Peak Inverse Voltage

Q: I'm so confused! The bridge rectifier and the full-wave rectifier both provide full-wave rectification. Yet, the bridge rectifier use 4 junction diodes, whereas the full-wave rectifier only uses 2. Why would we ever want to use the bridge rectifier?

A: First, a slight confession—the results we derived for the bridge and full-wave rectifiers are not precisely correct!

Recall that we used the junction diode CVD model to determine the transfer function of each rectifier circuit. The problem is that the CVD model does not predict junction diode breakdown!

If the source voltage $v_S$ becomes too large, the junction diodes can in fact breakdown—but the transfer functions we derived do not reflect this fact!

Q: You mean that we must rework our analysis and find new transfer functions!?
**A:** Fortunately no. Breakdown is an *undesirable* mode for circuit rectification. Our job as engineers is to design a rectifier that *avoids* it—that why the *bridge* rectifier is helpful!

To see why, consider the voltage across a *reversed biased* junction diode in each of our rectifier circuit designs.

Recall that the voltage across a *reverse biased ideal diode* in the *full-wave rectifier* design was:

\[ V_{D2} = -2V_s \]

so that the voltage across the *junction* diode is approximately:

\[ V_D = V_D^i + 0.7 = -2V_s + 0.7 \]

Now, assuming that the *source* voltage is a *sine wave* \( V_s = A \sin \omega t \), we find that diode voltage is at its *most negative* (i.e., breakdown danger!) when the *source* voltage is at its *maximum* value \( A \). I.E.,:

\[ V_D^{\text{min}} = -2A + 0.7 \]

*Of course, the largest* junction diode voltage occurs when in *forward* bias:

\[ V_D^{\text{max}} = 0.7 \text{ V} \]
Note that this minimum diode voltage $v_D$ is very negative, with an absolute value ($|v_D^{\text{min}}| = 2A - 0.7$) nearly twice as large as the source magnitude $A$.

We call the absolute value of the minimum diode voltage the Peak Inverse Voltage (PIV):

$$PIV = |v_D^{\text{min}}|$$

Note that this value is dependent on both the rectifier design and the magnitude of the source voltage $v_S$.

Q: So, why do we need to determine PIV? I’m not sure I see what difference this value makes.
A: The Peak Inverse Voltage answers one important question—will the junction diodes in our rectifier breakdown?

→ If the PIV is less than the Zener breakdown voltage of our rectifier diodes (i.e., if $\text{PIV} < V_{ZK}$), then we know that our junction diodes will remain in either forward or reverse bias for all time $t$. The rectifier will operate “properly”!

→ However, if the PIV is greater than the Zener breakdown voltage of our rectifier diodes (i.e., if $\text{PIV} > V_{ZK}$), then we know that our junction diodes will breakdown for at least some small amount of time $t$. The rectifier will NOT operate properly!

Q: So what do we do if PIV is greater than $V_{ZK}$? How do we fix this problem?

A: We have two possible solutions:

1. Use junction diodes with larger values of $V_{ZK}$ (if they exist!).
2. Use the bridge rectifier design.

Q: The bridge rectifier! How would that solve our breakdown problem?
A: To see how a bridge rectifier can be useful, let’s determine its Peak Inverse Voltage PIV.

First, we recall that the voltage across the reverse biased ideal diodes was:

\[ v_D^i = -v_S \]

so that the voltage across the junction diode is approximately:

\[ v_D = v_D^i + 0.7 \]
\[ = -v_S + 0.7 \]

Now, assuming that the source voltage is a sine wave \( v_S = A \sin \omega t \), we find that diode voltage is at its most negative (i.e., breakdown danger!) when the source voltage is at its maximum value \( A \). I.E.,:

\[ v_D^{\text{min}} = -A + 0.7 \]

Of course, the largest junction diode voltage occurs when in forward bias:

\[ v_D^{\text{max}} = 0.7 \text{ V} \]
Note that this minimum diode voltage is very negative, with an absolute value ($|v_{D}^{\text{min}}| = A - 0.7$), approximately equal to the value of the source magnitude $A$.

Thus, the PIV for a bridge rectifier with a sinusoidal source voltage is:

$$PIV = A - 0.7$$

Note that this bridge rectifier value is approximately half the PIV we determined for the full-wave rectifier design!

Thus, the source voltage (and the output DC component) of a bridge rectifier can be twice that of the full-wave rectifier design—this is why the bridge rectifier is a very useful rectifier design!