Example: Constructing a PWL Model

For a certain junction diode, we know that:

\[ i_b = 10 \text{ mA} \quad \text{when} \quad v_b = 0.7 \text{ V} \]

and

\[ i_b = 1 \text{ mA} \quad \text{when} \quad v_b = 0.6 \text{ V} \]

Say we wish to construct a PWL model that will approximate this junction diode behavior for diode currents from, say, approximately 1 mA to approximately 10 mA.

Recall that the resulting model will relate diode voltage \( v_D \) to diode current \( i_D \) as a line of the form:

\[ i_D = \left( \frac{1}{r_d} \right) v_D - \left( \frac{v_D}{r_d} \right) \]

We therefore need to determine the values of \( v_{D0} \) and \( r_d \) such that this PWL model “line” will intersect the two points \( i_{D1} = 1.0, v_{D1} = 0.6 \) and \( i_{D2} = 10.0, v_{D2} = 0.7 \).
The slope of this line must therefore be:

\[ m = \frac{i_{D2} - i_{D1}}{V_{D2} - V_{D1}} = \]

Thus our PWL model resistor value \( r_d \) must be:

\[ r_d = \frac{1}{m} = \]

Or in other words, \( r_d = 11.1 \Omega \).

Q: Wow! That’s a very small resistance value. Are you sure we calculated \( r_d \) correctly?

A: Typically, we find that the resistor value in the PWL model is small. In fact, it is frequently less than 1 \( \Omega \) when we attempt to match the junction diode curve in a “high” current region (e.g., from \( i_D = 50 \text{ mA} \) to \( i_D = 500 \text{ mA} \)).

Now that we have determined \( r_d \), we can insert either point into the model line equation and solve for \( V_{D0} \). For example, the equations:

\[ i_{D1} = \left( \frac{1}{r_d} \right) v_{D1} - \left( \frac{V_{D0}}{r_d} \right) \quad \text{or} \quad i_{D2} = \left( \frac{1}{r_d} \right) v_{D2} - \left( \frac{V_{D0}}{r_d} \right) \]
become either:

\[ V_{D0} = V_{D1} - i_{D1} r_d \]

\[ = \]

\[ = \]

or

\[ V_{D0} = V_{D2} - i_{D2} r_d \]

\[ = \]

\[ = \]

In other words, we can use either point to determine \( V_{D0} \).

Our PWL model is therefore:

\[
i_d = \begin{cases} 
0 & \text{for } V_d < 0.589 \text{ V} \\
\frac{V_d - 0.589}{0.0111} \text{ mA} & \text{for } V_d > 0.589 \text{ V}
\end{cases}
\]
Now, compare this PWL model to the CVD model:

\[ V_D = 0.589 \text{ V} \quad r_d = 11.1 \text{ } \Omega \]

\[ V_D = 0.70 \text{ V} \]

Note that the CVD model can be viewed as a PWL model with \( V_{D0} = 0.7 \text{ V} \) and \( r_d = 0.0 \). Compare those values with our model \( (V_{D0} = 0.589 \text{ V} \text{ and } r_d = 11.1 \Omega) \) — not much difference!

Thus, the PWL model is not a radical departure from the CVD model (typically \( V_{D0} \) is close to 0.7 V and \( r_d \) is very small). Instead, the PWL can be view as slight improvement of the CVD model.