ECE 3254 PreLab 5 notes

Edited 09-25-09

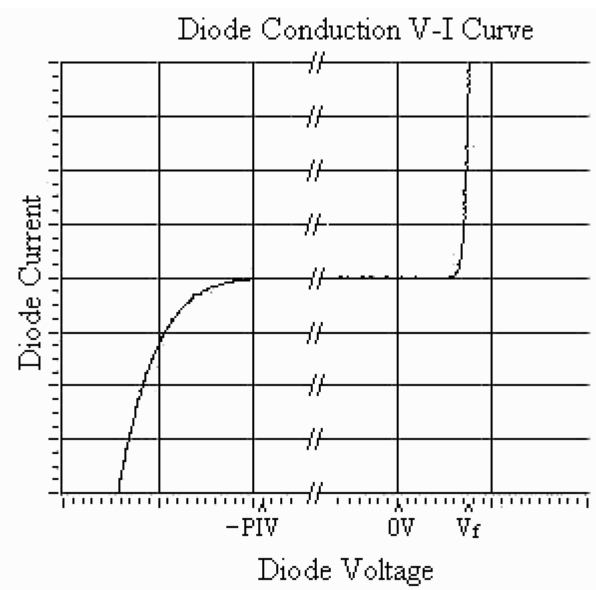
<u>Rectifier Diode</u> – may also be called a switching diode for high frequency use.

The ideal rectifier diode operates as a one-way "check valve". Conduction occurs only when the diode is forward biased. The ideal diode has no forward voltage drop and does not conduct at all when reverse biased.

A real diode has a typical forward voltage of 0.6V to 0.8V, and a reverse breakdown voltage that is greater than the diode's peak inverse voltage (PIV) rating. Conduction in both directions follows an exponential V-I curve. The diode current I is given by Equation 1 where I_S is a scale factor called the saturation current, q is the charge on an electron , k is Boltzmann's constant, T is the absolute temperature of the p-n junction and V_D is the voltage across the diode. The term kT/q is the thermal voltage, sometimes written V_T, and is approximately 26 mV at room temperature. n is the emission coefficient, which is typically 1 for most devices.

Equation 1: $$I = I_S \left(e^{\frac{qV_D}{nkT}} - 1 \right)$$

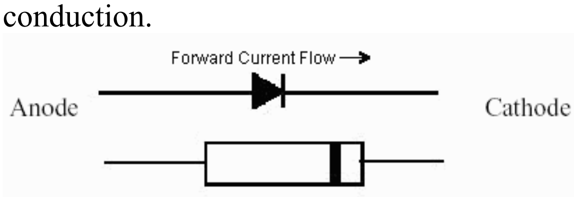
Silicone saturation current $I_S \approx 10^{-13}$A
Germanium saturation current $I_S \approx 10^{-8}$A



Rectifier diode ratings include:

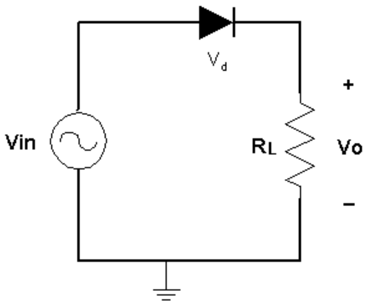
- Forward current
- PIV
- Forward voltage drop
- Reverse recovery time
- Junction Capacitance

Rectifier diodes are normally only operated in forward condition, forward cutoff, or reverse cutoff. The PIV rating is not an indication of where reverse conduction actually occurs; it only guarantees that the diode will not break down before the PIV rating is reached. It is not a good idea to design a circuit that depends on reverse conduction in a rectifier diode because the reverse conduction voltage can not be predicted. Because uncontrolled reverse breakdown quickly leads to diode failure, (which can also damage other circuit components) you should never attempt to operate a rectifier diode in reverse conduction.

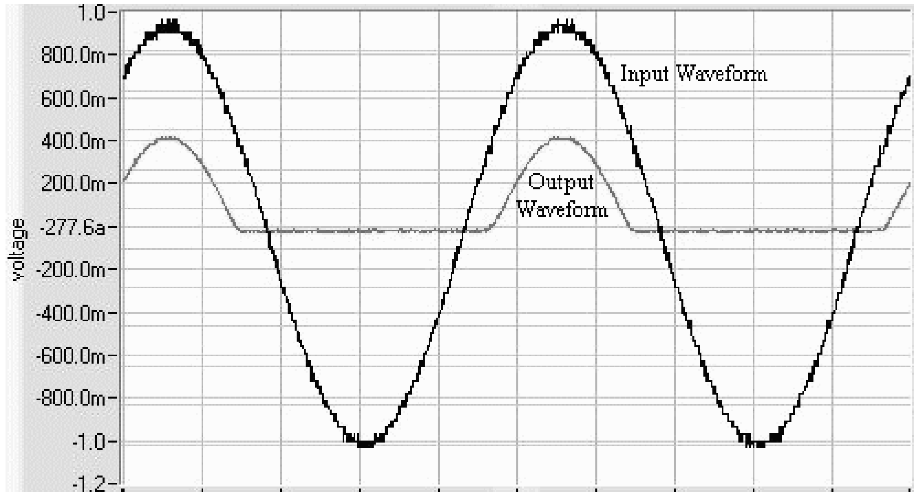


The diode Cathode is identified by a band on the cathode end.

A half wave rectifier produces an output pulse during only one half of the AC input waveform. Note that the forward voltage drop reduces the output voltage by one diode drop (V_d)

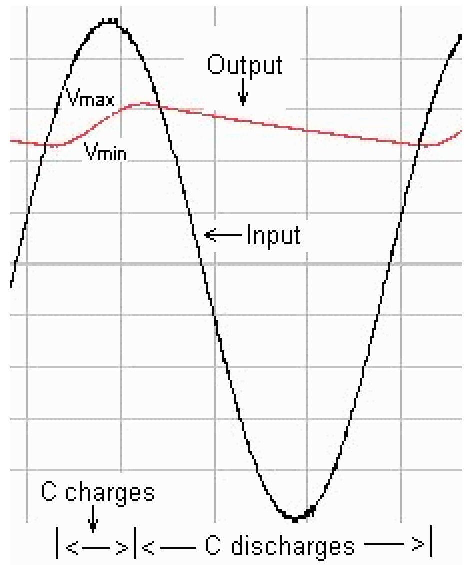


Half Wave rectifier circuit



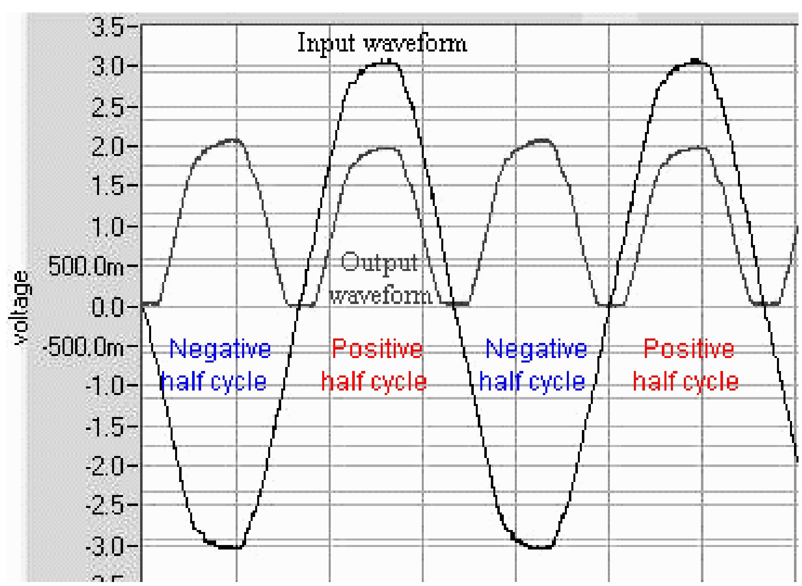
When a capacitor is connected in parallel with R_L, the half wave output becomes a "filtered" DC. As the voltage of the input sine wave increases, the diode will begin to conduct and charge the capacitor. When the input sine wave voltage falls below the capacitor voltage, the diode turns off and the capacitor discharges into the load.

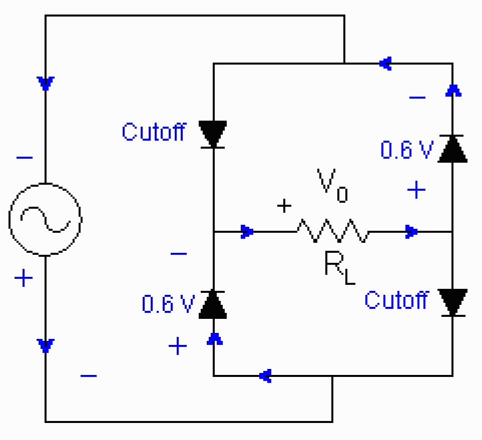
The size of the resistor will determine V_{min}. As the load resistance is increased: I_L decreases, the capacitor discharges less, V_{min} increases, V_{rms} (effective voltage) increases, and V_{pp} (ripple voltage) decreases. V_{max} does not change much because the diode forward voltage drop is relatively constant and $V_{max} = V_{in} - V_d$.



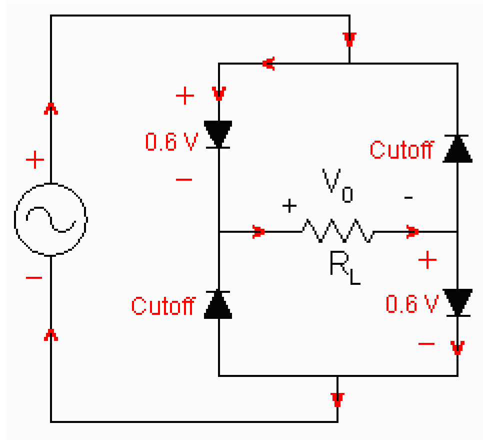
A full wave bridge rectifier produces an output pulse for both halves of the AC input waveform. Note that for each half cycle the output voltage is reduced by two diode drops because there are two legs conducting (each leg has a diode).

If a capacitor is connected to the load, the full wave charges the capacitor on both halves of the cycle, producing a higher V_{min} , a higher V_{rms}, and much lower V_{pp} than a half wave rectifier with the same load resistor.





Negative half cycle conduction



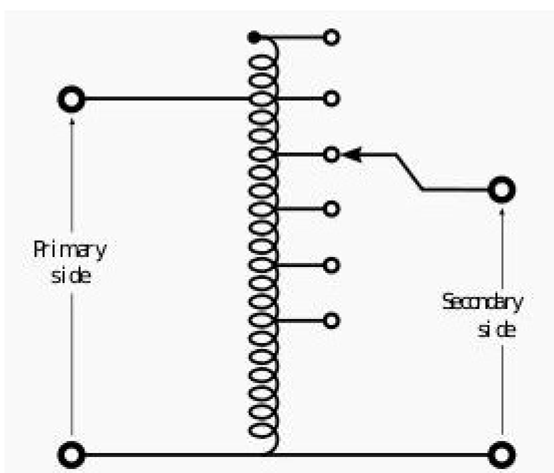
Positive half cycle conduction

The Autotransformer and Isolation Transformer

We need an AC source with no ground for the Full Wave Bridge rectifier measurements. The function generator and oscilloscope are grounded through the 120V bench AC power connection. We can not use a function generator to supply the input voltage to a bridge rectifier because the ground in the generator and the ground in the oscilloscope will short one leg of the rectifier bridge.

To create a ground isolated AC source, we will use an autotransformer as a variable AC voltage and a 10:1 isolation transformer to remove the ground from the autotransformer.

The Variac (a brand name of autotransformer) is a single winding coil with a movable tap. The primary side is plugged into the bench AC power receptacle. A receptacle on the top of the Variac provides a variable output voltage from 0 to 120Vrms.



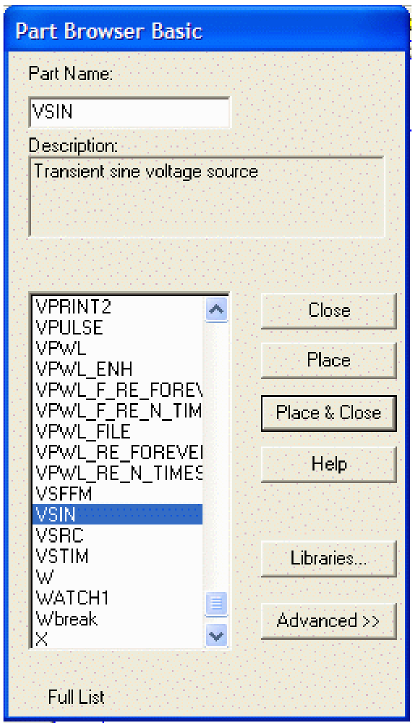
Auotransformer

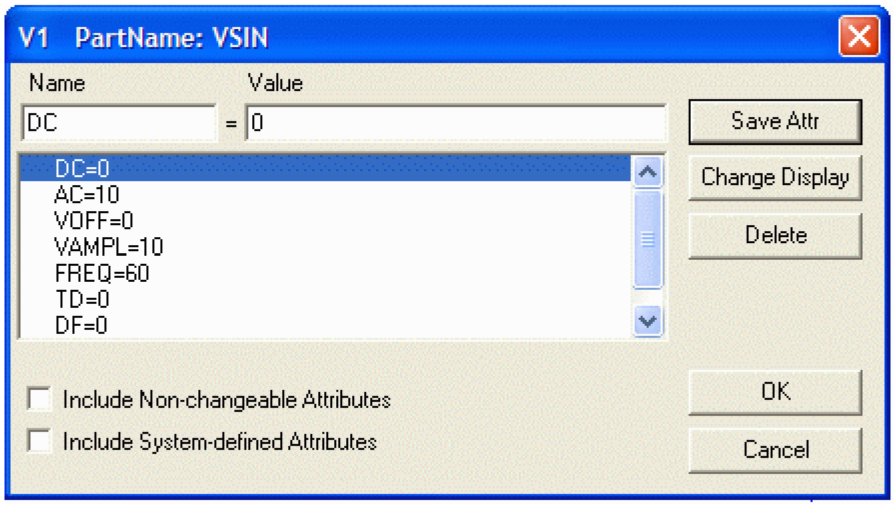
The Variac still has a ground through the neutral wire in the AC receptacle, so an isolation transformer, which has no connection between the primary and secondary windings, is required to remove the ground connection. The Lab isolation transformer also has a 10:1 voltage step-down, which is required for safety. 120Vrms is 170Vp! The 10:1 stepdown reduces the Variac voltage to a safe 17Vp, which provides us with up to 34Vpp for the rectifier circuit.

Pspice Transient Simulation of the Half Wave Rectifier Circuit

Build the circuit as you have been doing for previous labs. Remember to save you schematic frequently! For the source V1, select VSIN from the parts list and set the source values to:

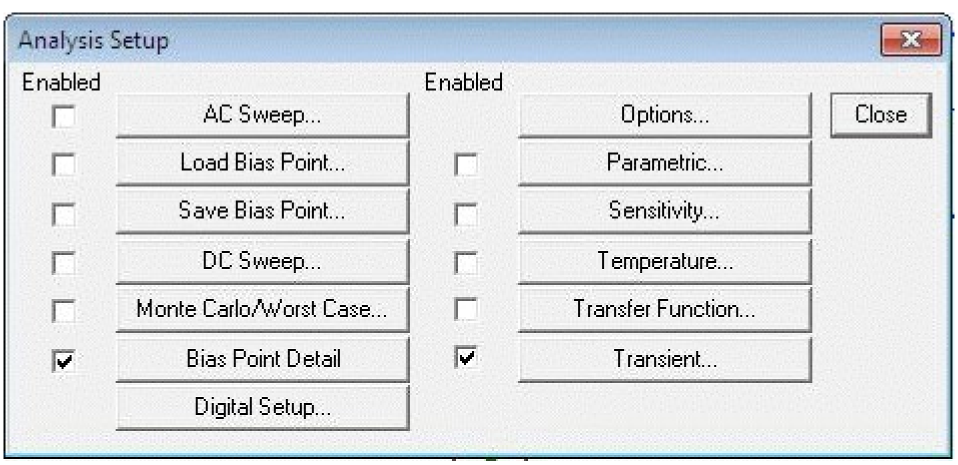
- DC = 0 (no DC offset)
- AC = 10 (10sin amplitude)
- VOFF = 0 (no DC offset)
- VAMPL = 10 (10sin amplitude)
- FREQ = 60 (60Hz)



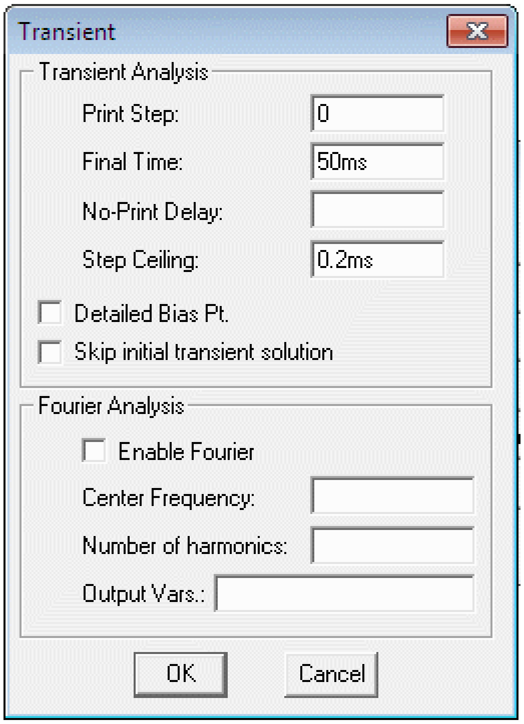


For D1, select D1N7002 from the parts list.

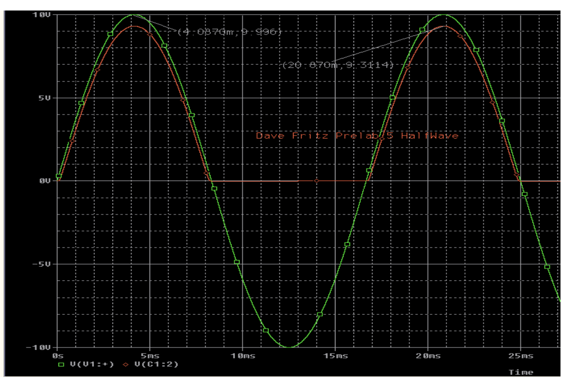
Set R2 = 1kΩ and C1 = 1nF (in this case, C1 is very small and has no effect at 60 Hz. You will increase C1 in the next prelab question). Don't forget to add the Earth Ground!
Set up Analysis by checking the boxes for "Bias Point Detail" and "Transient".



Click the “Transient” button and set the analysis to run from t = 0 (Print Step box), to t = 50ms (Final Time box) with 0.2ms time steps (Step Ceiling box).



Set voltage probes to measure V1 (which is Vin) and V_{R2} (which is Vout).
Run the simulation, you should see something like this (partial view shown):



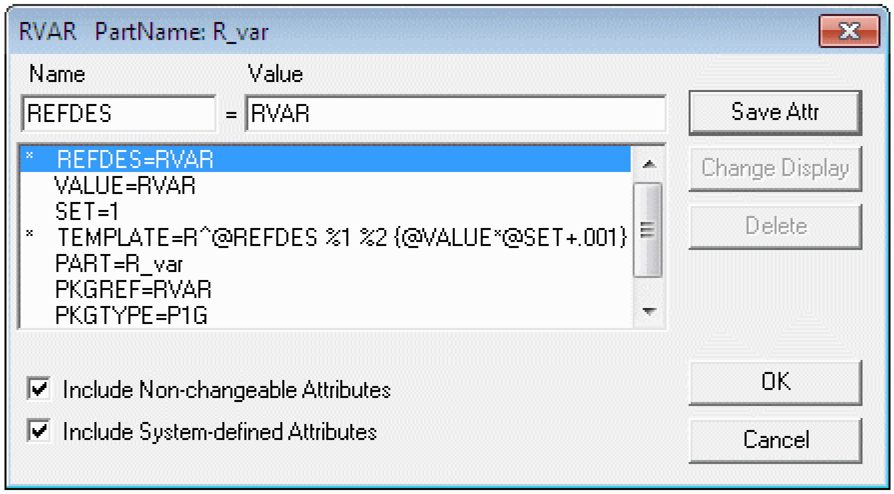
Now turn on the cursor, move it the maximum voltage on Vin (or Vout), and mark the value as you did in previous labs. Switch traces and mark the maximum voltage on the Vout (or Vin) trace.

Pspice Parametric Simulation of the Half Wave Rectifier Circuit

[This parametric sweep repeats the transient simulation for several values of RL.]

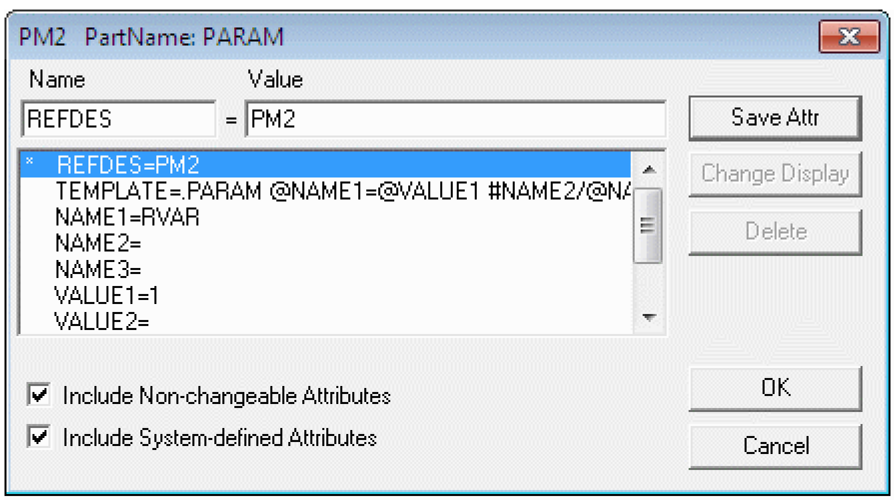
Delete R2 and add the part RVAR as you did in Lab 3 and set the values to (image capture is on next page):

- REFDES = RVAR
- VALUE = RVAR
- SET = 1

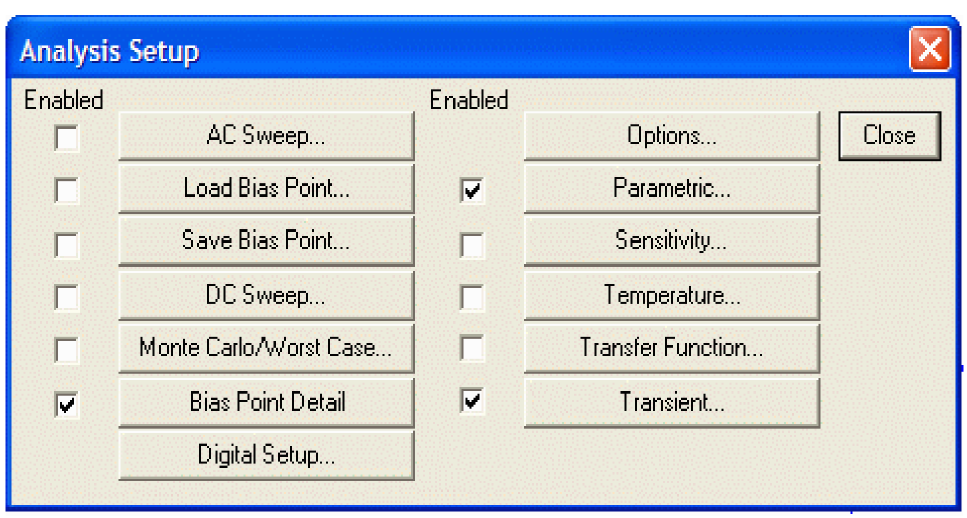


Add a Parameter as you did in in Lab 3 and set the values to:

- NAME1 = RVAR
- VALUE1 = 1

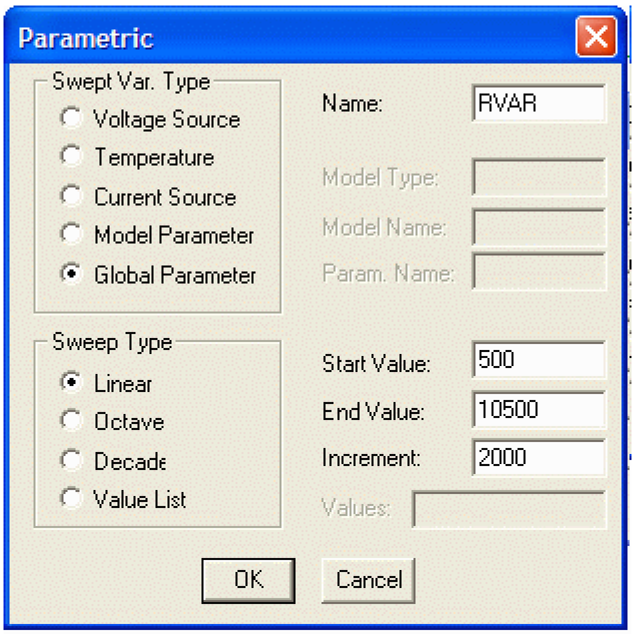


Enable the Parametric Sweep by checking the “Parametric...” box.



Click the "Parametric..." button and set:

- Swept Var Type to Global Parameter
- Sweep type to Linear
- Name = RVAR
- Start Value = 500 (1st resistor value)
- End Value = 10500 (last resistor value)
- Increment = 2000 (resistor value increments by 2000 each iteration)



This simulation should look something like (partial display shown):