Part 1

a)

Diode Parameters

|  |  |  |
| --- | --- | --- |
| 1 | VF | Forward Voltage:  The voltage drop observed at diode when it is on. |
| 2 | VR | Reverse Voltage/Breakdown Voltage:  The maximum voltage that diode can withstand in off region before avalanche breakdown occurs. |
| 3 | trr | Reverse Recovery Time:  Amount of time passes after diode turns off, lets negative current and stops passing. |
| 4 | Irr | Reverse Recovery Current:  Maximum amount of negative current passes through the diode in reverse recovery. |
| 5 | Tj | Maximum Operating Junction Temperature:  The highest temperature diode can operate under without it break down. |
| 6 | S | Softness Factor:  The value that shows the characteristics of of diode’s reverse recovery. If S=1, recovery oscillations are very small, so the recovery is soft, if S<1, oscillations are high and the recovery is fast. |
| 7 | IR | Reverse Leakage Current:  The current that is flowing through diode while it is off. It is usually very small. |
| 8 | Rth | Thermal Resistance Parameter:  Indicates the temperature increase per watts of power dissipated from diode. |
| 9 | IFRM | Repetitive Peak Forward Current:  The amount of current that can pass through diode, but for an extremely short time (in µs terms), without permanently damaging or destroying it. |
| 10 | IF(AV) | Average Forward Current:  The maximum average forward current for square wave that can pass through the diode without damaging the diode. |

We concluded that the top 5 most important diode characteristics we define in the table above are VF , VR , trr, Rth and IF(AV) , but not in order.

VF is important for the fact that it is a main factor of the power dissipation in the diode as conduction losses. We can choose a voltage with a lower forward voltage if we want to increase efficiency of our design.

VR is a limiting factor when we work with high voltage values. If we want to rectify 1000V AC, a diode with lower reverse voltage will not be of use for us, since it can not block the current in negative direction.

Reverse recovery is an important characteristic of the diode when we use diodes with high frequency signals. If we use a diode to rectify a 50 Hz AC voltage, a high reverse recovery time will not issue a problem since it will be insignificant next to AC voltage’s period. However, if we use such a diode while switching at kHz levels, we will not have the desired outcomes.

Rth is an important parameter in power electronics since we work with high values of dissipated power and this power dissipation will result with temperature increase at diodes. If we do not put this character into consideration, we will not reach a desired level of reliability since the device can break because of high temperature.

IF(AV) is also an important characteristic while designing power electronics circuits. Since we aim to rectify the input voltage to DC to run a DC equipment, and some DC equipment can draw great amounts of current, such as DC motors, we need the average forward current into consideration, or the device will fail when it is applied to such equipment.

b)

1 A:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | CD214A-R12000R | 1N4007 | SB120 | UF4003 | 1N4004GP |
| VR (maximum repetitive peak) | 2000 V | 1000 V | 20 V | 200 V | 400 V |
| trr | - (standard recovery diode/no info on datasheet) | - (standard recovery diode/no info on datasheet) | 0 (Schottky diode) | 50 ns | 2 µs |
| Rth | 65(to ambient)  /15(to lead) Co/W | 65 Co/W  (depends on mounting method) | 50 Co/W | 60(to ambient)  /15(to lead) Co/W | 55(to ambient)  /25(to lead) Co/W |
| IF(AV) | 1 A | 1 A | 1 A | 1 A | 1 A |
| VF  (at 1 A) | 1.1 V | 1.1 V(max)  /0.93(Typ) | 0.48 V | 1 V | 1.1 V |

10 A:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | VS-10ETF12THM3 | FFPF10F150S | BYV10X-600P | PDS1040L |
| VR (maximum repetitive peak) | 1200 V | 1500 V | 600 V | 40 V |
| trr | 80 ns | 170 ns | 40 ns | 0 (Schottky diode) |
| Rth | 62 Co/W | 3 Co/W (junction to case) | 55 Co/W | 50 Co/W |
| IF(AV) | 10 A | 10 A | 10 A | 10 A |
| VF  (at 10 A) | 1.33 V | 1.6 V (25 Co)  1.4 V (125 Co) | 2 V (max.)  1.5 V (typ.) @25 Co  1.6 V @150 Co | 0.44 V (typ.)  0.49 V (max.) |

100 A:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | VS-100BGQ015 | VS-100BGQ100 | R502\_\_10 | STTH200F04 |
| VR (maximum repetitive peak) | 15 V | 100 V | 1200 V | 400 V |
| trr | 0 (Schottky diode) | 0 (Schottky diode) | 300 ns | 105 ns |
| Rth | 0.5 Co/W (junction to case) | 0.28 Co/W (junction to case) | 0.28 Co/W (junction to case) | 0.60 (per diode)  0.35 (total)  Co/W (junction to case) |
| IF(AV) | 100 A | 100 A | 100 A | 100 A |
| VF  (at 100 A) | 0.45 @ 25 Co  0.39 @ 125 Co | * 1. @ 25 Co   0.77 @ 125 Co | 2.7 V | 0.95 @ 125 Co  0.90 @ 150 Co |

We observed that as the rated current increases, we observe an increase in reverse voltage for standard diodes. For Schottky diodes, we cannot say the same, on the contrary, we observed some drop in the reverse voltage. Also we observed Schottky diodes has much smaller rated voltage values for same rated currents.

c)

5V:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | RB886CM | NTE112 | BAS17 | NSVR351SDSA3 |
| VR | 5 V | 5 V | 5V | 5V |
| trr | 0 | 0 | No info | 0 |
| Rth | No info | 400 Co/W | 500 Co/W | No info |
| IF(cont.) | 10 mA | 30 mA | 200 mA | 30 mA |
| VF | 0.35 V | 0.55 V (@ 1 mA) | 0.58-0.96 V | 0.23 V |

50V:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1N4454 | B350 | SBRT5A50SA | RB400VAM-50 | S1A |
| VR | 50 V | 50 V | 50 V | 50 V | 50 V |
| trr | No info | 0 | No info | 7.35 ns | 1.8 µs |
| Rth | 300 Co/W | 90 Co/W | 40 Co/W | 77 Co/W | 85 Co/W |
| IF(cont.) | 400 mA | 3 A(Av.) | 5 A(Av.) | 0.5 A(Av.) | 1 A (Av.) |
| VF | 1 V (max.) | 0.7 V | 0.53 V (max.) | 0.55 V | 1.1 V |

500V:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | FES16HT | 1N4051 | BYV29-500 | NTE5860 | 1N5396 |
| VR | 500 V | 500 V | 500 V | 500 V | 500 V |
| trr | 50 ns | No info | 60 ns | No info | 2 µs |
| Rth | 16 Co/W | 0.18 Co/W (junction to case) | 60 Co/W | 2.5 Co/W  (junction to case) | 55 Co/W |
| IF(AV) | 16 A | 275 A | 9 A | 6 A | 1.5 A |
| VF | 1.5 V | 1.3 V | 1.03 V | 1.1 V | 1.4 V |

We observed the forward currents can increase significantly as we increase voltage values. For example, 1N4051 has a forward current of 275 A average, which is much higher than the average lower voltage diodes. We also observed that the number of Schottky diodes w.r.t all of the diodes decrease significantly as we searched for a 500 V diode. And many high voltage diodes did not have any info about their reverse recovery time or characteristics. The reason behind that might be high voltage high frequency switching is not common and these diodes are usually used for rectifiers.

d)

Over engineering a diode selection might not be optimal in many cases, since increase of a parameter usually results in a change in another parameter. We can see such a case in:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | VR | trr | Rth | IF(AV) | VF |
| VS-10ETF12THM3 | 1200 V | 80 ns | 62 Co/W | 10 A | 1.33 V |
| R502\_\_10 | 1200 V | 300 ns | 0.28 Co/W (junction to case) | 100 A | 2.7 V |

If we consider changing the VS-10ETF12THM3 diode with R502\_\_10 diode to increase rated current, we will also increase reverse recovery time and forward voltage. With higher forward voltage, and same average current drawn, we will observe more dissipated power from the diode, almost doubles. Consequently, we will have a power-wise less efficient design. Also, if we were using this diode with high frequencies, 3.75 times greater reverse recovery time will be undesired.

On the other hand, this might be the issue. Over-engineering a diode can be unnecessarily expensive. From the Digikey website, we saw that NTE5860 is almost 6 times of the BYV29-500, while both has the same rated current. (1.08-6.19 dollars). Another problem might be the size and volume of the diode. Again, between the two diodes we just mentioned, NTE5860 is a much bigger screw type diode while BYV29-500 is 10 mm wide.

In the end, over-engineering a characteristic of a diode without considering other characteristics might cause more harm than good, or no good at all. An engineer should assess all the gains and losses of a design choice and choose accordingly.