MicroNotes

MicroNote Series 010

by Kent Walters, Microsemi Corporate Applications

How to Quickly Obtain Spice Parameters for Diodes

Component SPICE modeling has become a frequently used analysis tool by design engineers to evaluate circuit performance. This MicroNote provides background information and methods useful for quickly obtaining many of the discrete diode SPICE parameters such as BV, IBV, IS, EG, TBV1, etc. from either specified data sheet parameters or other known information. Others may be approximated as described herein or obtained from the manufacturing source with other related physical design or characteristic background information. The SPICE parameters for diodes described in this MicroNote begin with the reverse diode characteristics and conclude with the forward parameter features. For quick reference, each of the SPICE parameter acronyms are underlined and are then described in further detail.

In our first example of BV for *reverse breakdown knee voltage*, this simply approximates the avalanche breakdown voltage or what has been identified in data sheets as "V_{BR}" for Rectifiers and Transient Voltage Suppressors (TVSs) or "V_Z" for zener diodes. If the V_{BR} parameter is not specified for rectifiers, it may be approximated as somewhat higher than the commonly rated reverse voltage (V_{RWM}) of a rectifier. A 10 to 20% higher value is typical for "fast" and "ultrafast" Rectifiers or Schottkys. For lower voltage "standard" rectifiers in a JEDEC registered series where reverse recovery time is not critical (e.g. 1N4000 series), the actual V_{BR} can be many times higher than rated V_{RWM}. This occurs when rectifiers are downgraded from higher voltages in a series by a manufacturer where all other parameters (such as forward voltage) are identical in ratings.

The IBV that represents *reverse breakdown knee current for onset of breakdown voltage* can be approximated as ten times greater than the maximum specified leakage current (I_R). In other examples for a conservative or worst case (highest) value, this may instead be specified as I_{ZK} for knee current on zeners or I_{BR} (sometimes listed as I_T) for TVSs. It may also simply be those values shown separately for the V_{BR} current on some signal/switching diode data sheets. Many of these latter examples often specify the V_{BR} at 100 µA that is applicable for IBV.

The *saturation current* IS may be *approximated* as the "process norm" of the leakage current in *large-scale signal dc modeling* with SPICE. This may be further represented in data sheets by I_R for rectifiers or zeners and I_D for TVSs. For glass passivated pn junction designs (as primarily offered by Microsemi), this may typically be 10% to 20% of maximum leakage current specified for diodes in many of the 1NXXXX JEDEC registrations. For a worst case (highest value) scenario, it can also be simply modeled as the maximum leakage current I_R (or I_D) value specified. This may be in the range of 10^{-8} to 10^{-5} Amps depending on size of the diode. For low voltage zeners or TVSs that do not avalanche with a sharp knee region, the leakage current or saturation current approaches that of the rated maximum I_R of zeners or I_D of a TVS. This can sometimes approach 100 to 5000 µA (10^{-4} to $5x10^{-3}$ A) again depending on size of the device.

If the IS value is needed for a *linearized small-signal ac* SPICE model, then this would equate to smaller saturation current values when measured at 0.026 volts (kT/q). This results in very low IS values in the 10^{-9} to 10^{-15} Amps range (or nA to fA) depending on size of the diode.

The *zero bias pn junction capacitance* CJO is also often specified in various diode data sheets. This may simply be shown as "C" if also stated at zero volts. If not, it will require direct measurement or further information from the manufacturing source. Much like a parallel plate capacitor, the diode capacitance will be dictated by its pn junction area size and depletion layer spread (or plate separation). This results in higher capacitance for larger size rectifiers (or Schottkys) as well as zeners and TVSs. It is similarly dependent on the actual voltage V_Z or V_{BR} (or effective plate separation). The higher the actual voltage...the lower the capacitance. This is particularly evident when comparing the capacitance for an overall family series listing of zeners or TVSs where low voltage devices are depicted with much higher capacitance than high voltage types.

The *pn grading coefficient* M further characterizes sensitivity of capacitance and its decline with applied reverse voltage on a logarithmic scale. It is not directly shown on data sheets, but the effective M values generally lie between the value of 0.25 to 0.45 for most conventional pn junction diodes. Low voltage zeners below 5 volts using alloy-diffused pn junction technology may only have an M value of 0.25 whereas higher voltage zeners (50 to 100 volts) may be 0.35. Higher voltage rectifiers of many hundreds of volts may approach 0.45. An abrupt junction or Schottky diode has an M

MicroNotes

MicroNote Series 010

value of 0.5 if there is no graded pn junction guardring present. Modern Schottky Rectifiers have pn guardrings typically resulting in M values of approximately 0.4.

The *BV temperature coefficient (linear)* of TBV1 is equivalent to the specified zener voltage temperature coefficient α_{VZ} parameter specified for most zeners as well as the breakdown voltage temperature coefficient $\alpha_{V(BR)}$ for TVSs on numerous data sheets. For rectifiers, it approximates the same value as high voltage zeners or TVSs or approximately +0.11%/°C. This positive temperature coefficient (where V_{BR} increases with temperature) is also the reason that V_{BR} for rectifiers must be 10 % or more higher than rated voltage V_{RWM} at 25 °C when operating temperatures are reduced. This will ensure an operating temperature range down to –55 °C where V_{BR} also declines but still remains above V_{RWM} with this initial 10 % design margin at 25 °C.

The *parasitic resistance* RS is not a value directly given on data sheets. It is determined by the diode element contact resistance and bulk resistance R through the material of resistivity ($\Re$), of area (A), and length in current flow (L) on either side of the pn junction. The length of this current flow is primarily related to semiconductor element thickness. The Resistivity $\Re$ also varies over this thickness as dictated by device geometry and diffusion profile. The effective resistance R is then primarily determined by the classic relation of $R = \Re x L/A$ that may be integrated over this thickness. It can also be measured with special test methods or acquired from the manufacturer.

One example of parasitic resistance effects on zeners or TVSs is described in MicroNote 202. Small area configured devices have higher RS compared to large devices of the same voltage rating. Also higher voltage devices will have higher RS than low voltage due to higher resistivity material or thickness required for generating higher voltage V_Z or V_{BR} characteristics. These overall effects can result in large low voltage zeners running as low as 0.001 ohms whereas small geometry size high voltage rectifiers may run many ohms in RS value. Many diode types are typically in the range of 0.01 to 0.1 ohms.

The *RS temperature coefficient* TRS1 is often given a default value of zero, however it is better approximated as +0.76%/°C for silicon if needed for critical circuit analysis in PSPICE regarding slight variations of RS over a broad operating temperature range.

The *transit time* TT is often given a default value of zero when it is not considered a critical feature in circuit design. When needed, the TT value is a complex parameter to quantify for pn diodes since it is also dependent on the operating current and slew rate (di/dt) similar to that observed for reverse recovery time (trr). This may be further reviewed in MicroNote 302 describing trr. The TT value may be approximated by a value somewhat greater than specified for trr in fast or ultrafast rectifier data sheets. It can be somewhat less than 10 ns for small signal or switching diodes, or in the range of approximately 50 ns for ultrafast rectifiers, or 250 ns in fast rectifiers. For zeners or TVSs where trr is not specified or controlled, this value typically varies from 200 ns for low voltage types less than ten volts to as much as 3 ms for high voltage devices exceeding 100 volts including standard rectifiers. For Schottky rectifiers the TT value is zero.

The *bandgap voltage* (barrier height) EG is 1.11 eV for *silicon* pn diodes and typically 0.7 eV for Schottky diodes. Germanium diodes have an EG of 0.67 eV. Most diode types are silicon.

In rectifiers where forward voltage characteristics can also be important in SPICE modeling for circuit designs, the *pn potential* VJ for most diodes is considered 0.8 volts in default value and the *forward bias depletion capacitance coefficient* FC is 0.5. The *emission coefficient* N can be used to modify the slope of the low level forward current versus voltage I-V characteristics curve. Its default value is 1.0 and typical value is 1.1. In the high level injection forward current region the slope is primarily determined by the resistive effects of the diode as influenced by the previously described RS parasitic resistance. To help identify these two regions, the *forward knee current* Ikf models the intersecting asymptotes of low to high forward current injection versus forward voltage. When viewing typical forward current characteristics on a log scale, versus linear forward voltage scale, this intersection or subtle inflection point for determining the value of Ikf is often in the same vicinity as the average forward current rating I_O for rectifiers.

Other SPICE parameters exist but these are the primary ones of interest for most applications. In summary, the descriptions provided herein may serve as a quick approximation method for many diode SPICE parameters and how they may vary based on specified parameters found in data sheets or as additionally provided by the manufacturing source.

Kent Walters is the head of Microsemi's Application Engineering Department. Located in our Scottsdale, AZ facility Kent works with the product specialists at all Microsemi divisions to promote and assist with the technical questions pertaining to our products and their use.

Kentwltrs@aol.com
(602) 941-6524

MicroNotes is a program managed by Kent Walters to bring you ,the customer, useful application notes to assist in you in your design.

Additional MicroNotes can be viewed on Microsemi's Website at

http://www.microsemi.com/scripts/micnotes/micfamily.idc?

or by calling our Fax On Demand System at 800-713-4113