FREQUENTLY ASKED QUESTIONS

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Content Questions

How do energy levels affect conductivity?

This is a major subject, based on quantum mechanics. We are using a pretty simplified picture, but one that has the important features for understanding how solid state electronic devices. In quantum mechanics, electrons in atoms are only allowed in certain energy levels (solutions to the Schrödinger equation). In crystalline solids, like silicon or germanium, the solutions to the Schrödinger equation need to take into account interactions, and the resulting solutions correspond to bands of allowed energies. There tends to be a band of allowed energies available to the "valence" electrons outside the last closed shell, corresponding to electrons localized around the nuclei. There is then often a gap in energy, representing energies that electrons are not allowed to have, and then another band of allowed energies, corresponding to delocalized electrons. When electrons are in this upper band, the "conduction band", they are allowed to move around and conduct current.

So, only when electrons are promoted into the band (by thermal energy, a battery, photons, etc.) can they carry current. Materials for which there is little or no band gap are good conductors.

Does the $I - V$ curve go to ∞ as the V goes to ∞?

In the model of the $I - V$ curve as an exponential, I *does* go to infinity as V goes to infinity, and doesn't asymptote out (but it disappears off into the clouds very fast).

In practice you would blow up the diode before reaching infinity, of course!

Why is the diode symbol as it is? What direction does the "arrow" point?

I don't know the historical origin of the diode symbol, but I imagine that the arrow-like symbol is intended to represent the one-way flow of current through the diode (in its simplest "one-way-valve" model). The arrow points in the direction of forward bias (positive to negative). With bias in this direction, the current flows in the arrow direction.

(Note that for a Zener diode in avalanche mode, the current flows in a direction opposite to that of the arrow!)

If we don't reach 0.6 V across the diode, do we just approximate the current as 0?

Yes, in the simplest model. If there's less than ∼0.6 V (for silicon) across, there will be some depletion zone left and so poor conductivity (there will still be a little bit of current flow from minority carriers). For a diode to be fully forward-biased, there must be at least V_{pn} across it.

How are photodiodes useful?

Photodiodes are devices that produce current when light is incident on them. The photons in the light promote electrons into the conduction band. These are useful whenever you need to *measure* an amount of light, since the current will depend on the number of incident photons. They are also useful even just to detect some light (say, you want to tell when it's daytime, etc.)

Why is there a negative piece in the wave for the half-wave rectifier?

In the half-wave rectifier, this corresponds to the slightly-less-cartoonish model of the diode, in which you take into account the V_{pn} voltage drop and the forward and backward resistances of the diode. When the diode is forward-biased at greater than V_{pn} (assume here 0.6 V), the output follows the positive swing of the input. You get a positive hump, but at lower than the signal voltage according to $V_o = \left(\frac{R}{R+R_f}\right)(V_s - V_{pn})$, taking into account both the voltage drop across the diode, V_{pn}, and the voltage division (note that here, because R_f is small, the voltage divider factor is ~ 1). Then, during the negative swing of the input, you treat the diode as a large resistance R_r, and the output follows the input according to the voltage divider equation, as $V_o = \left(\frac{R}{R+Rr}\right)V_s$, where $\frac{R}{R+Rr}$ is now a small number– so you get a much reduced (but non-zero) negative swing on the output.

How does a Zener diode work? What design enables the Zener diode to control avalance?

A Zener diode is made to be robust enough to handle a large flow of breakdown current at high reverse-bias voltage (instead of blowing up or otherwise damaging the diode, it conducts). How are Zeners engineered? I don't know many of the details, but I think it has to do with having a large amount of doping and a small depletion region, so that you get a very high electric field and high tunneling probability for electrons to jump the gap between materials. Presumably other physical characteristics matter for allowing the diode to handle current.

How does the full wave bridge work? What were the positive and negative swings?

The idea is to consider each part of the "swing" of the input sinusoid and look at which parts of the full-wave bridge are more positive or negative, in order to figure out which way the diode conducts. We can treat the diodes in our simplest model, as one-way current valves that conduct when the back-of-the-arrow side is more positive than the vertical line side.

During the positive swing (positive hump of the sinusoid), the top node of the bridge is more positive than the bottom. The top left diode won't conduct but the top right one will, as it will be forward-biased. The right node will be only 0.6 V less positive than the top. The bottom right diode will be reverse-biased and won't conduct. Current can flow right to left across the center resistor, so there will be a $+$ to $-$ voltage drop across it; the current will flow through the forward-biased bottom left diode to the bottom.

During the negative swing, it's a similar situation, except that the current flows from the positive bottom node, through the forward-biased bottom right diode, right to left across the center resistor, and through the top left diode to the more-negative top node. In both cases there a $+$ to $-$, right to left voltage drop across the center resistor. Since that's where the output voltage is taken from, the output swing will always be positive.