Lecture (01) Power Semiconductor Device (1)

By:

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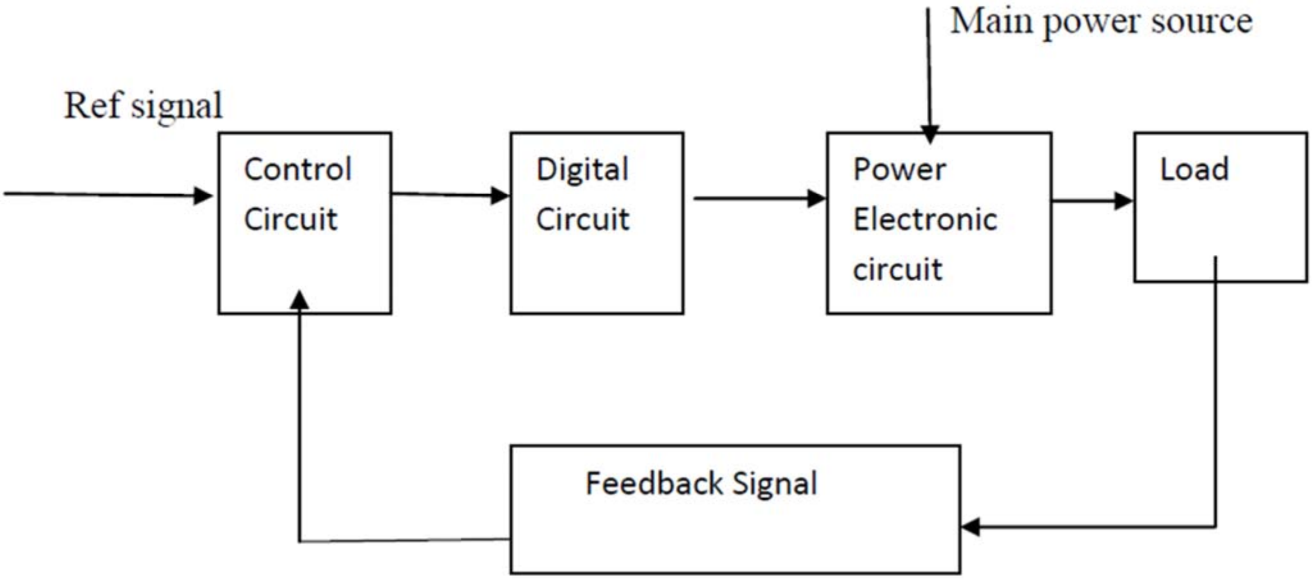
Introduction

- The control of electric motor drives requires control of electric power.
- Power electronics have eased the concept of power control.
- Power electronics signifies the word power electronics and control or we can say the electronic that deal with power equipment for power control.



- Power electronics based on the switching of power semiconductor devices.
- With the development of power semiconductor technology, the power handling capabilities and switching speed of power devices have been improved tremendously.

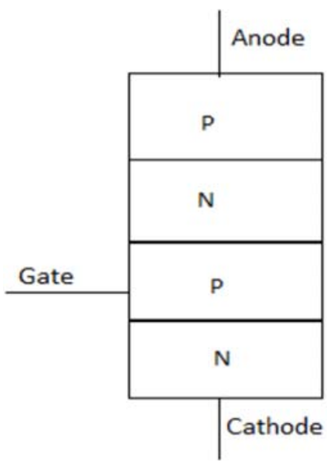
Power Semiconductor Devices

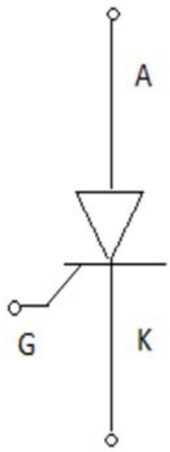
- The first SCR (The Silicon-Controlled Rectifier) was developed in late 1957.
- Power semiconductor devices are broadly categorized into 3 types:
  - 1. Power diodes (600V,4500A)
  - 2. Transistors
  - 3. Thyristors (10KV,300A,30MW)

* A Silicon-Controlled Rectifier, or *SCR*, is essentially a Shockley diode with an extra terminal added. This extra terminal is called the gate, and it is used to trigger the device into conduction (latch it) by the application of a small voltage

Thyristors

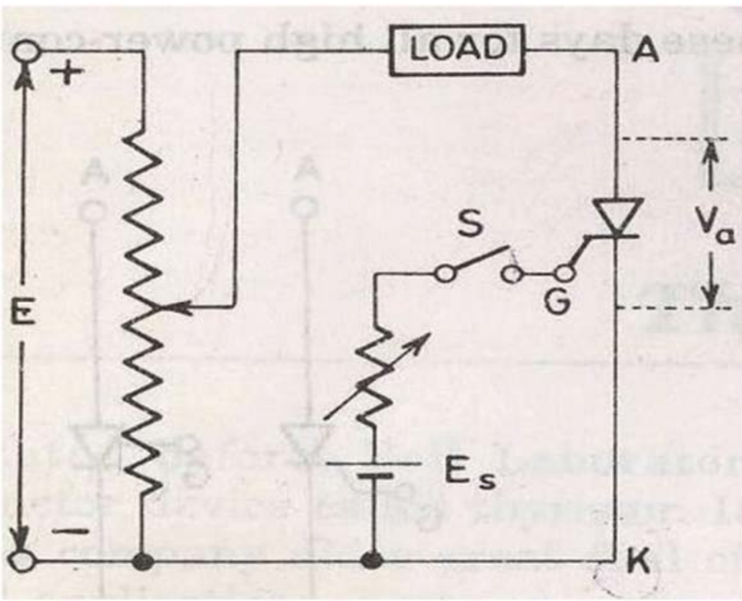
- Thyristor is a four layer three junction pnpn semiconductor switching device.
- It has 3 terminals these are anode, cathode and gate.
- SCRs (The Silicon-Controlled Rectifier) are solid state device, so they are compact, possess high reliability and have low loss.





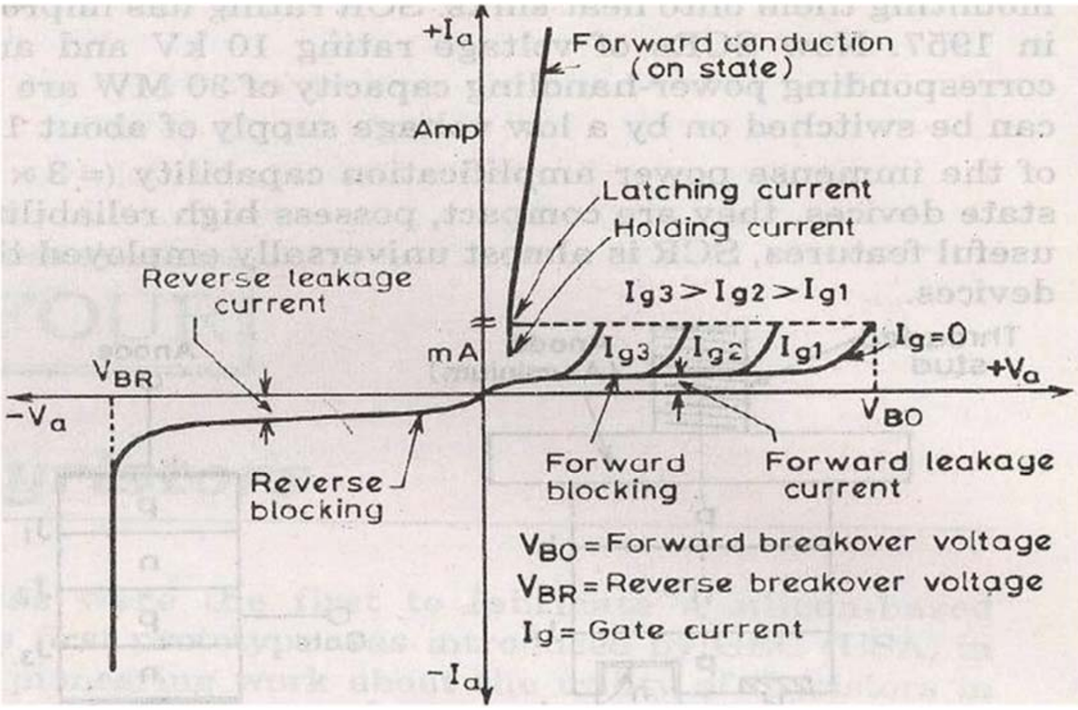
- SCR is made up of silicon, it act as a rectifier; it has very low resistance in the forward direction and high resistance in the reverse direction.
- It is a unidirectional device.

- **Static V-I characteristics of a Thyristor**
- Anode and cathode are connected to main source voltage through the load. The gate and cathode are fed from source E S.



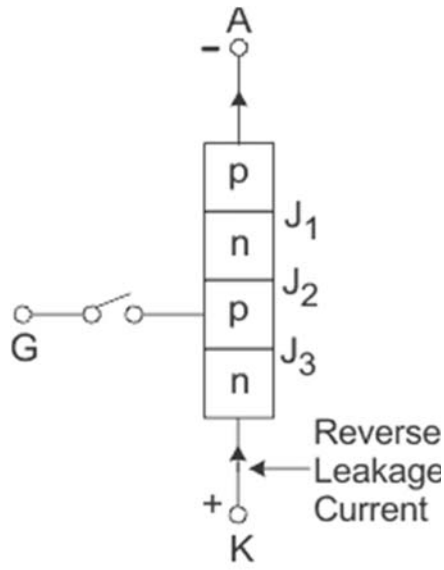
VBO=Forward breakover voltage
VBR=Reverse breakover voltage
Ig=Gate current
Va=Anode voltage across the thyristor terminal A,K.
Ia=Anode current

- A typical SCR V-I characteristic is as shown below:

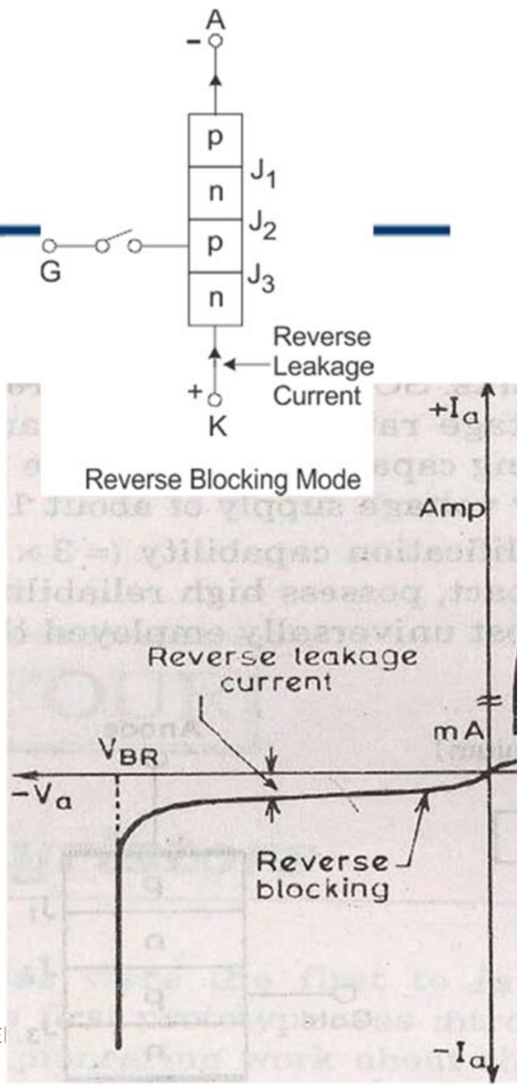


- It can be inferred from the static V-I characteristic of SCR.
- SCR have 3 modes of operation:
  – 1. Reverse blocking mode
  – 2. Forward blocking mode (off state)
  – 3. Forward conduction mode (on state)

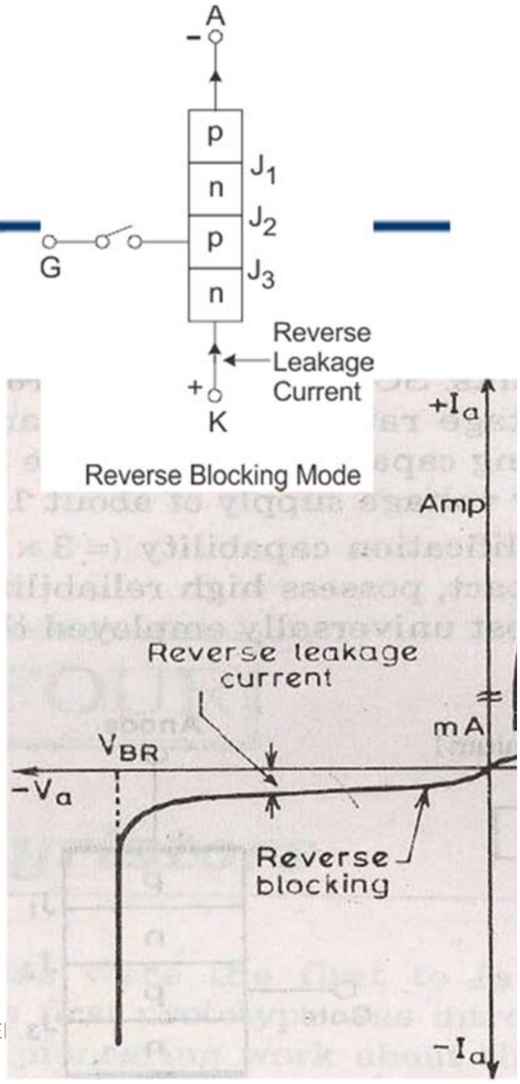
- **Reverse Blocking Mode**
- When cathode of the thyristor is made positive with respect to anode with switch open thyristor is reverse biased.
- Junctions $J1$ and $J3$ are reverse biased where junction $J2$ is forward biased.
- The device behaves as if two diodes are connected in series with reverse voltage applied across them.



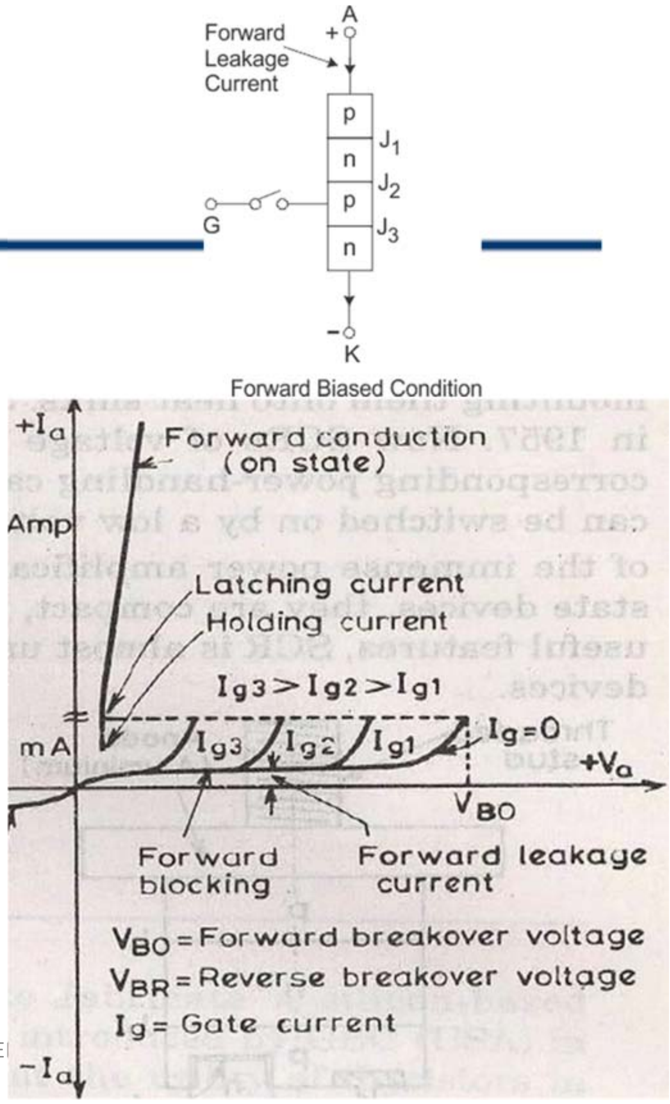
Reverse Blocking Mode



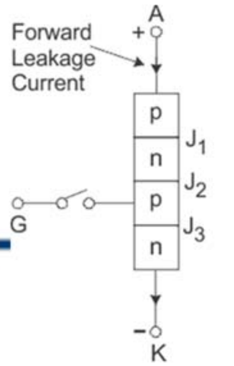
- A small leakage current of the order of few mA only flows.
- As the thyristor is reverse biased and in blocking mode.
- It is called as acting in reverse blocking mode of operation.
- Now if the reverse voltage is increased, at a critical breakdown level called reverse breakdown voltage VBR ,an avalanche occurs at $J1$ and $J3$ and the reverse current increases rapidly.
- As a large current associated with VBR and hence more losses to the SCR.



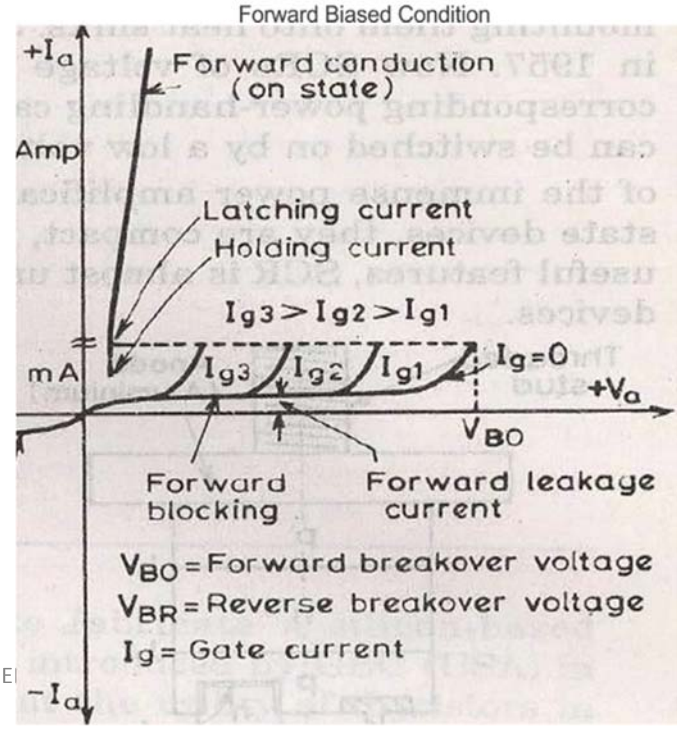
- This results in Thyristor damage as junction temperature may exceed its maximum temperature rise.



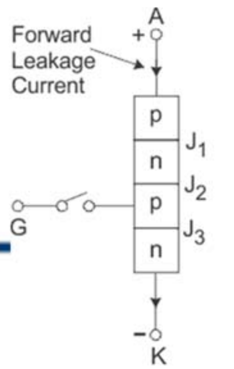
- **Forward Blocking Mode**
- When anode is positive with respect to cathode, with gate circuit open, thyristor is said to be forward biased.
- Thus junction $J1$ and $J3$ are forward biased and $J2$ is reverse biased.
- As the forward voltage is increases junction $J2$ will have an avalanche breakdown at a voltage called forward breakover voltage VBO.



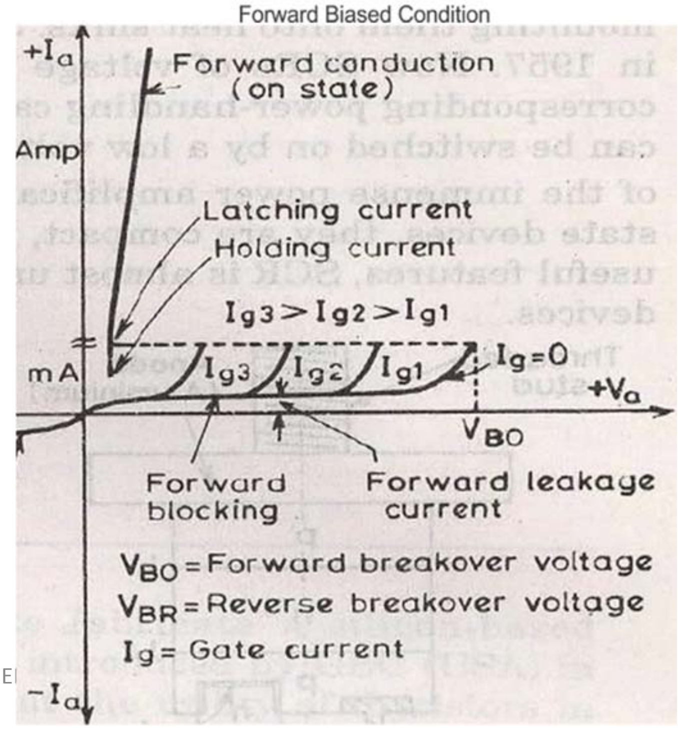
Forward Biased Condition



- When forward voltage is less then VBO thyristor offers high impedance.
- Thus a thyristor acts as an open switch in forward blocking mode.

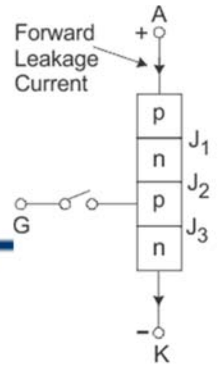


Forward Biased Condition



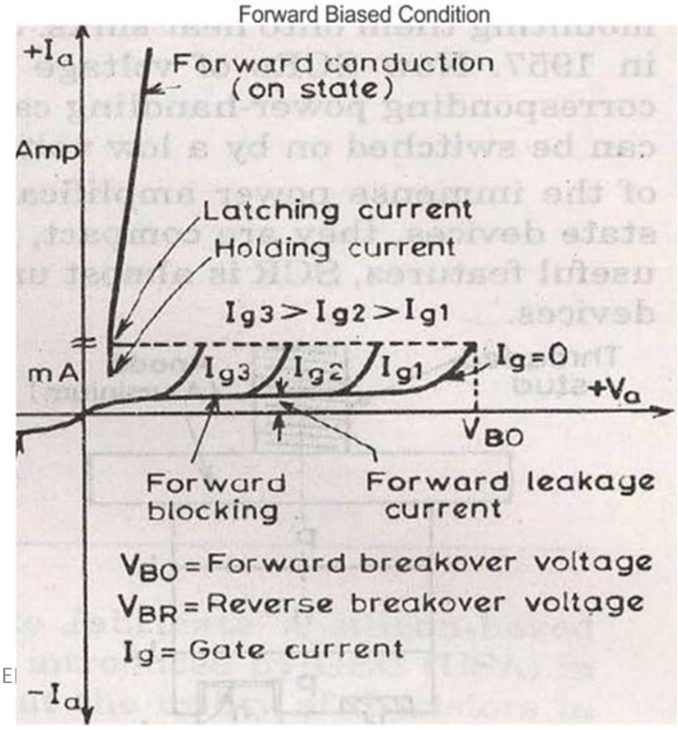
Forward Conduction Mode

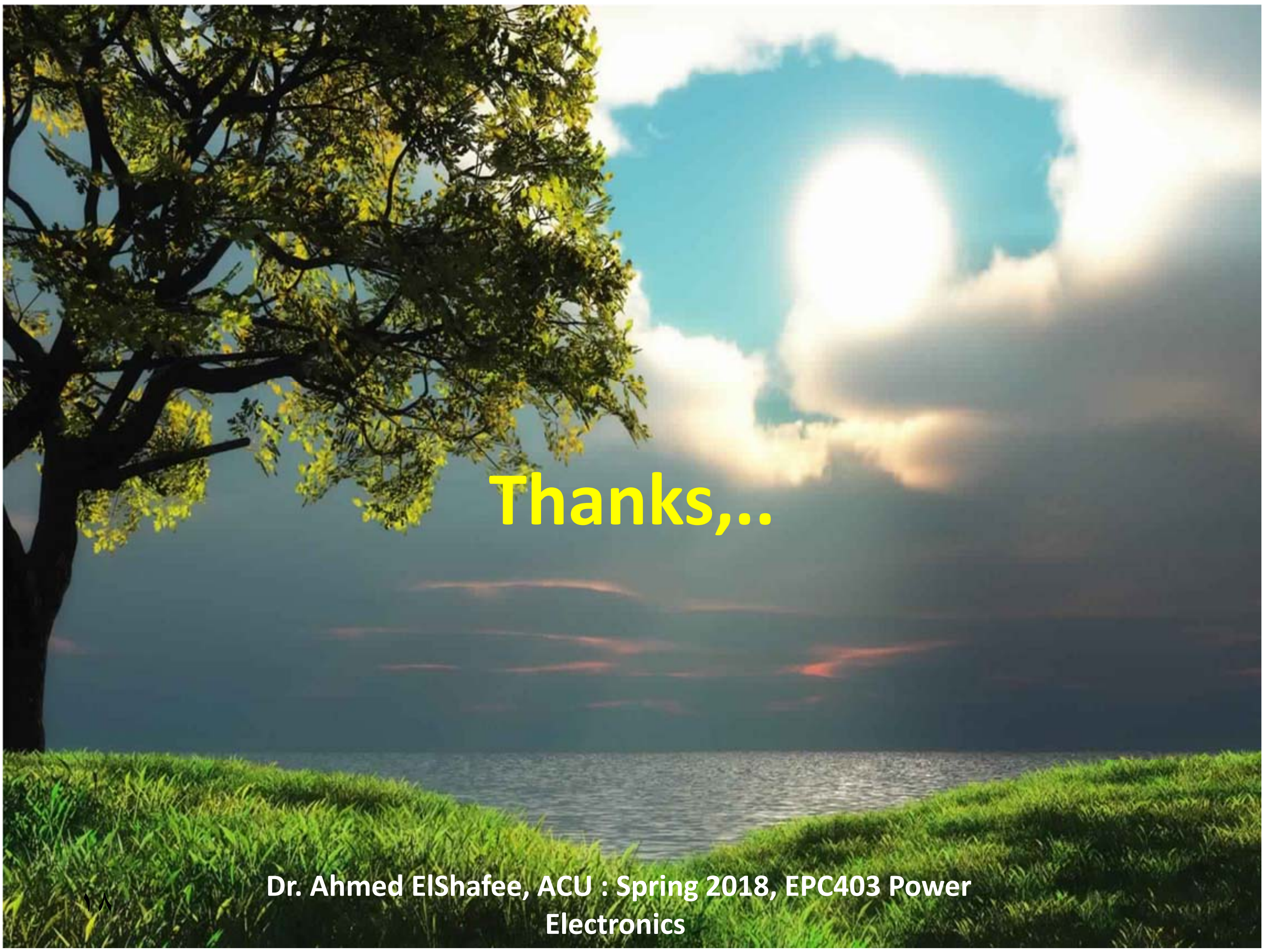
- Here thyristor conducts current from anode to cathode with a very small voltage drop across it.
- So a thyristor can be brought from forward blocking mode to forward conducting mode:
- 1. By exceeding the forward breakover voltage.
- 2. By applying a gate pulse between gate and cathode.



Forward Biased Condition

- During forward conduction mode of operation thyristor is in on state and behave like a close switch.
- Voltage drop is of the order of 1 to 2mV.
- This small voltage drop is due to ohmic drop across the four layers of the device





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