**Department of Electrical Engineering**

**Power Electronics**

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# Q No1:

### 1) Power diode

The simplest semiconductor device having only two layers on it , with having two terminals and one junction. In signal diodes the doping level of both P and N sides is same and hence we get a PN junction, but in power diodes we have a junction formed between a heavily doped $P^+$ and a lightly doped $N^-$ layer which is epitaxially (extremely pure silicon) grown on a heavily doped $N^+$ layer. Hence the structure looks as shown in the figure below.
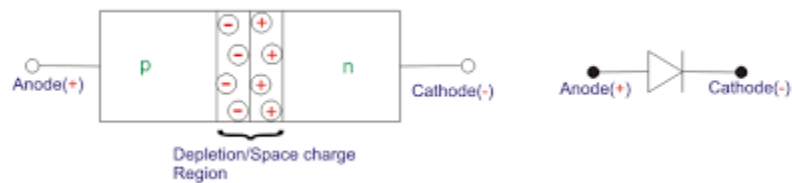


**Fig**

### 1.1)    Characteristics

I.     The $N^-$ layer is the key feature of the power diode which makes it suitable for high power applications.

II.    This layer is very lightly doped, almost intrinsic and hence the device is also known as PIN diode, where i stands for intrinsic.

III.   As we can see in the figure above that the net charge neutrality of the space charge region is still maintained as in the case of signal diode but the thickness of charge region is quite high and penetrated deeply into the $N^-$ region. This is due to its light doping concentration, as we know that the thickness of space charge region increases with decrease in doping concentration.

IV.    This increased thickness of depletion region or the space charge region helps the diode to block larger reverse biased voltage and hence have a greater breakdown voltage.

V.     However, adding this $N^-$ layer significantly increases the ohmic resistance of the diode leading to more heat generation during forward conduction state.

VI.    Hence power diodes come with various mountings for proper heat dissipation.
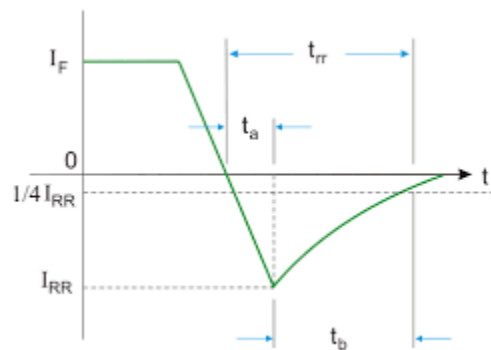
### 1.2)    I-V Characteristics

The figure below shows the I-V characteristics of a power diode which is almost similar to that of a signal diode.



I-V characteristic Curve of Power Diode
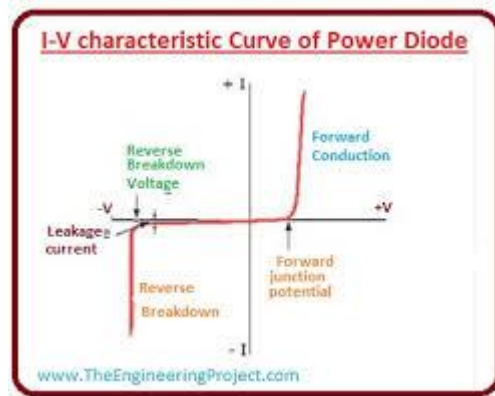
**Fig**

For forward biased region in the signal diodes the current increases exponentially but in power diodes high forward current leads to high ohmic drop which dominates the exponential growth and the curve increases almost linearly. The maximum reverse voltage that the diode can withstand is depicted by $V_{RRM}$, i.e. peak reverse repetitive voltage. Above this threshold voltage reverse current becomes very high in diodes and it changes abruptly and as the diode is not designed to bear such high amount of heat, it may catch fire and get destroyed. This voltage of the diode also known as peak inverse voltage (PIV).

**1.3) Reverse Recovery Characteristics of Power Diode**



**Fig**

The above figure depicts the reverse recovery characteristic of a power diode. Whenever the diode is switched off the current decays from $I_F$ to zero and further continues in reverse direction owing to the charges stored in the space charge region and the semiconductor region. This reverse current attains a peak $I_{RR}$ and again start approaching zero value and finally the diode is off after time $t_{rr}$. This time is defined as reverse recovery time and is defined as time between the

instant forward current reaches zero and the instant the reverse current decays to 25% of $I_{RR}$. After this time the diode is said to attain its reverse blocking capability.

# Q No 2:

## 2.1) Merits

I. The PN-junction region of this diode is large & can supply huge current, however, the capacitance of this junction can also be large, which works at a lower frequency & it is generally used for rectification only.

II. It will resolve AC at high current and a high voltage.

## 2.2) Demerits

I. The main disadvantage is its size & probably needs to be fixed to a heat sink while conducting a high current.

II. It needs specialized hardware for installing and insulating from the metal frames which are available in the surrounding.

# Q No 3: Power Electronics circuit

## 3.1) Rectifier

Rectifier which do rectification and need to handle huge power uses power diode for switching purposes. One such type of rectifier is discussed in details in the subsequent sections.

# Q No 4:

## 4.1) Bridge Rectifier

**Working**

A type of rectifier circuit that produces the similar DC output waveform as a full wave rectifier circuit is a full wave bridge rectifier circuit. As the name indicates, the full wave bridge rectifier requires four power diodes arranged as a bridge circuit as shown in figure to give full wave rectification without any need of a center tapped transformer. It has to be observed for each and every half cycle, the diodes in opposite pairs will conduct, while the amount of current flowing across the load remains in the same polarity for both the positive and negative half cycles.

**Role of the selected switch i.e. Power diode**

The power diodes are used as switches in the circuit where Diodes D1 and D2 conduct for the positive half cycle of the input (AC supply) while D3 and D4 conduct for the negative half cycle.
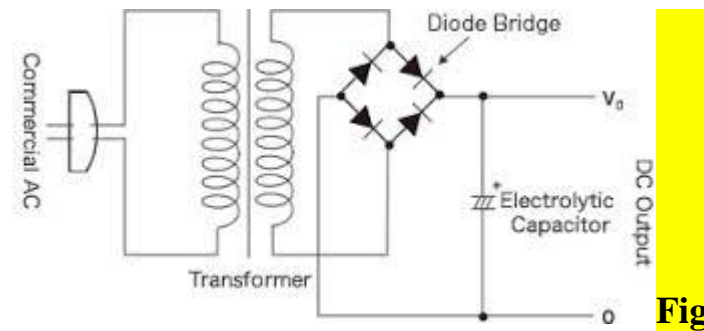


**Role of other components**

**Smoothing Capacitor:**

To eliminate the ripples, present in the DC output waveform, the smoothing capacitor having a typical value of 100 micro Farads or more is used. In choosing the smoothing capacitor, the parameters that should be kept in mind are the working voltage and capacitance value. The value of working voltage should be greater than the output value of rectifier when no load is connected.

**Transformer:**

Transformer is used to step down the coming input AC voltage to a value the rectifier is designed for.

# Q No 5: Application of the above circuit

## 5.1) Application

This Bridge rectifier is used to drive industrial DC motors as the DC motors draws huge current and consume huge power so the power diodes-based bridge rectifier can easily handle the power needed for DC motor drive. Industrial DC motors power consumption ratings ranges from 1 Kilo Watt to several hundred Kilo Watts. The Bridge rectifier that we are designing is suitable to use for DC motor which is used to run belt conveyor of packing plant of the cement industry. This DC motor consumes 1.5 kilo Watts power. The bridge rectifier provides DC output voltage to the DC motor.

## Q No 6: Design of the circuit of selected application

The circuit is designed in MATLAB Simulink.



## Q No 7: Parameters of the circuit:

Parameters of the circuit are discussed as in the afore mentioned questions.

# Q No 8: Equations and Explanation:

**(1)**

Reverse recovery characteristics of Power Diode.



The figure depicts the reverse recovery characteristic of a power diode whenever the diode is forward current reaches zero and the instant the reverse current decays to 25% of $I_{RR}$. After this time the diode is said to attain its reverse blocking capability.
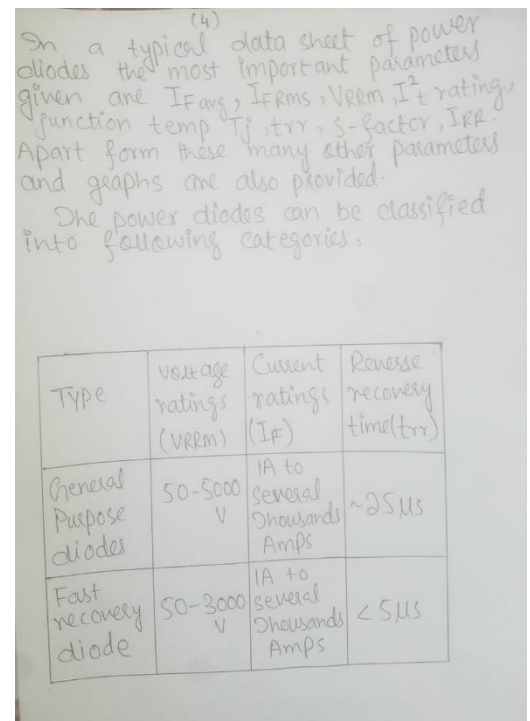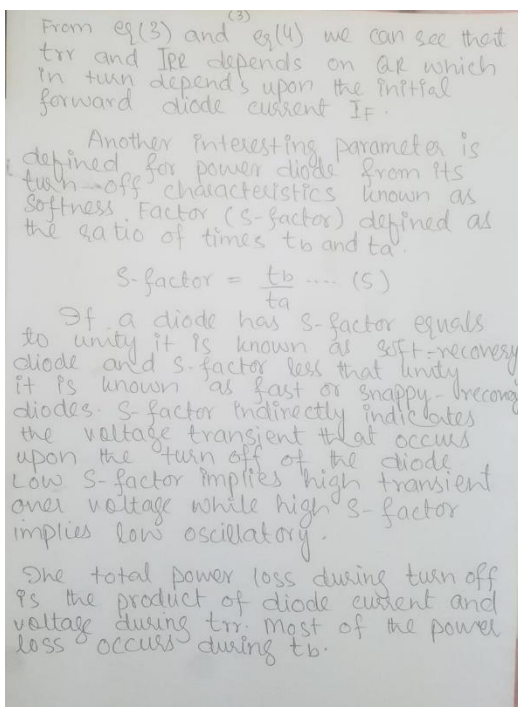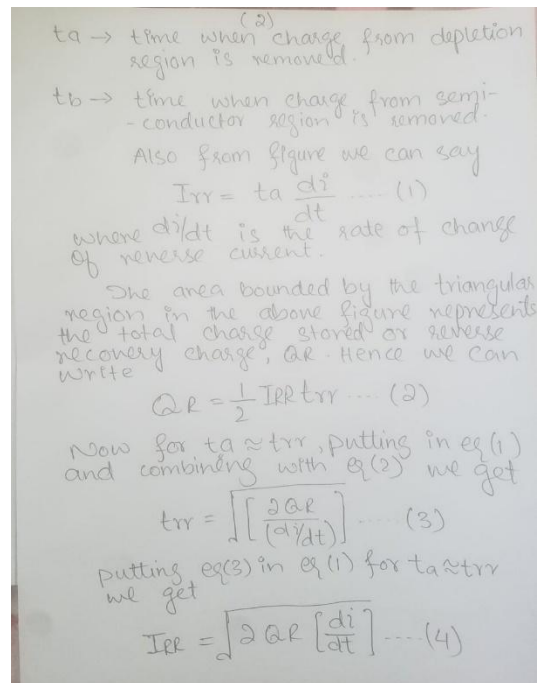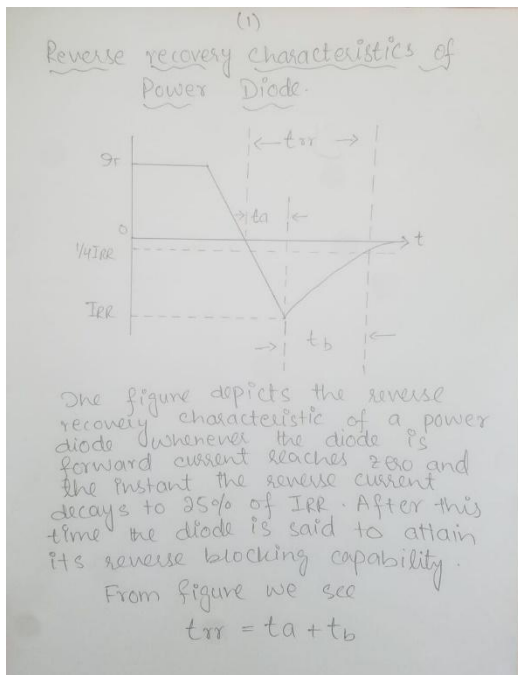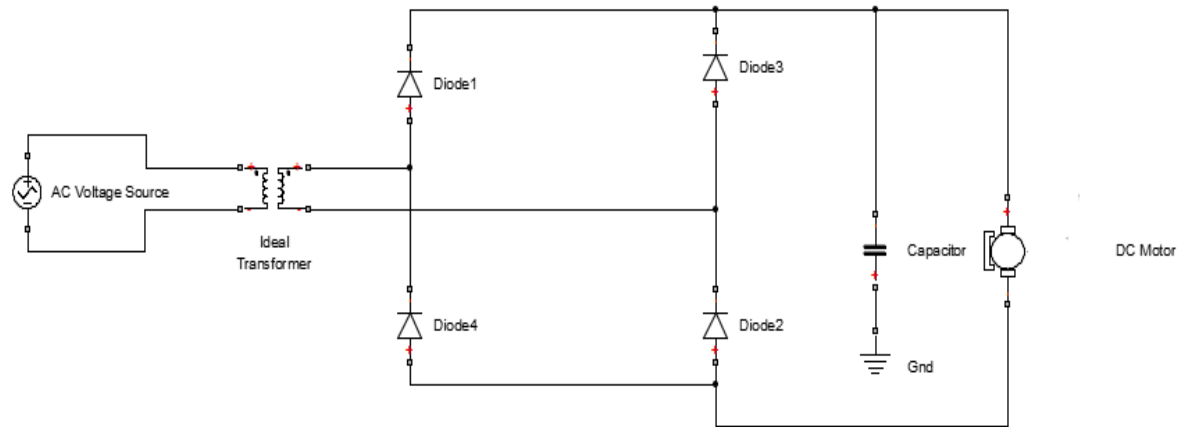
From figure we see

$$trr = ta + t_b$$

**(2)**

$ta \rightarrow$ time when charge from depletion region is removed.

$tb \rightarrow$ time when charge from semi-conductor region is removed.

Also from figure we can say

$$Irr = ta \frac{di}{dt} \quad \cdots (1)$$

where $di/dt$ is the rate of change of reverse current.

The area bounded by the triangular region in the above figure represents the total charge stored or reverse recovery charge, $Q_R$. Hence we can write

$$Q_R = \frac{1}{2} I_{RR} \, trr \cdots (2)$$

Now for $ta \approx trr$, putting in eq (1) and combining with eq (2) we get

$$trr = \sqrt{\left[\frac{2 Q_R}{(di/dt)}\right]} \quad \cdots (3)$$

putting eq(3) in eq (1) for $ta \approx trr$ we get

$$I_{RR} = \sqrt{2 Q_R \left[\frac{di}{dt}\right]} \cdots (4)$$

**(3)**

From eq (3) and eq (4) we can see that $trr$ and $I_{RR}$ depends on $Q_R$ which in turn depends upon the initial forward diode current $I_F$.

Another interesting parameter is defined for power diode from its turn-off characteristics known as Softness Factor (S-factor) defined as the ratio of times $t_b$ and $ta$.

$$S\text{-}factor = \frac{t_b}{ta} \cdots (5)$$

If a diode has S-factor equals to unity it is known as soft-recovery diode and S-factor less that unity it is known as fast or snappy-recovery diodes. S-factor indirectly indicates the voltage transient that occurs upon the turn off of the diode. Low S-factor implies high transient over voltage while high S-factor implies low oscillatory.

The total power loss during turn off is the product of diode current and voltage during trr. Most of the power loss occurs during $t_b$.

**(4)**

In a typical data sheet of power diodes the most important parameters given are $I_{Favg}$, $I_{FRMS}$, $V_{RRM}$, $I^2t$ rating, junction temp $T_j$, trr, S-factor, $I_{RR}$. Apart form these many other parameters and graphs are also provided.

The power diodes can be classified into following categories.

| Type | Voltage ratings ($V_{RRM}$) | Current ratings ($I_F$) | Reverse recovery time(trr) |
|---|---|---|---|
| General Purpose diodes | 50-5000 V | 1A to several Thousands Amps | ~25µs |
| Fast recovery diode | 50-3000 V | 1A to several Thousands Amps | <5µs |

## Q No 9: Simulation of the Circuit:



## Q No 10: Conclusion:

This Project centers around the examination of the fundamental attributes of a diode. This was led as an early on to Electronics research facility and in accordance with certain themes in address classes. From the examination, the accompanying ends were drawn:

The diode test is one of the establishments of gadgets.

It is in forward-one-sided when its obstruction has a littler worthwhile it is backward one-sided when its opposition has a bigger worth.

The forward-Biased voltage of diode is its obstruction potential while the reverse biased voltage of diode is vast over range which shows that the diode is in sound condition.

This test demonstrated that diode controls the bearing of the current.

In forward-biased, the LED turned on the grounds that the voltage of the force source defeated the voltage of the diode and there is a current streaming on the circuit.

In Reverse biased, the LED killed in light of the fact that there it is an open circuit and no current streaming.

The voltage of the diode, voltage over the resistor and the current of diode are legitimately relative to each other.

In switch one-sided, there is no voltage over the resistor and there is no current on the diode when the voltage of the diode is equivalent or under 0.

In forward one-sided, there is a voltage on resistor and a current on the diode if the voltage of the diode is more noteworthy than 0.