Reverse Recovery V1

This is a Simplis simulation model of a reverse recovery test circuit showing the capabilities of a Simplis diode sub-circuit with reverse recovery behavior and a Boost application circuit.

To better view the schematic, do the following from the SIMetrix command shell to set up the fonts for the text:

File → Options → Font → Schematic – user 1 → Arial,Bold,14

File → Options → Font → Schematic – user 2 → Times New Roman,Bold,22

Read below on for information on how the model is created and to adjust its parameters.

<u>The following are simulation circuits:</u>

Rev_Rec.sxsch – Reverse recovery test circuit. Performs only a transient simulation.

Boost_Rev_Rec.sxsch – Continuous mode boost circuit to show the effects of reverse recovery from the output diode. Performs only a POP simulation run.

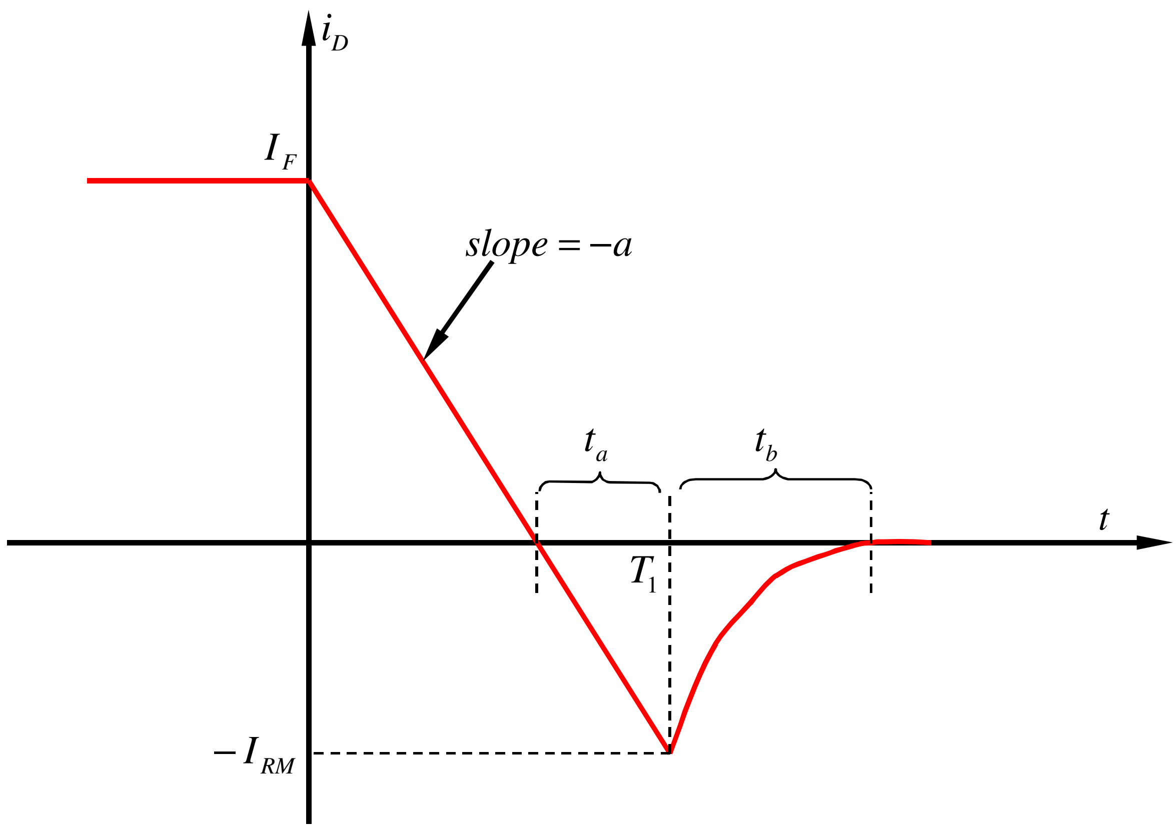
<u>The following are required models to run the simulation circuits:</u> The internal schematic can be viewed by highlighting the component, and clicking on Hierarchy → Descend Into

Rev_Rec_Diode.sxcmp - This is a component model of a general purpose opto

A simple diode model to incorporate reverse recovery

- The proposed model is based on the model published by Peter Lauritzen and Clifford Ma in the IEEE Transaction on Power Electronics, Vol. 6, No. 2, April 1991, pp. 188 – 191.
- Lauritzen and Ma published a followed-up model in the IEEE Transaction on Power Electronics, Vol. 8, No. 4, October 1993, pp. 342 – 346. This enhanced model includes forward recovery as well.
- We are NOT interested in the modeling of the forward recovery at this point. But the 1993 paper does provide a little better but briefer explanation of the reverse recovery.
- The proposed model is based on the model presented in the 1991 paper by Lauritzen and Ma.

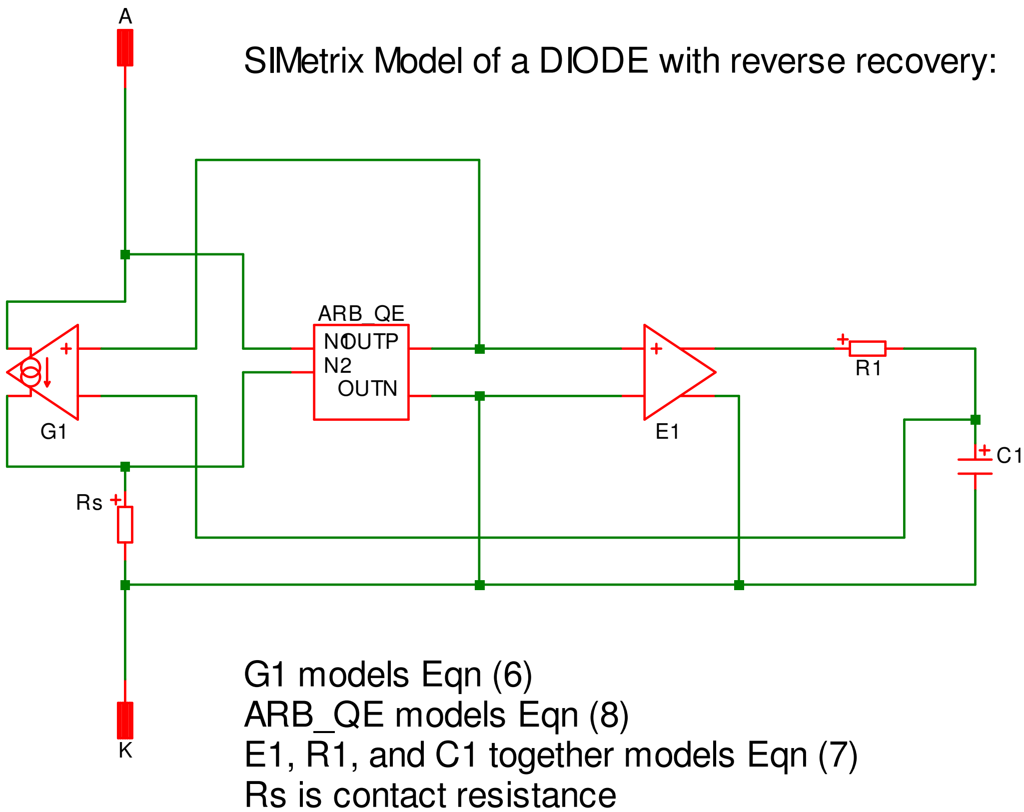
Typical diode current waveform during turning off from an inductive load



In this figure, the diode current i_D is conducting at a value I_F for $t \le 0$. In the time duration from $t = 0$ to $t = T_1$, the diode current ramps down linearly from the value of I_F at $t = 0$ to the value of $-I_{RM}$ at $t = T_1$. Once the diode current has reached the value of $-I_{RM}$, the reverse recovery phase begins and the diode current will exponentially decrease to zero.

The Lauritzen and Ma model implemented in SIMetrix

If we use SIMetrix, the model of Lauritzen and Ma could be implemented by the following modeling structure, with the terminal A representing the anode and the terminal K representing the cathode.



Notice that all components in this model, except for the arbitrary source ARB_QE, are linear. The output of ARB_QE represents q_E in the paper and the capacitor voltage of C1 represents q_M in the paper.

Procedure for deriving the necessary parameters for the Lauritzen and Ma model for implementation in SIMetrix.

Section III of the 1999 Lauritzen and Ma paper defined the procedure for deriving the necessary parameters to define the model. The procedure is repeated here with explicit reference to the shown SIMetrix model structure.

1) Measure in the laboratory the diode current turning-off waveform from an inductive load. Make sure the di/dt is relatively constant from the moment the diode current starts dropping to the moment the diode current reaches the maximum reversed value of $-I_{RM}$.

2) Set the reverse recovery time constant τ_{rr} to be 1/10 of t_b where t_b is the amount of time it takes the diode current to exponentially decay from $-I_{RM}$ to zero. Set the R-C time constant of R1 and C1 in the model to τ_{rr}.

3) Use Eq. (13) of the paper to solve for the recombination life time τ . This equation is a transcendental equation. So a nonlinear equation solver or some trial and error is needed. Notice that τ cannot be smaller than τ_{rr}.

4) The value of T_M is calculated from the equation $1/\tau_{rr} = (1/\tau) + (1/T_M)$

5) Set the gain of E1 to $\tau/(\tau + T_M)$. Hence, the gain constant for E1 is always less than 1.

6) Set the gain of G1 to $1/T_M$.

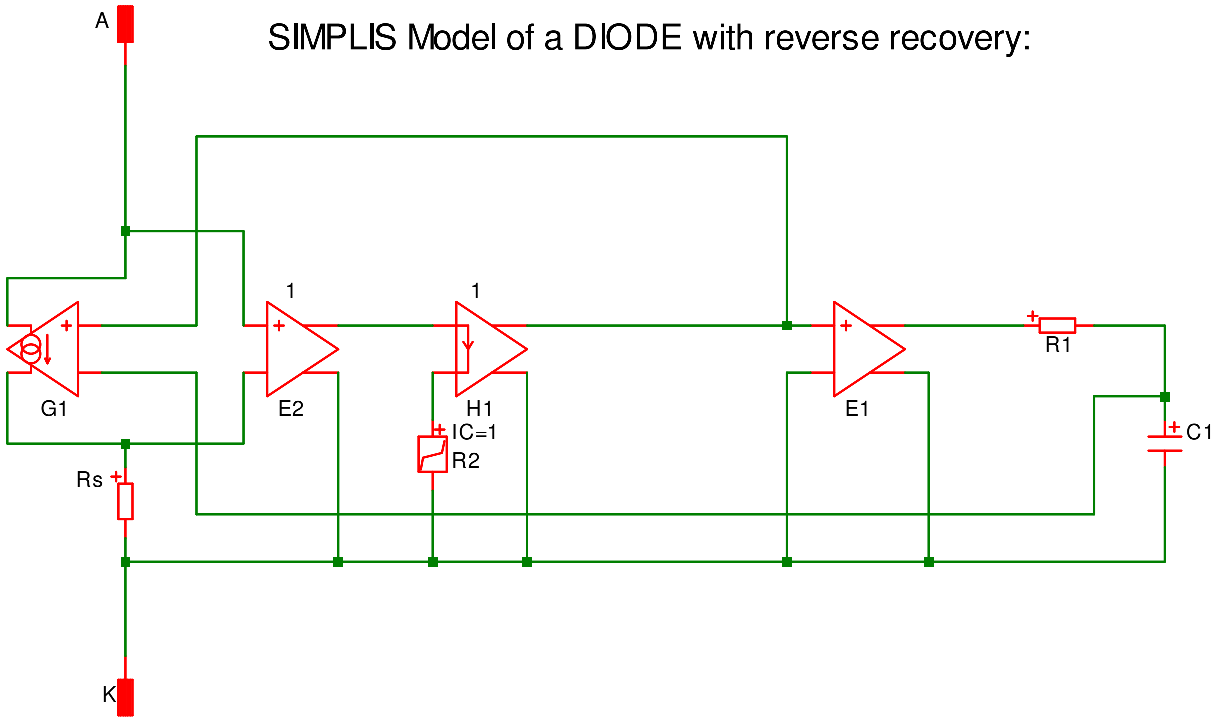
7) Measure the diode's forward-bias static *i-v* characteristics to determine the value of I_S , n , and R_S through the use of Eq. (9). The contact resistance R_S is not mentioned in the paper but it is a widely used parameter in the modeling of diodes in SPICE.

8) Use the arbitrary source ARB_QE to model Eq. (8) of the paper now that I_S , n , and τ are known.

This procedure should be repeated for different values of di/dt and different values of I_F . The different values obtained for τ and T_M can then be averaged to give a model that is reasonably accurate over a wide range of di/dt and I_F .

The Lauritzen and Ma model implemented in SIMPLIS

If we use SIMPLIS, the model of Lauritzen and Ma could be implemented by the following modeling structure, with the terminal A representing the anode and the terminal K representing the cathode.



In this model, all components are linear except for the PWL resistor R2. The gain constants for E2 and H1 are both set to 1. The time constant formed by R1 and C1 should be set to the same value of τ_{rr} as in the SIMetrix model. The gain constant of G1 and the coordinates of the break points of R2 can be derived in the following procedure:

1) Measure the diode's static *i*-*v* characteristics to determine the value of the contact resistance R_S. Then subtract the contribution of the voltage due to the contact resistance R_S to obtain a new static *i*-*v* characteristics. The *i*-*v* characteristics of the PWL resistor R2 is set to represent and model this new static *i*-*v* characteristics.

2) Set the gain constant of G1 to $(T_M + \tau)/T_M$. Hence, the value of G1 is always larger than 1.

Example

An example diode with the following parameters is used to create a diode model to account for reverse recovery: $I_F = 10.8A$, $I_{RM} = 2.7A$, $a = 100A/\mu s$, $T_1 = 135ns$, $t_a = 27ns$, and $t_b = 59ns$.

Following the procedure described above, we have found $\tau_{rr} = 5.9ns$, $\tau = 33.82ns$, and $T_M = 7.147ns$. Depending on whether SIMetrix or SIMPLIS is used, the remaining parameters were derived accordingly

Epilogue

- The model is relatively simple to implement and to make measurements to determine the parameters.
- This model does not model the junction capacitance.
- There were some simplifying assumptions made in the Lauritzen and Ma paper. This would have some effect on the accuracy of the model.
- The model as implemented has neglected the effect of emitter recombination under very high current level. If the computed values for τ and T_M have high variations over different values of I_F, then the effect of emitter recombination may need to be included in the model. All it does, as far as SIMPLIS is concerned, is another PWL resistor in parallel with the trans-conductance G1.
- The model could be very slow in SIMPLIS due to very small basic step size.