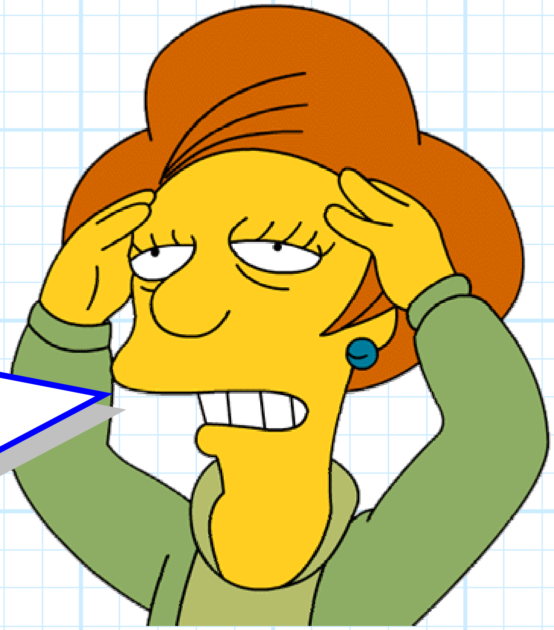
Peak Inverse Voltage

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:

$$v_{D2}^{i} = -2v_S$$

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

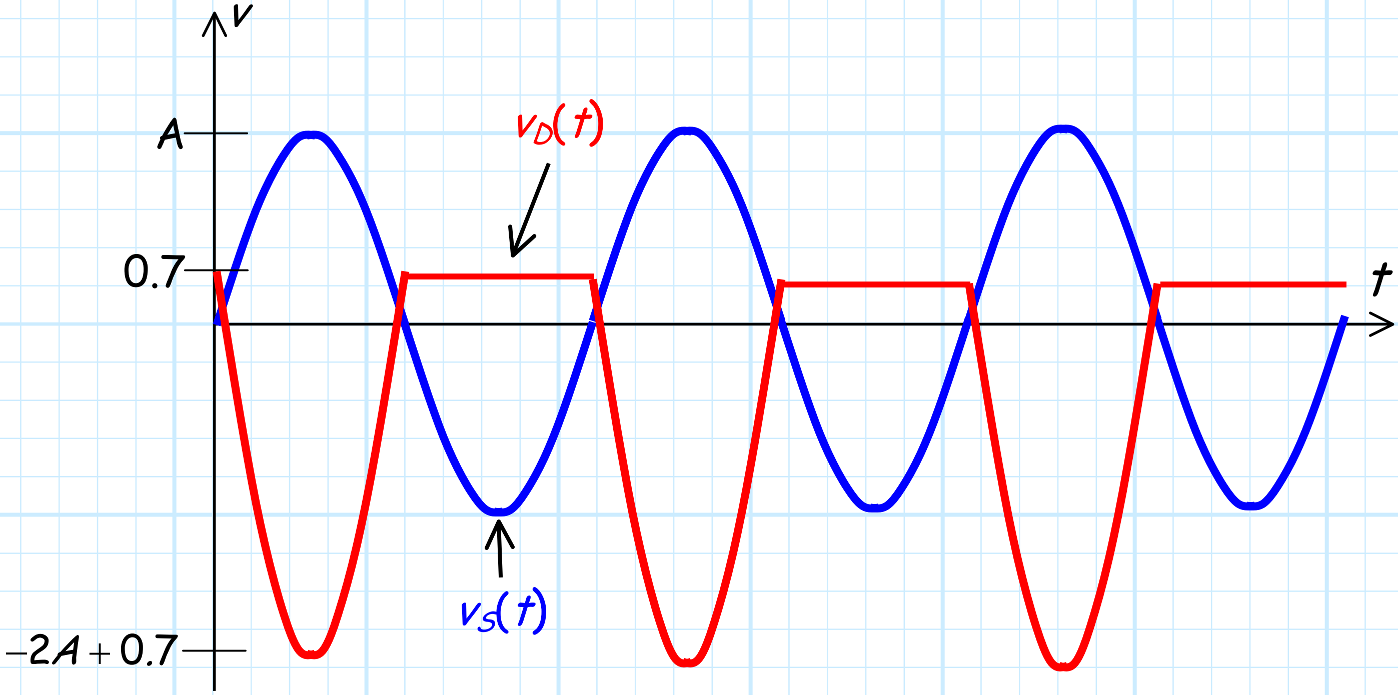
$$\begin{aligned} v_D &= v_D^{i} + 0.7 \\ &= -2v_S + 0.7 \end{aligned}$$

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

$$v_D^{min} = -2A + 0.7$$

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

$$v_D^{max} = 0.7 \text{ V}$$

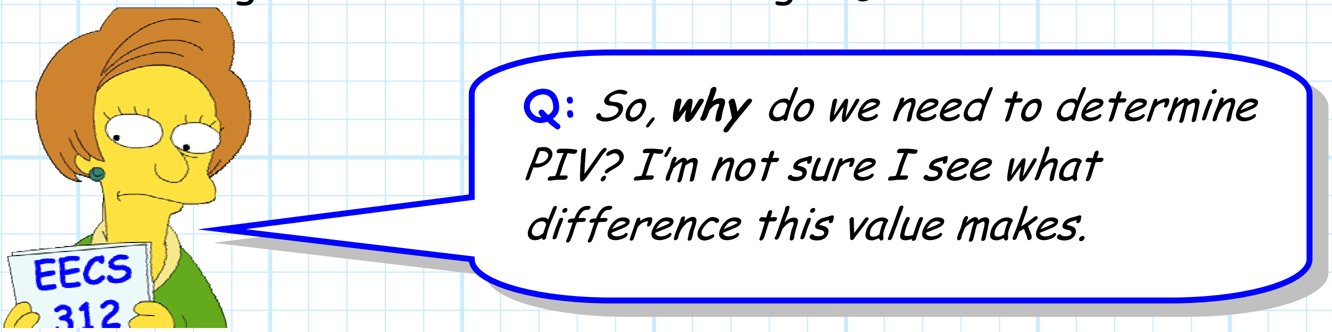


Note that this **minimum** diode voltage v_D is **very negative**, with an absolute value ($\left|v_D^{min}\right| = 2A - 0.7$) nearly **twice** as large as the source magnitude A.

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

$$PIV = \left|v_D^{min}\right|$$

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



A: The Peak Inverse Voltage **answers** one important question—**will** the junction diodes in our rectifier **breakdown**?

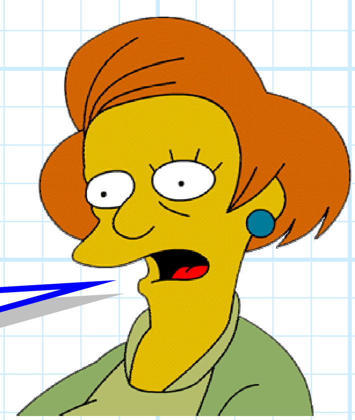
→ **If** the PIV is **less** than the Zener breakdown voltage of our rectifier diodes (i.e., if $PIV < V_{ZK}$), then we know that our junction diodes will **remain** in either forward or reverse bias for all time *t*. The rectifier will operate "properly"!

→ However, **if** the PIV is **greater** than the Zener breakdown voltage of our rectifier diodes (i.e., if $PIV > V_{ZK}$), 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:

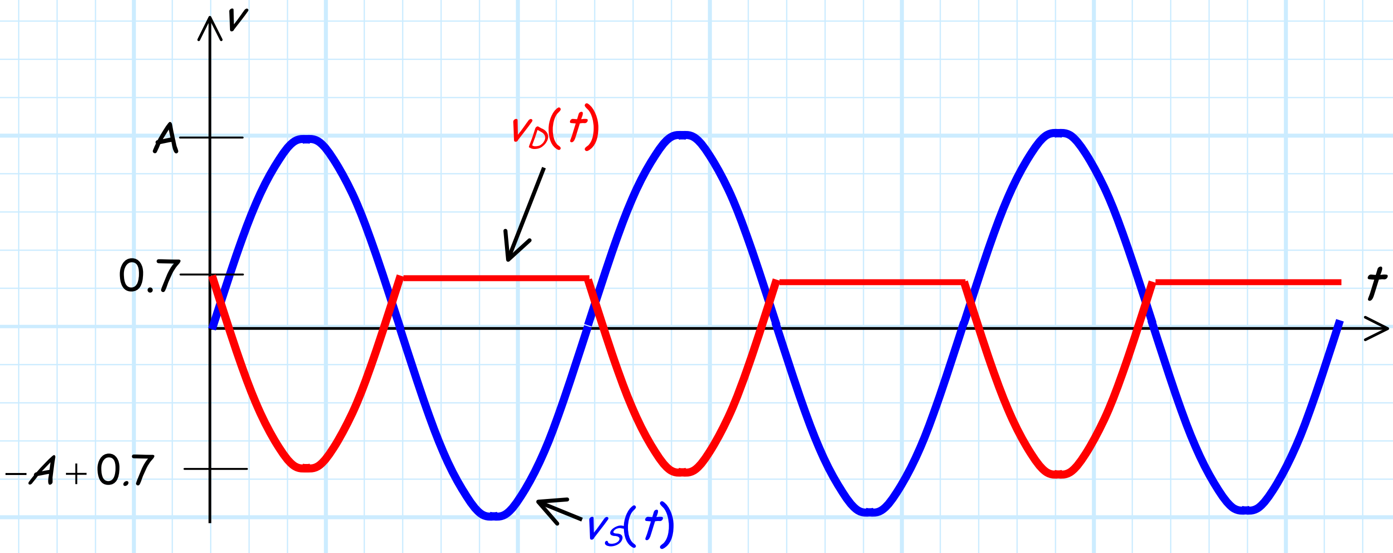
$$\begin{aligned} v_D &= v_D^i + 0.7 \\ &= -v_S + 0.7 \end{aligned}$$

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

$$v_D^{min} = -A + 0.7$$

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

$$v_D^{max} = 0.7 \text{ V}$$



Note that this minimum diode voltage is **very negative**, with an absolute value ($\left|v_D^{min}\right| = A - 0.7$), 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!