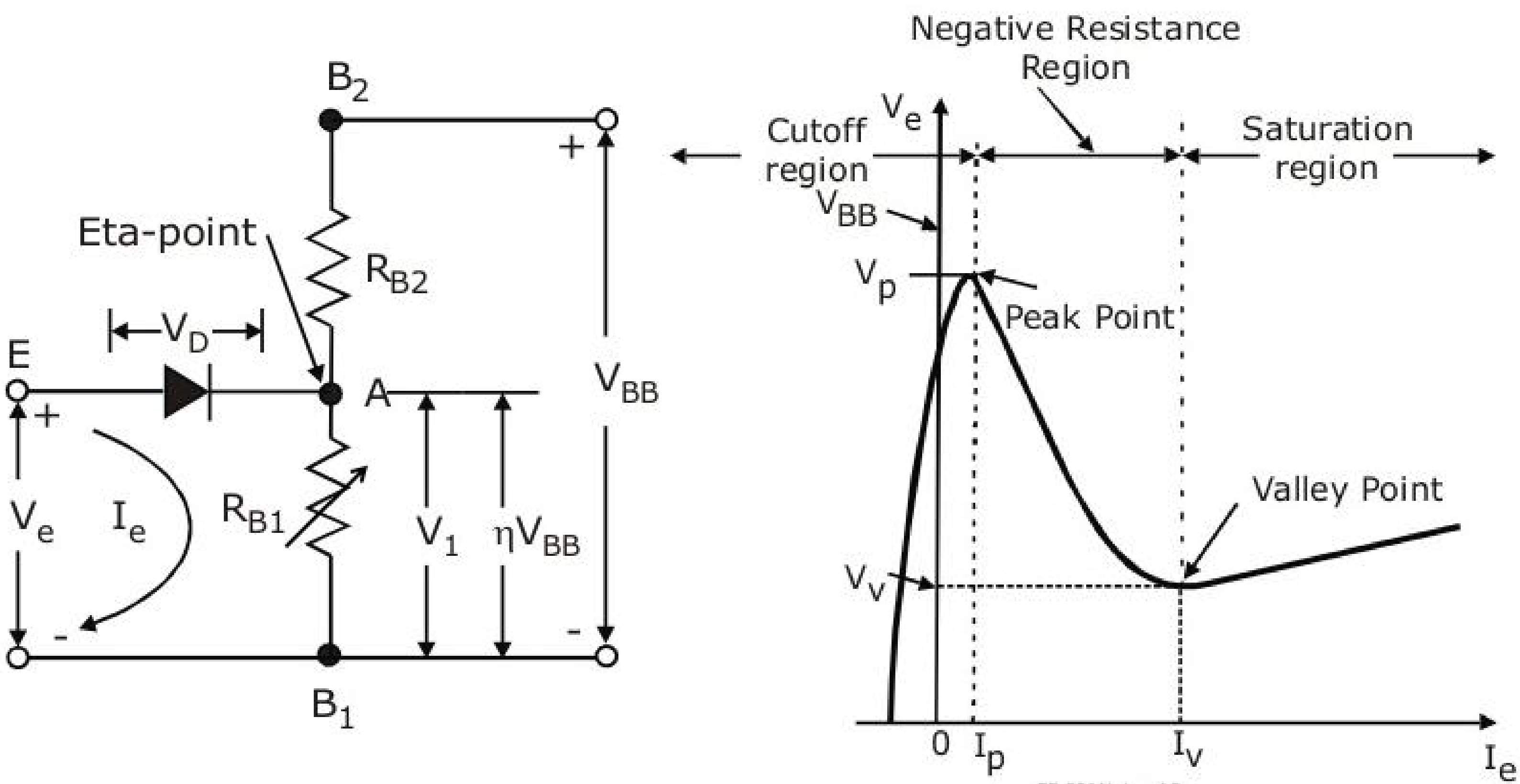
$$V_{AB_1} = \frac{R_{B_1}}{R_{B_1} + R_{B_2}} V_{BB} = \eta \, V_{BB}$$

η is called intrinsic standoff ratio

Value of η varies from 0.5 – 0.8

- When V_e is more than V_1+V_D, then the diode is forward biased and a current flows through R_{B1}
- Number of carriers in R_{B1} increases and the resistance reduces
- V_e decreases with increase in I_e and the therefore the device is said to exhibit negative resistance

UJT Characteristics



At peak point, $V_e = V_1 + V_D$,

At Valley point, R_{B1} is minimum

UJT parameters

Maximum emitter reverse voltage

- Maximum reverse bias which the emitter – base2 junction can tolerate without breakdown. Typ: 30V

Maximum inter-base voltage

- Maximum voltage possible between base1 and base2. Decided by the power dissipation. Typ: 35 V

Interbase resistance

- Typ: 4.7 k – 9.1 k

Intrinsic stand off ratio

- Typ: 0.56 – 0.75

Maximum peak emitter current

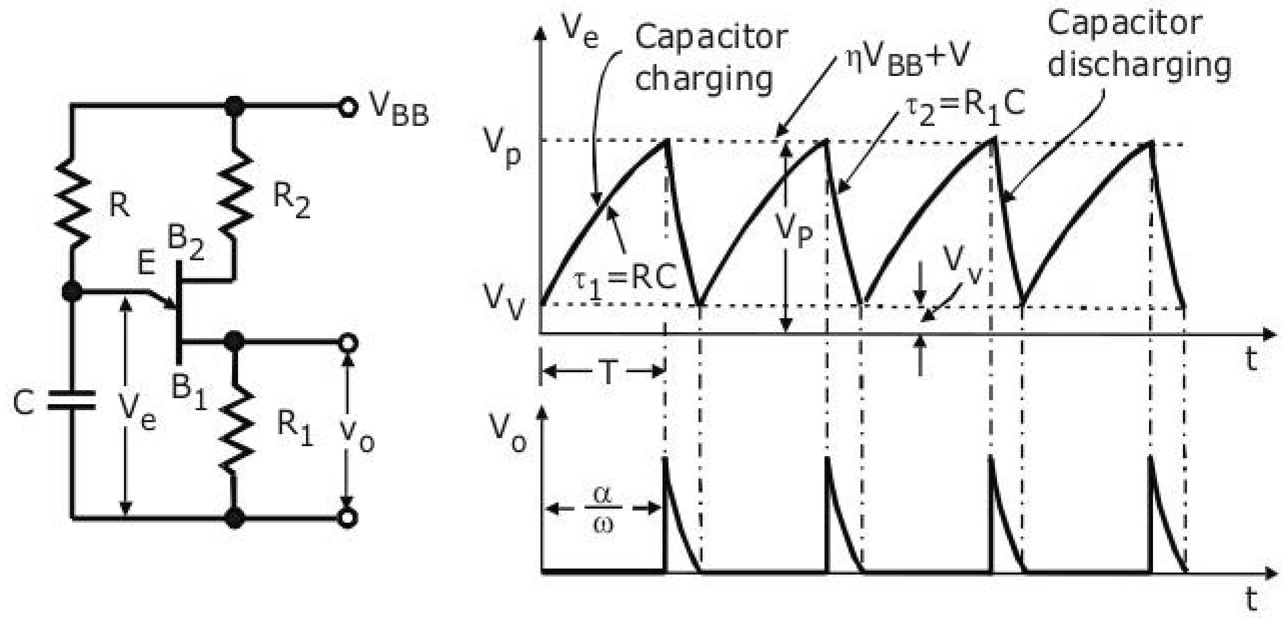
- Typ : 2A

Emitter leakage current

- The emitter current when V_e is less than V_p and the UJT is off.
- Typ 12 µA

Typical values are of 2N2646

UJT Oscillator



- R_1 and R_2 are much less than the inter-base resistance
- The output pulses can be used to trigger an SCR

Design

$$V_C = V_{BB}\left(1 - e^{-t/RC}\right)$$

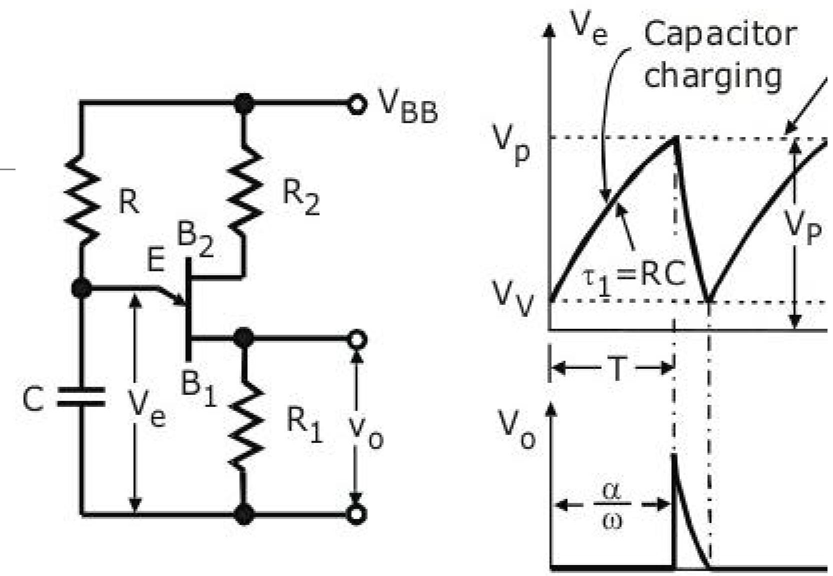
Time required for C to charge from V_v to V_p is obtained as follows

$$V_p = \eta V_{BB} + V_D = V_v + V_{BB}\left(1 - e^{-t/RC}\right)$$

Assuming $V_D = V_v$ $\quad \eta = \left(1 - e^{-t/RC}\right)$

For this case, $t \cong T$

$$T = \frac{1}{f} = RC \ln\left(\frac{1}{1-\eta}\right)$$

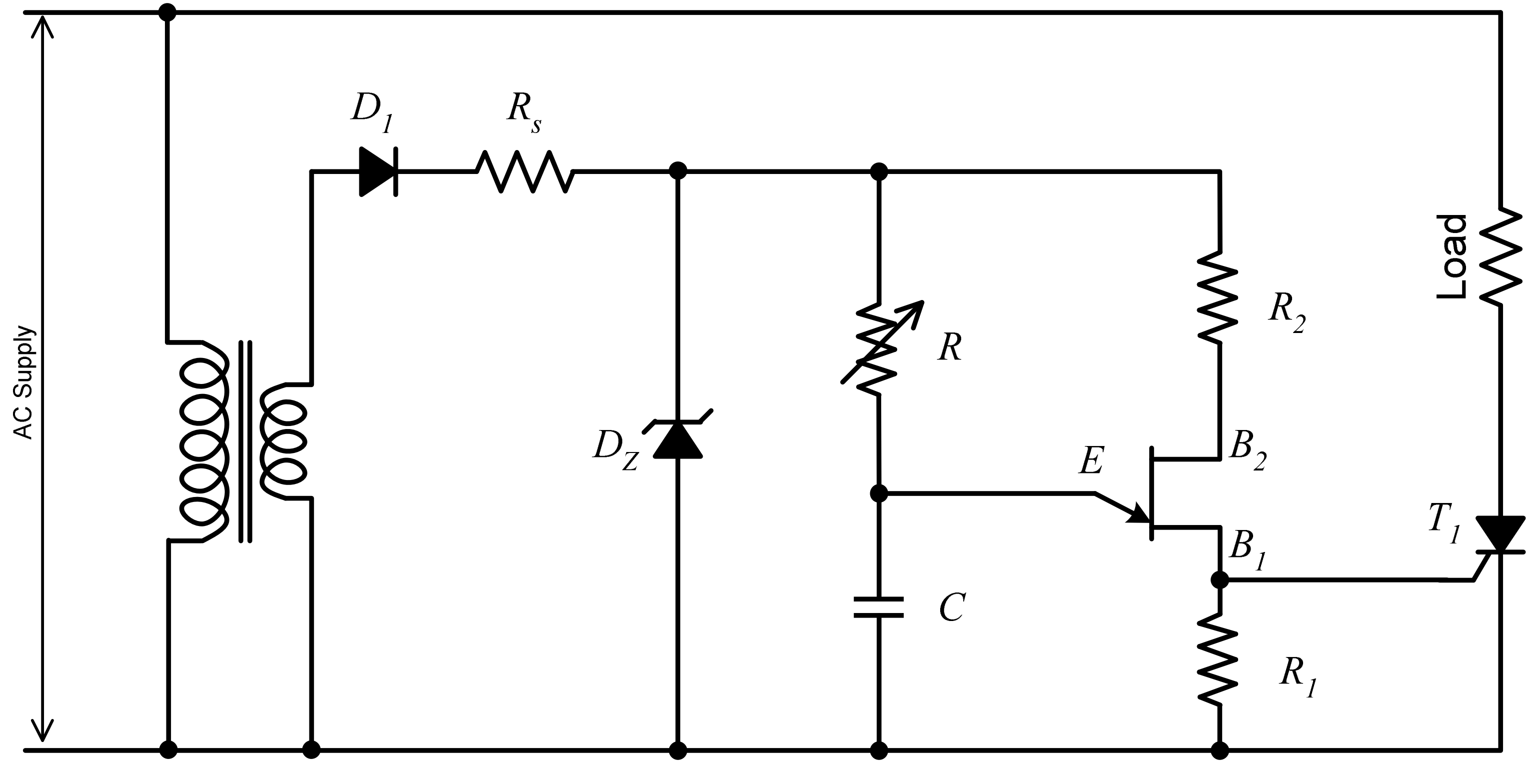


R_1 is selected based on voltage level required to trigger the SCR

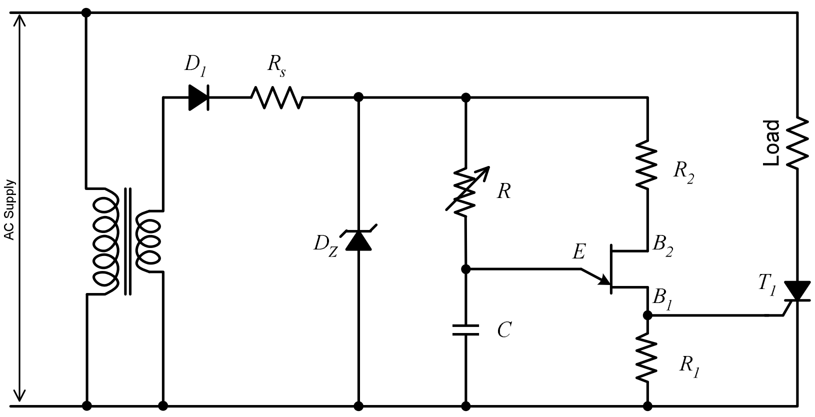
R_2 is selected using the empirical formula:

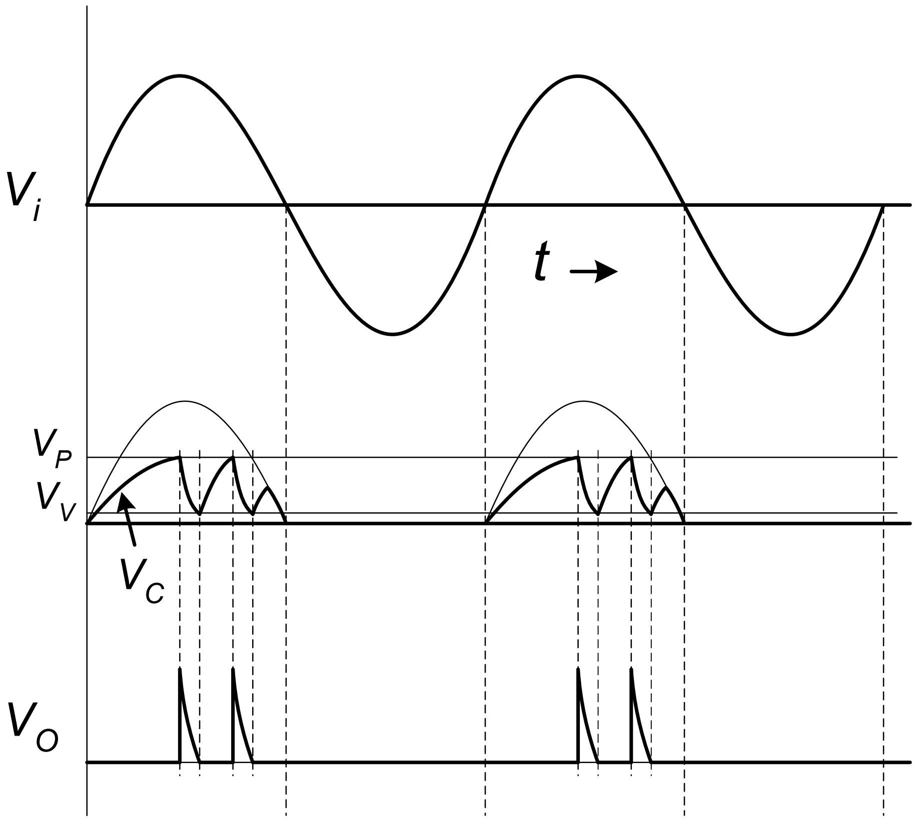
$$R_2 = \frac{10^4}{\eta V_{BB}}$$

UJT firing circuit for Half Wave Controller

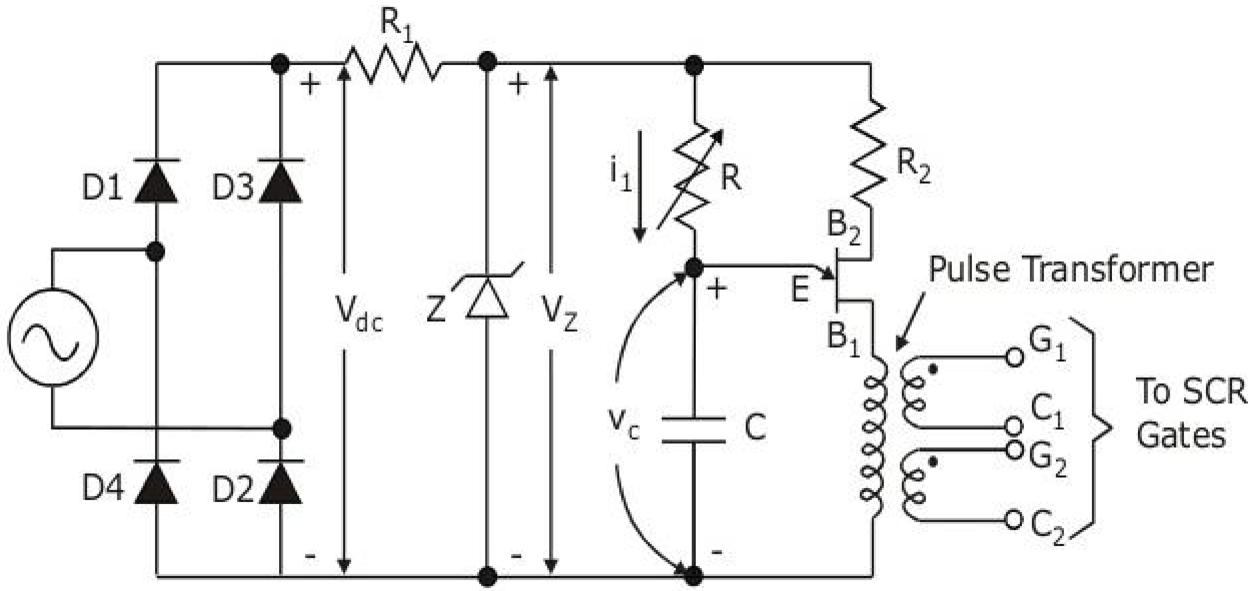


Waveforms for Half Wave Controller





Full wave UJT trigger Circuit



Problem

Design a UJT relaxation oscillator using UJT2646 for triggering an SCR. The UJT has the following parameters

$\eta = 0.63$, $V_{BB} = 20$ V, $V_P = 13.2$ V, $I_P = 50$ μA

$V_V = 2$ V, $I_V = 6$ mA, $R_{BB} = 7$ kΩ, leakage current = 2.5 mA

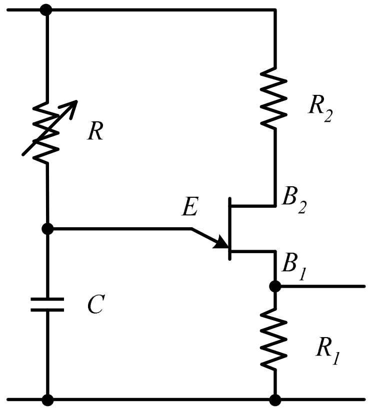
Also find the minimum and maximum time period of oscillation.

Solution:

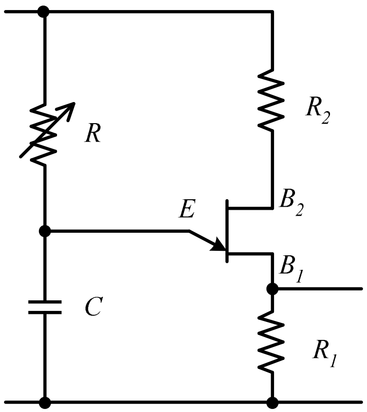
Assume C = 0.1 μF

$$R_{\max} = \frac{V_{BB} - VP}{I_P} = \frac{20 - 13.2}{50 \times 10^{-6}} = 136\, k\Omega$$

$$R_{\min} = \frac{V_{BB} - V_V}{I_V} = \frac{20 - 2}{6 \times 10^{-3}} = 3\, k\Omega$$



Approximate value of $R_2 = \frac{10^4}{\eta \, V_{BB}} = \frac{10^4}{0.63 \times 20} = 794\,\Omega$



$$R_1 = \frac{V_{g\text{min}}}{Leakage\,current} = \frac{0.7}{2.5 \times 10^{-3}} = 280\,\Omega$$

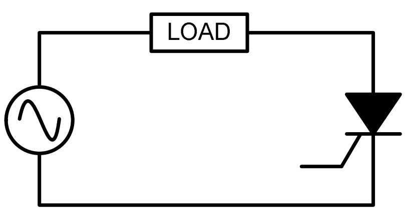
$$T_{\text{max}} = RC\ln\left(\frac{1}{1-\eta}\right) = 136 \times 10^3 \times 0.1 \times 10^{-6} \times \ln\left(\frac{1}{1-0.63}\right) = 13.5\,ms$$

$$T_{\text{min}} = 3 \times 10^3 \times 0.1 \times 10^{-6} \times \ln\left(\frac{1}{1-0.63}\right) = 0.3\,ms$$

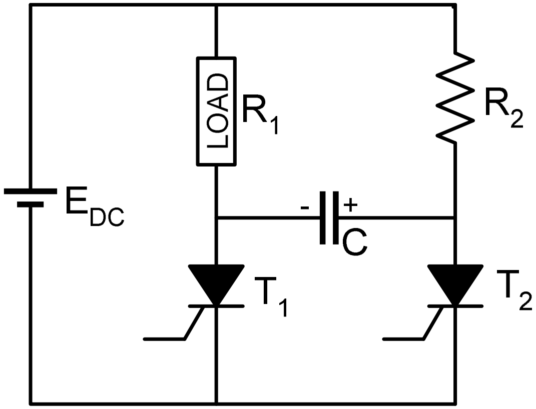
Commutation

- Commutation us the process by which a thyristor is turned off or current diverted to another path.
- There are two types of commutation
  - Natural Commutation
  - Forced Commutation

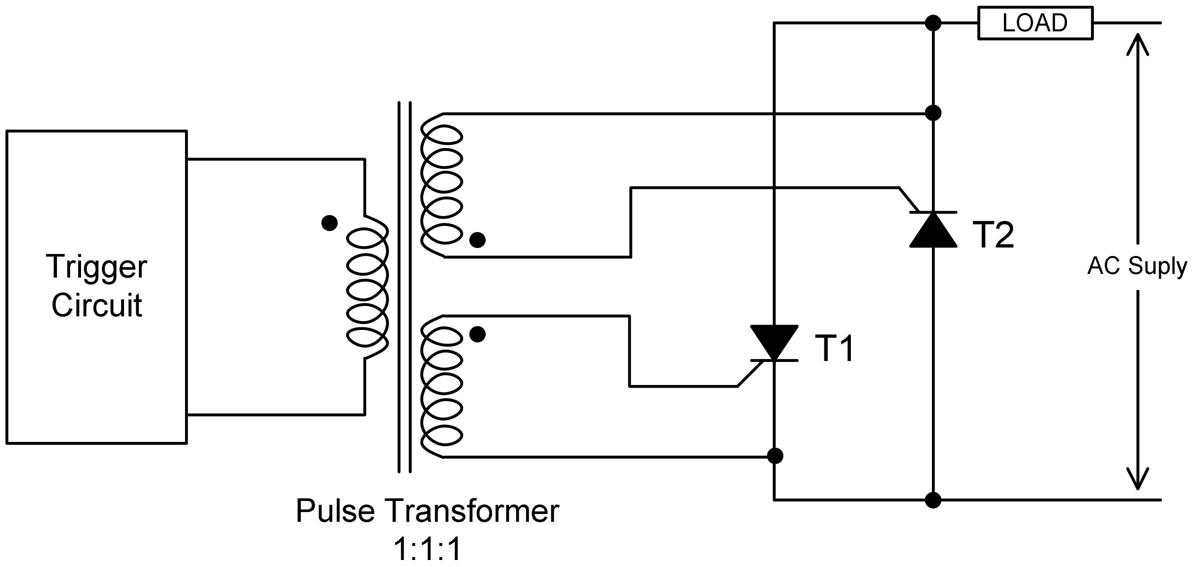
- In natural commutation, the reversing nature of alternating voltages turn off the thyristor
- Suitable for AC circuits only
- Current passes through a zero in every half cycle
- No external circuit is required for natural commutation



- In DC circuits, external circuits are necessary for turn off of thyristors
- Turn off with external circuits is called forced commutation

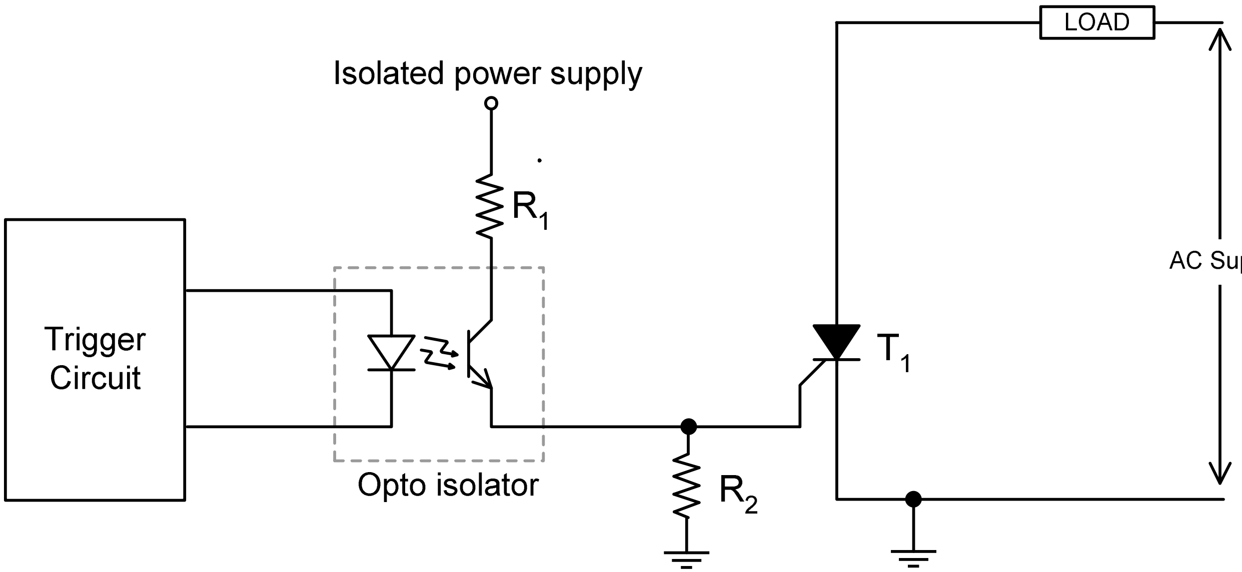


Pulse Transformer



- Used to trigger SCR, TRIAC etc
- Provides Electrical isolation between power circuit and control circuit

Optical Isolation



- Used to trigger SCR, TRIAC etc
- Provides Electrical isolation between power circuit and control circuit