COMMUTATION CIRCUITS

Basic Overview:

Commutation circuits are crucial in power electronics for turning off conducting thyristors (or other power semiconductors) to control the flow of electrical power. They can be either natural (occurring in AC circuits due to the current naturally dropping to zero) or forced (requiring external circuitry to achieve the same effect in DC circuits or when natural commutation is not possible). Forced commutation involves using auxiliary circuits like capacitors and inductors to reverse bias the thyristor or reduce its current below the holding current.

Key Concepts:

- **Commutation:**

The process of turning off a conducting semiconductor switch.

- **Natural Commutation:**

Occurs naturally in AC circuits when the current flows through a thyristor drops to zero during the negative half-cycle.

- **Forced Commutation:**

Requires external circuitry to turn off a thyristor, especially in DC applications or when natural commutation is not desired.

- **Commutation Circuit:**

The auxiliary circuit used for forced commutation, typically consisting of capacitors, inductors, diodes, and other components.

- **Commutating Components:**

The individual components within the commutation circuit (e.g., capacitors, inductors).

- **Holding Current:**

The minimum current a thyristor needs to maintain its ON state. Reducing the current below this value will cause it to turn off.

- **Turn-off Time:**

The time it takes for a thyristor to transition from the ON state to the OFF state.

Types of Forced Commutation:

- **Voltage Commutation:**

Involves applying a reverse voltage across the thyristor to turn it off, as in complementary commutation.

- **Current Commutation:**

Reduces the anode current of the thyristor below the holding current, as in impulse commutation.

Applications of Commutation Circuits:

- **Choppers:**

Commutation circuits are essential in DC choppers to control the average voltage delivered to a load.

- **Inverters:**

They are used in inverters to convert DC power to AC power, enabling switching between different phases.

- **Rectifiers:**

Commutation is important in rectifier circuits, especially for forced commutation in DC applications.

- **AC Circuits:**

Commutation circuits are used to control the flow of current in AC circuits, such as in motor control applications.

Examples of Commutation Circuits:

- **Class A Commutation:**

A simple commutation circuit using a capacitor and resistor to reverse bias a thyristor.

- **Class B Commutation:**

A more complex circuit using a capacitor and inductor to provide a reverse voltage.

- **Class C Commutation:**

Uses a capacitor and inductor to provide a reverse voltage and current.

- **Class D Commutation:**

Uses a capacitor and inductor to create an impulse to turn off the thyristor.

- **Impulse Commutation:**

A specific type of forced commutation where a capacitor and inductor are used to generate an impulse to turn off the thyristor.

Let us dive deep into the topic to develop an in depth understanding :

SECTION 1. BASICS OF COMMUTATION IN POWER ELECTRONICS

Q1: What is commutation in power electronics?

Ans:
Commutation is the process of transferring current from one thyristor (SCR) to another in a controlled manner. It is essential for turning off a conducting thyristor, as SCRs cannot turn off by gate signal alone once turned on.

Q2: Why is commutation necessary in thyristor circuits?

Ans:
Thyristors are latching devices; once triggered, they remain on until the current falls below the holding current. Hence, commutation circuits are required to force the current to zero and turn off the SCR.

SECTION 2. TYPES OF COMMUTATION TECHNIQUES

Q3: What are the different types of commutation in power electronics?

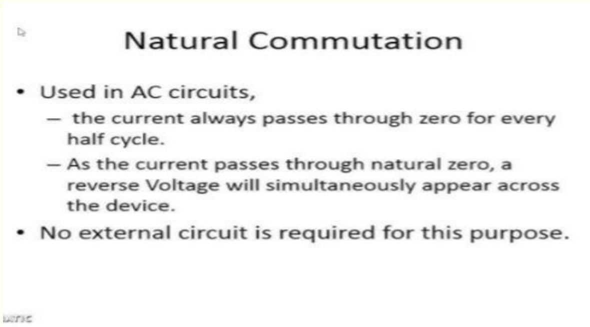
Ans:
There are mainly five types of commutation:

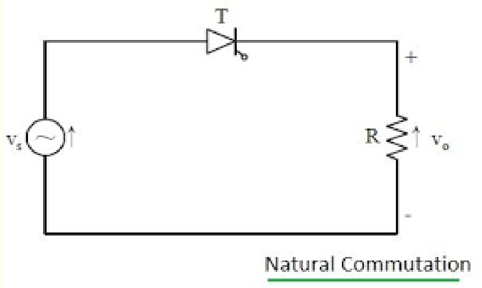
- **Natural Commutation (Class F)**
- **Resonant or Load Commutation (Class A)**
- **Forced Commutation (Class B)**
- **Complementary Commutation (Class C)**
- **External Pulse Commutation (Class D)**
- **Line Commutation (Class E)**

Sr. No.	Natural commutation	Forced commutation
1	Requires AC voltage at input	Requires DC voltage at input
2	External components are not required.	External components are required.
3	Used in controlled rectifiers, AC voltage controller	Used in choppers, inverters etc.
4	SCR turns off due to negative supply voltage.	SCR turns off due to current & voltage both
5	No Power loss takes place during commutation	Power loss takes place during commutation
6	Zero cost	Significant cost

Q4: What is natural commutation? In which applications is it used?

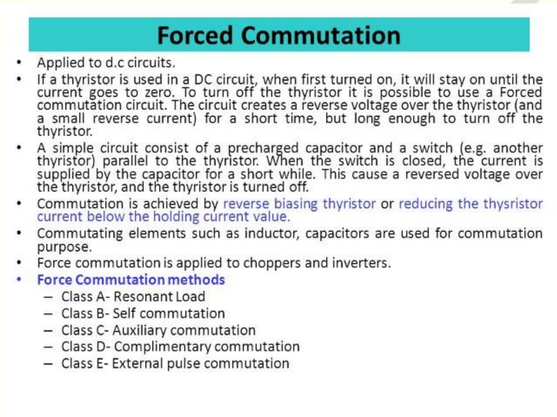
Ans:
Natural commutation occurs when the supply voltage naturally goes to zero, such as in AC circuits. It is commonly used in **AC to DC converters (controlled rectifiers)** where the supply voltage reverses every half cycle

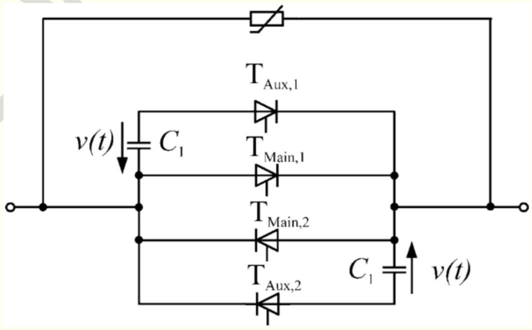




Q5: What is forced commutation? When is it required?

Ans:
Forced commutation is used in DC circuits where the voltage does not naturally reverse. An external circuit is used to momentarily reverse the voltage or force the current to zero. It is required in **DC choppers and inverters**.





Q6: What are the types of forced commutation circuits?

Ans:
Forced commutation is classified into:

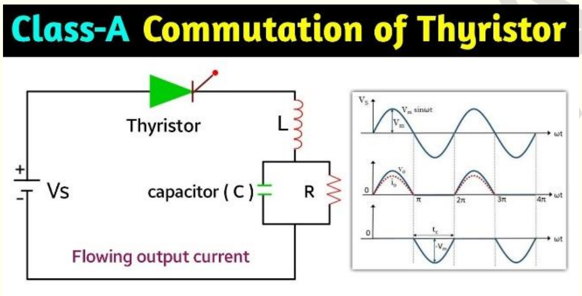
- **Class A: Resonant Load Commutation**
- **Class B: Self-Commutation by LC Circuit**
- **Class C: Complementary Commutation**
- **Class D: Auxiliary Commutation**
- **Class E: External Pulse Commutation**

Each method uses different combinations of capacitors and inductors to reverse the SCR current.

SECTION 3. EXPLANATION OF EACH COMMUTATION CLASS

Q7: Explain Class A (Resonant Load) Commutation.

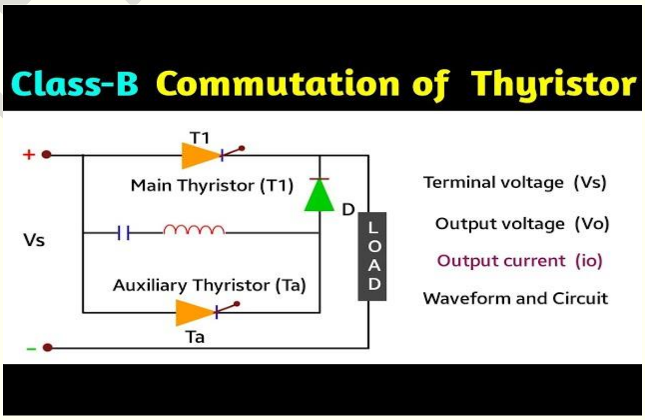
Ans:
In this, the load itself is LC resonant. When SCR is triggered, current flows through the load. As the capacitor discharges and current reverses, it naturally brings the SCR current to zero. Used in low power circuits.



• Circuit diagram of class A - commutation

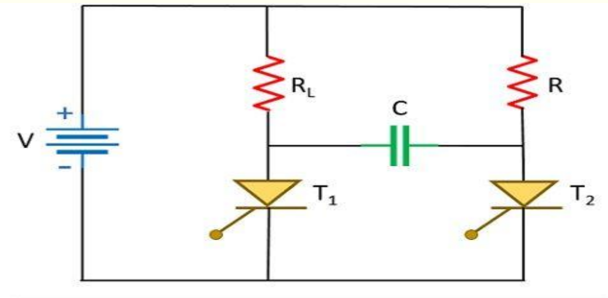
Q8: Explain Class B (Self-Commutation using LC).

Ans:
A charged capacitor and inductor form a resonant circuit. Once SCR conducts, the LC circuit discharges, reversing the voltage across SCR and turning it off.



Q9: Explain Class C (Complementary Commutation).

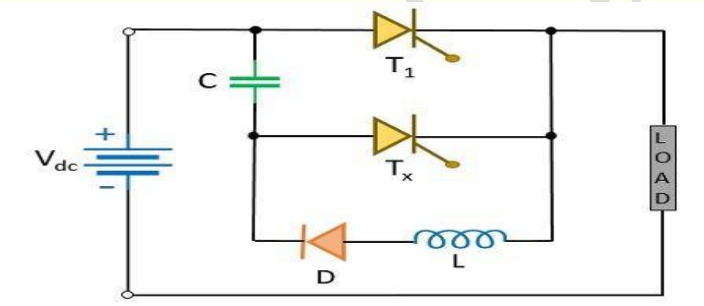
Ans:
Two SCRs are used. One SCR's turn-on causes the other to commutate. The capacitor is charged by one SCR and discharged through the other, achieving commutation.



Circuit of Class C Commutation

Q10: Explain Class D (Auxiliary Commutation).

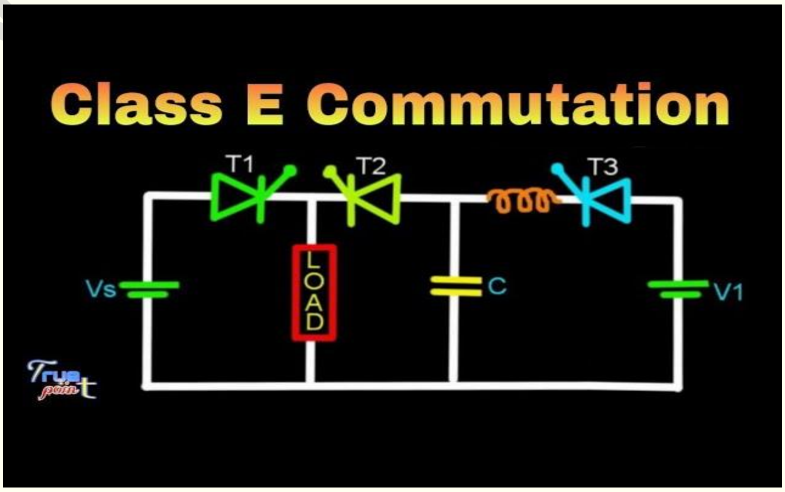
Ans:
An auxiliary SCR and capacitor are used to provide a reverse current to the main SCR to turn it off. Used in medium to high power applications.



Circuit of Class D Commutation

Q11: Explain Class E (External Pulse Commutation).

Ans:
An external pulse source like a voltage pulse generator is used to apply a reverse voltage to turn off the SCR. This is not common due to complexity and cost.



SECTION 4. COMPARISON AND APPLICATIONS

Q12: Which commutation technique is best for high-frequency applications?

Ans:
Class B and Class D commutation techniques are preferred due to fast turn-off capability and suitability for high-speed switching.

Q13: Where is complementary commutation used?

Ans:
Used in **inverter circuits** and **dual-converter systems**, where one SCR naturally commutates the other.

SECTION 5. PRACTICAL CONSIDERATIONS AND LIMITATIONS

Q14: What are the limitations of forced commutation circuits?

Ans:

- Require bulky components (inductors and capacitors)
- Increased complexity
- Reduced efficiency due to switching losses
- Higher cost compared to naturally commutated systems

SECTION 6. ADVANCED CONCEPTS

Q15: What is the role of commutation capacitor?

Ans:
The capacitor stores energy and is used to generate a reverse voltage across the SCR to reduce current to zero, enabling commutation.

Q16: What is turn-off time in context of SCR and commutation?

Ans:
Turn-off time is the minimum time interval between the instant SCR current becomes zero and the instant a positive voltage can be reapplied across it without re-triggering.

Q17: Define commutation margin angle (γ). Why is it important?

Ans:
Commutation margin angle (γ) is the angle between the instant when the outgoing SCR is expected to turn off and the voltage reversal point. It ensures safe commutation. If γ is too small, commutation failure may occur.

Q18: What are the design challenges in forced commutation circuits?

Ans:

- Precise timing required for commutation pulses
- Bulky passive components
- Heat dissipation from high di/dt and dv/dt
- Voltage overshoot and ringing due to resonance

Q19: Can commutation be controlled digitally in modern power electronics?

Ans:
Yes. **Digital signal controllers (DSCs)** and **microcontrollers** can precisely generate control pulses for commutation circuits. This improves timing accuracy, enhances protection, and enables software-based fault diagnosis.

Q20: What factors affect the selection of a commutation technique in practical circuits?

Ans:

- Type of load (AC/DC)
- Power level of application
- Desired switching frequency
- Size and cost constraints
- Device used (SCR vs IGBT/MOSFET)

SECTION 7. APPLICATION-ORIENTED QUESTIONS

Q21: Why is commutation important in choppers and inverters?

Ans:
In **DC-DC choppers** and **DC-AC inverters**, the supply is DC and hence SCRs will not turn off automatically. Commutation circuits are essential to switch SCRs off and continue power conversion.

Q22: How do modern devices like IGBTs and MOSFETs compare with SCRs in terms of commutation?

Ans:
IGBTs and MOSFETs are **self-commutating devices**, i.e., they turn off by gate signal, unlike SCRs which require complex commutation circuits. This simplifies design and increases switching frequency.

Q23: How is commutation handled in a single-phase full converter feeding a DC motor?

Ans:
In a single-phase full converter (bridge), **natural commutation** is used because the input is AC. The negative half-cycle of the AC supply naturally commutates the conducting SCRs. This makes it suitable for controlled rectification applications such as **DC motor drives**.

Q24: How are commutation techniques applied in HVDC systems?

Ans:
In **HVDC converter stations**, **line commutation (natural commutation)** is used with thyristors in the rectifier/inverter bridges. However, modern HVDC systems like **VSC-HVDC** use self-commutating devices (e.g., IGBTs), removing the need for external commutation circuits.

Q25: Why is forced commutation not used in high-power AC applications?

Ans:
Because **forced commutation** requires large and costly inductors and capacitors to handle high power and high currents, it becomes inefficient and bulky. In AC systems, **natural commutation** is preferred due to simplicity and lower cost.

Q26: How do commutation circuits influence inverter design for induction motor drives?

Ans:
Inverters for induction motors often use self-commutated devices like IGBTs. But if thyristors are used, **Class C or D commutation circuits** must be integrated to ensure reliable turn-off, especially in **cycloconverter-fed drives** or **older VFDs**.

Q27: How does commutation affect the selection of switching frequency in converters?

Ans:
Forced commutation circuits limit the switching frequency due to the time required to charge/discharge LC components. Hence, **low switching frequencies** are used in SCR-based converters, impacting the size and efficiency of filters.

Q28: What happens if commutation fails in a thyristor-based circuit?

Ans:
If the thyristor fails to turn off:

- Short-circuit or overcurrent conditions may occur
- Next thyristor may not be triggered
- Entire converter/inverter operation is disrupted
  Thus, **reliable commutation** is critical for circuit protection and proper sequencing.