EEE-2103: Electronic Devices and Circuits

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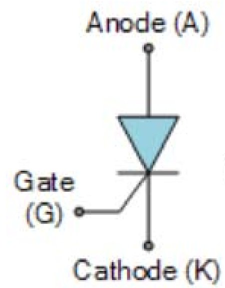
Silicon-Controlled Rectifier (SCR)

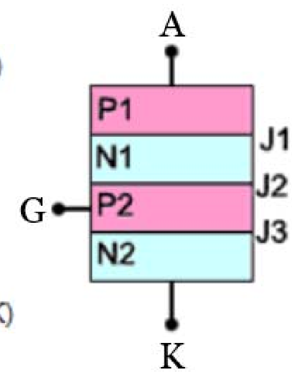
SCR operation:

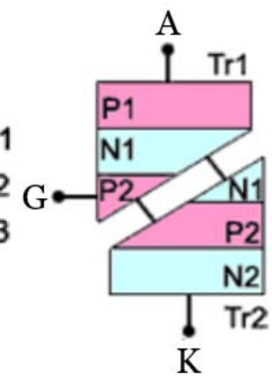
4 layers of semiconductor materials.

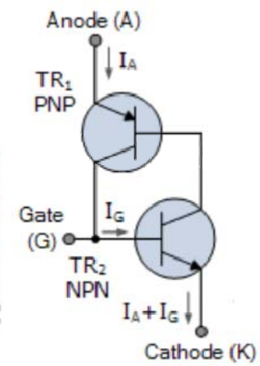
3 junctions- J_1, J_2 and J_3.

3 terminals- anode (A), cathode (K) and gate (G).





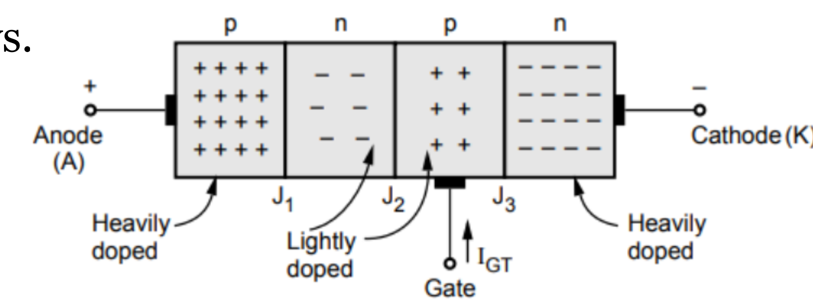


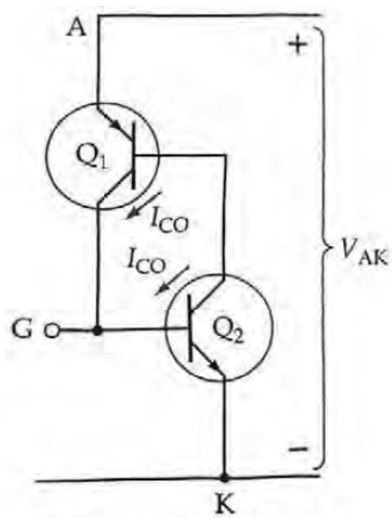


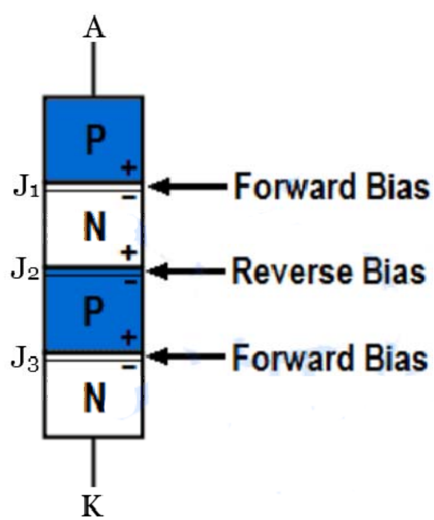
$+V_{AK}$ = +ve on A and –ve on K.

G is left unconnected (I_G = 0) →

TR_1 and TR_2 = off; small leakage current I_{CO} flows.







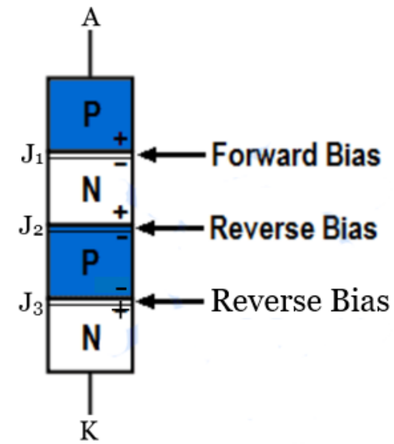
Silicon-Controlled Rectifier (SCR)

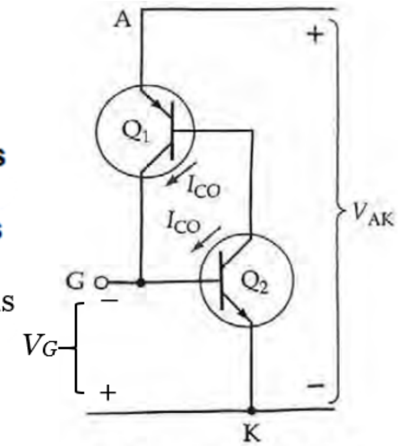
SCR operation:

$+V_{AK}$ = +ve on A and –ve on K.

-ve gate-cathode voltage (V_G = -ve) →

TR_1 and TR_2 = off; small leakage current flows.





$+V_{AK}$ = +ve on A and –ve on K.

+ve gate-cathode voltage (V_G = +ve) →

$I_G = I_{B2} \rightarrow I_{C2}$

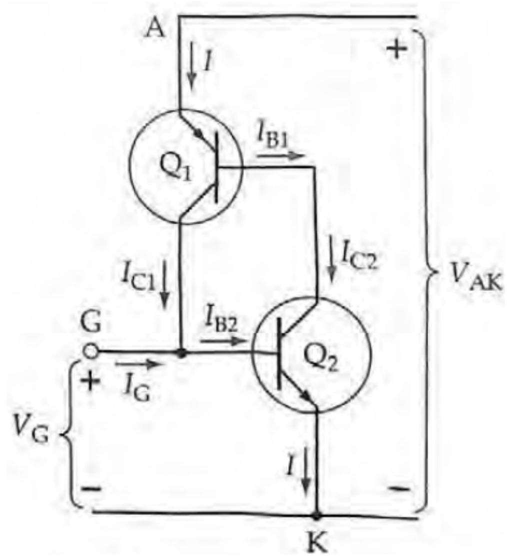
$I_{C2} = I_{B1} \rightarrow I_{C1}$

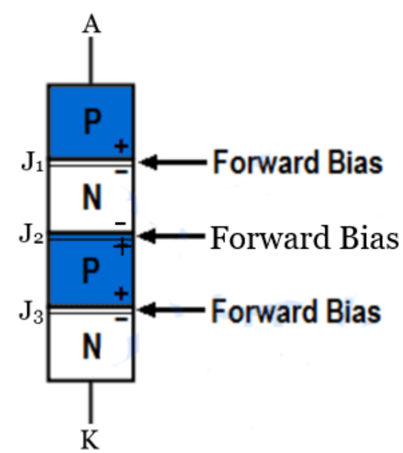
$I_{C1} = I_{B2} \rightarrow$ latching

To switch off SCR →

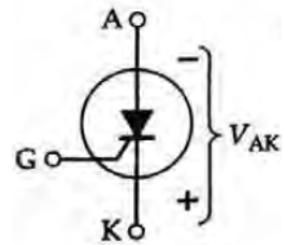
no gate control.

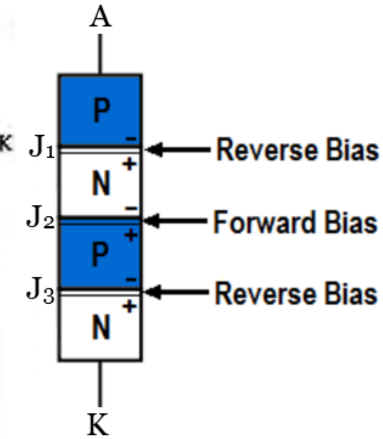
$V_{AK} \approx 0$





Silicon-Controlled Rectifier (SCR)





<u>SCR characteristics:</u>

Reverse bias →

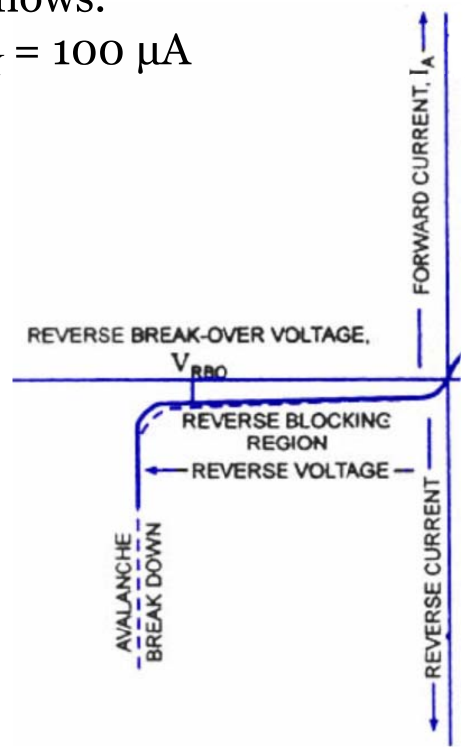
$-V_{AK}$ = -ve on A and +ve on K.

G is left unconnected (I_G = 0) →

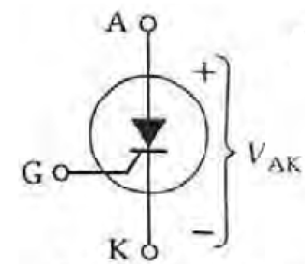
small $-V_{\mathrm{AK}}$ → reverse leakage current I_{RX} flows.
reverse blocking current I_{RX} = 100 µA

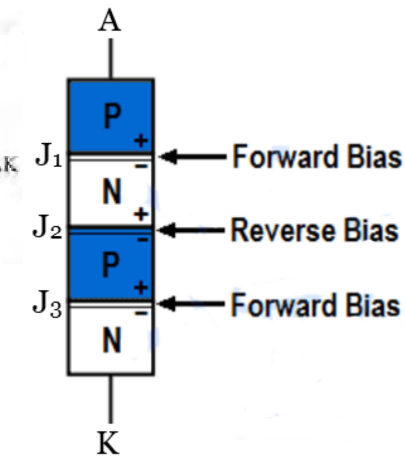
$-V_{AK}$ is increased →

I_{RX} remains constant.
reverse breakdown voltage is reached →
J_1 and J_3 break down
reverse current I_R increases rapidly



Silicon-Controlled Rectifier (SCR)





SCR characteristics:

Forward bias →

$+V_{AK}$ = +ve on A and -ve on K.

G is left unconnected (I_G = 0) →

small $+V_{AK}$ → forward leakage current I_{FX} flows.

reverse leakage current at J_2, I_{FX} = 100 μA

$+V_{AK}$ is increased →

I_{FX} remains constant.

forward breakover voltage $V_{F(BO)}$ is reached →

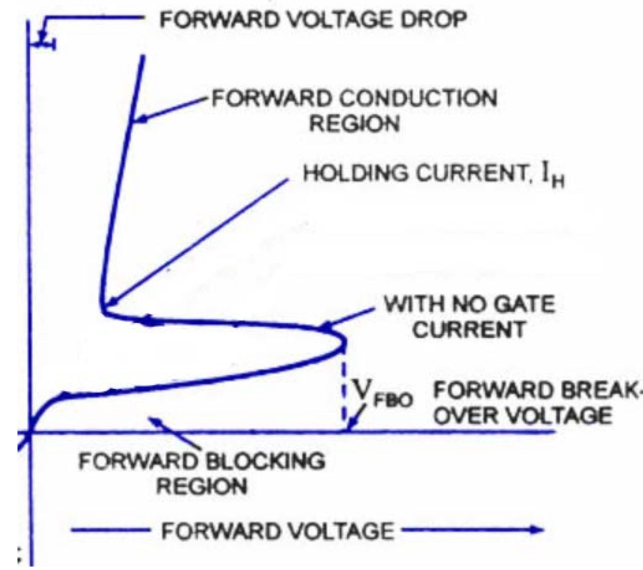
J_2 breaks down

forward current I_F increases rapidly

V_{AK} falls rapidly →

$V_{AK} = V_F$ (= forward conduction voltage)

device = forward conduction region



Silicon-Controlled Rectifier (SCR)

SCR characteristics:

Forward bias, $I_G > 0 \rightarrow$

$I_G > I_{B2} \rightarrow Q_2$ becomes on.

SCR switches on.

Forward blocking region

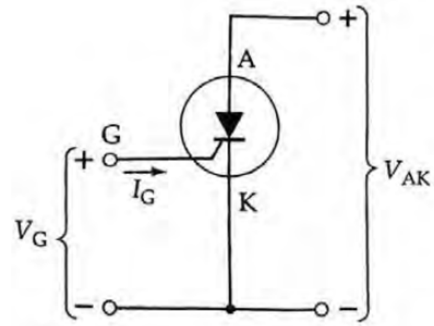
Forward conduction region

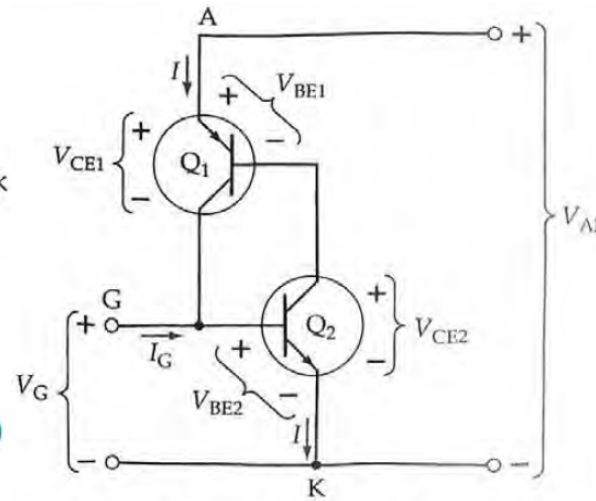
Holding current, $I_H \rightarrow$ minimum I_F that maintains SCR conduction.

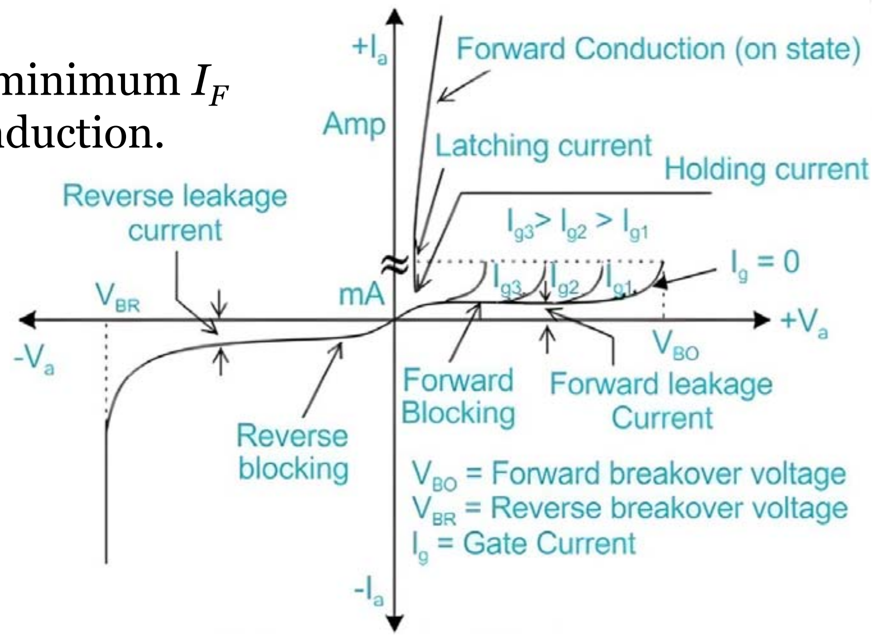
To switch SCR off $\rightarrow$

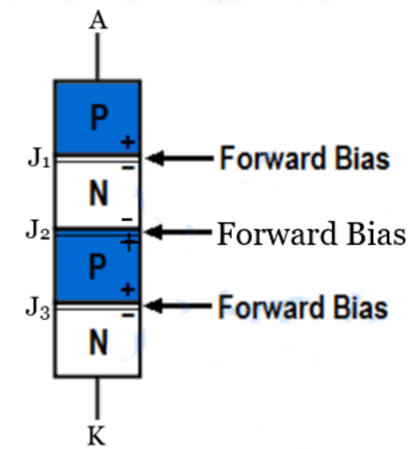
$I_F < I_H$

$V_{F(on)} = 1.7$ V









SCR Control Circuits

Pulse control:
SCR is triggered on by gate pulse.

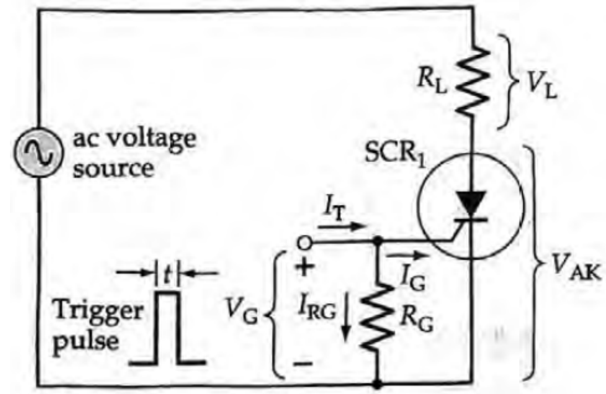
Average load power is varied with SCR conduction angle.

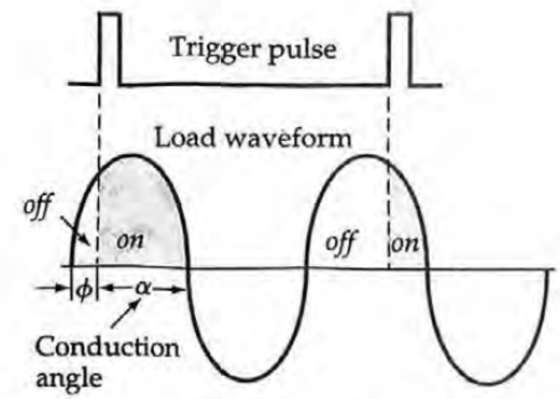
SCR is not triggered at $\alpha = 0^o$.
$V_{AK} >= V_{TM}$ (= forward on voltage).

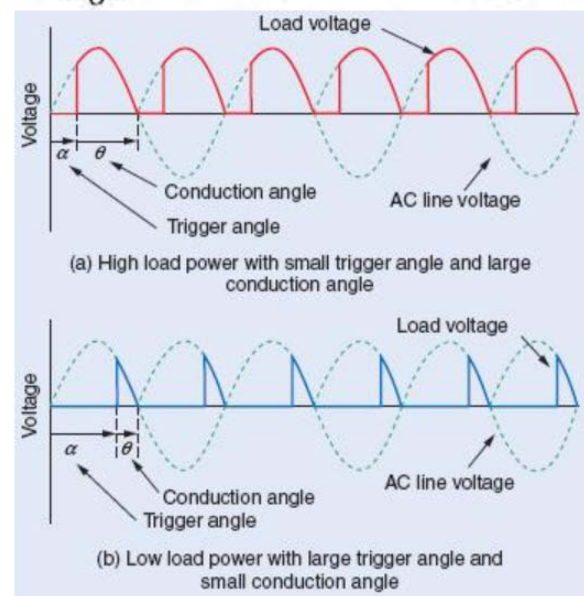
SCR will switch off at $\alpha < 180^o$.
I_L falls below I_H.

$V_L = e_s - V_{TM}$ [e_s = supply voltage]
$I_L = I_A \approx I_K$ [$I_K = I_A + I_G, I_G << I_A$]

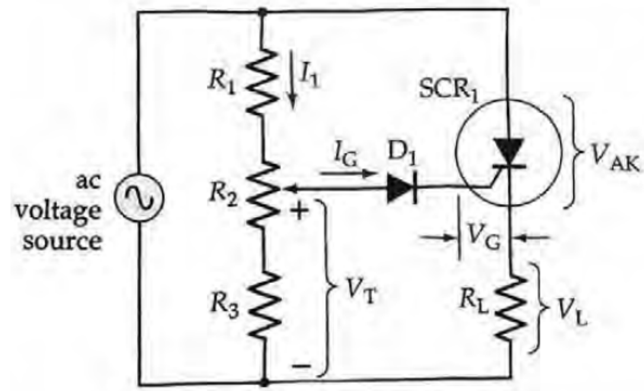
Instantaneous supply voltage that causes SCR to switch off
$e_{s(o)} = V_{TM} + I_H R_L$

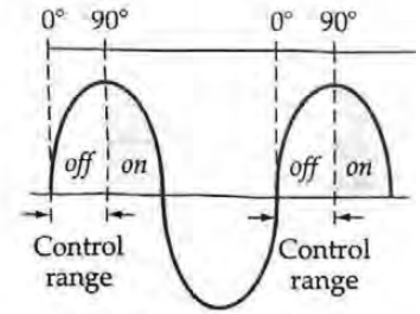






SCR Control Circuits





<u>90° phase control:</u>
Moving contact is set to top of R_2 →
SCR is triggered on at ≈ 0°.

Moving contact is set to bottom of R_2 →
SCR is triggered on at ≈ 90°.

Moving contact controls $\alpha \approx 0^o \sim 90^o$.

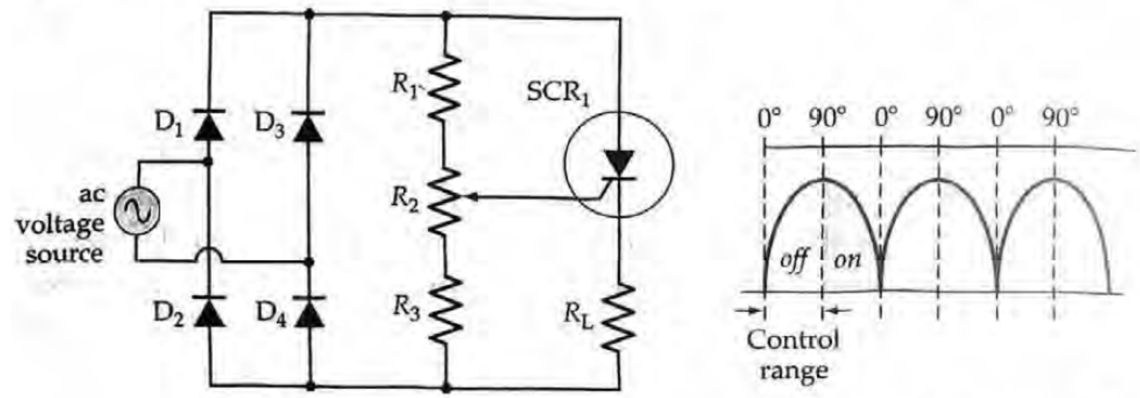
D_1 protects SCR gate from $-V_G$ during -ve half-cycle of ac supply.

Instantaneous triggering voltage at switch-on

$$V_T = V_{D1} + V_G$$

SCR Control Circuits

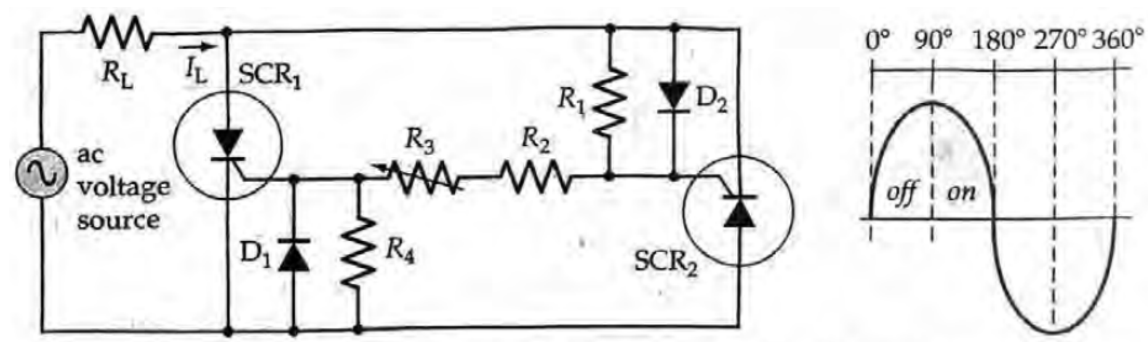
90° phase control (full-wave-rectified):



90° full-wave phase control:
+ve half-cycle →
D_2 is forward-biased.
Current flows through R_2, R_3 and R_4

-ve half-cycle →
D_1 is forward-biased.
Current flows through R_1, R_2 and R_3

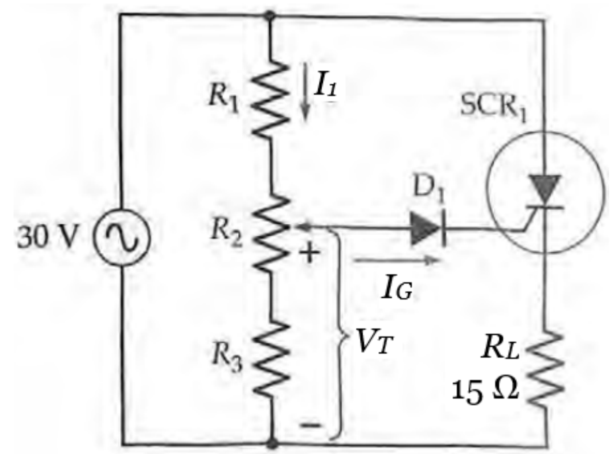
$R_1 = R_4 \rightarrow \alpha_1 = \alpha_2$



SCR Control Circuits

Problem-41:

The SCR in Fig. 41 is to be triggered on between 5° and 90° during the positive half-cycle of the 30 V supply. The gate triggering current and voltage are 200 μA and 0.8 V. Determine suitable resistance values for R_1, R_2 and R_3. Also, determine the SCR anode-cathode voltage at the instant of switch-on when the moving contact of potentiometer R_2 is set to (a) its center position and (b) its zero (bottom) position.



Peak supply voltage, $V_{s(pk)} = 1.414 \times V_s = 1.414 \times 30 = 42.4$ V

At 5°, $e_s = V_{s(pk)} \sin 5^{\circ} = 42.4 \times \sin 5^{\circ} \approx 3.7$ V

At 90°, $e_s = V_{s(pk)} = 42.4$ V

Triggering voltage at switch-on, $V_T = V_{D1} + V_G = 0.7 + 0.8 = 1.5$ V

To trigger at $e_s = 3.7$ V, R_2 moving contact is at top.

$V_{R2} + V_{R3} = V_T = 1.5$ V

$V_{R1} = e_s - V_T = 3.7 - 1.5 = 2.2$ V

Select $I_{1(min)} = 1$ mA ($>> I_G = 200$ μA)

$R_1 = V_{R1}/I_1 = 2.2/1\times10^{-3} = 2.2$ kΩ

$R_2 + R_3 = V_T/I_1 = 1.5/1\times10^{-3} = 1.5$ kΩ

SCR Control Circuits

Problem-41:

To trigger at e_s = 42.4 V, R_2 moving contact is at bottom.

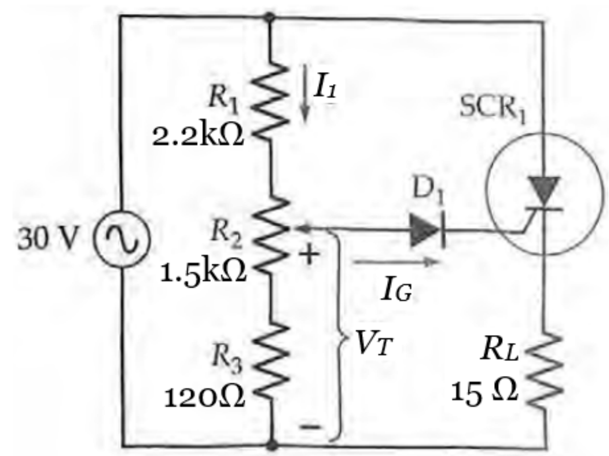
$V_{R3} = V_T$ = 1.5 V

$I_1 = \frac{e_s}{R_1+R_2+R_3} = \frac{42.4}{2.2\times10^3+1.5\times10^3} \approx$ 11.5 mA

$R_3 = V_T/I_1 = 1.5/11.5\times10^{-3}$ = 130 Ω (use 120 Ω standard value)

$R_2 = (R_2 + R_3) - R_3 = 1.5\times10^3 - 120$ = 1.38 kΩ

(use 1.5 kΩ standard value)



(a) SCR will trigger when V_T = 1.5 V (R_2 contact at center)

$V_{AK} = \frac{V_T(R_1+R_2+R_3)}{R_3+0.5R_2} = \frac{1.5(2.2\times10^3+1.5\times10^3+120)}{120+\frac{1}{2}(1.5\times10^3)}$ = 6.6 V

(b) With R_2 contact at zero

$V_{AK} = \frac{V_T(R_1+R_2+R_3)}{R_3} = \frac{1.5(2.2\times10^3+1.5\times10^3+120)}{120}$ = 47.85 V

Because $V_{s(pk)}$ = 42.4 V, SCR will not trigger with R_2 at zero position.