Experiment 3:

Small-Signal Behavior of The PN-Junction Diode

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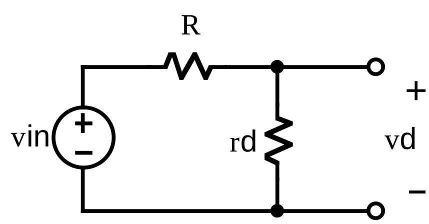
Purpose:

To determine the incremental, or small-signal response of a diode; to measure the incremental resistance $\Delta v_D / \Delta i_D$.

Method :

The operating point, or dc voltage level of a series resistor-diode circuit will be set so that the diode is in forward bias. The diode voltage will then be changed by a small amount Δv_D above and below the operating point, and the corresponding change in diode current Δi_D will be measured. The ratio $\Delta v_D / \Delta i_D$, which is the incremental resistance r_d, will be calculated. This quantity can be used to predict the slopes of the voltage-transfer curves that you observed in Experiment 2.

The small-signal model of the series resistor-diode circuit is shown below.



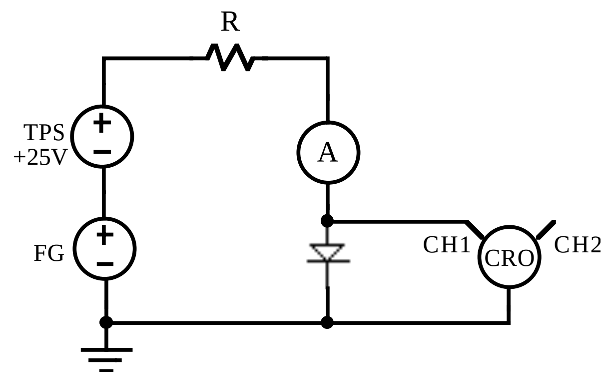
The lower-case quantities are the incremental values; the bias, or operating-point values are not included in the model. By voltage division, we have

$$v_d = v_{in} \frac{r_d}{r_d + R} \qquad (3\text{-}1).$$

In forward bias, where the i_D vs v_D curve is steep, r_d is very small. Thus $v_d \ll v_{in}$. This situation exists on the voltage transfer curve above V_f, where the diode is in forward bias.
In reverse bias, or well below V_f, the i_D vs v_D has a slope near zero. Therefore r_d is very large, and $v_d \approx v_{in}$. This situation exists on the voltage transfer curve below V_f (if there is no load resistor in parallel with the diode).

Hardware Setup:

The following circuit will be used.



Use a 1 kΩ resistor and the pn-junction diode that you measured in experiment 2. Remember that one side of both the function generator output and the oscilloscope input is always grounded, but that both outputs of the triple power supply can be floating. Therefore, the function generator and power supply cannot be interchanged in this circuit without creating a ground loop that would short circuit the power supply. The oscilloscope is used as a voltmeter to measure v_D. Remember that its vertical sensitivity is not important as long as the trace remains on screen.

Software Setup:

Since the voltage Δv_{IN} will be applied in steps, the function generator panel is set for DC operation with zero offset, and the multimeter for DC Amps. Set the channel 1 sensitivity of the oscilloscope panel to 0.2 V/div and the probe factor to 10.

The function generator component driver obtains its symmetrical **offset** input from a For Range object. You can set all three values of the range manually, or you may want to try this somewhat more elegant approach. Add both a **from** and a **to** input terminal to the For Range object. Connect the **to** terminal to the output of a Real Knob or Real Slider. Connect the **from** terminal to the same output, but with an intervening **Formula** object that contains the expression **-a**. Now, when you set a single positive value on the knob, the corresponding symmetrical range is established. You must still set the **step** value manually.

The bias voltage will be obtained from the +25-V component of the triple power supply, which requires a Direct I/O object (***Menu Bar --> I/O --> Other Instrument --> dc@705 --> Direct I/O --> Get Instr***). You should refer to exercise 3 in the introductory document
Using Agilent VEE. The direct I/O object needs one input data terminal and the following statements:

> ***WRITE TEXT "output on"***
> ***WRITE TEXT "appl p25v,",a,",0.1".***

The value of **a** is set by a Real Knob or a Real Slider connected to the **a** input terminal.

The graph of i_D vs v_D will be shown on an X vs Y Plot object whose X input comes from the **MEAS_V_AVRG** output terminal of the oscilloscope component driver and whose Y input comes from the **READINGS** output of the multimeter. Although the scope output during any one voltage interval is presumably constant, the average value is read to smooth out any random fluctuations that might occur during the interval.

Your program will also calculate and display the value of r_d. One way to do this is described here. You may try another method if you wish. Collect all the v_D values in an array and do the same for the i_D values by connecting the outputs of the oscilloscope and the multimeter, respectively, to Collector objects. The **xeq** input of each collector is connected to the sequence output pin of the v_{IN} For Range object. When the program runs, the complete sequence of values is stored in each Collector until the sequence is completed. Then the For Range object emits a pulse from its sequence pin that instructs each collector to create an array, which is accessible at its output terminal. The outputs of the two collectors go to a **Formula** object with two inputs (named **a** and **b** by default). If **a** represents the voltage array and **b** represents the current array, then the expression in the box should be

(max(a)-min(a))/(max(b)-min(b)).

Feed the formula output to an Alphanumeric Display object, and do the same with the multimeter output. As the program runs, the r_d value and the corresponding i_D value will appear in the windows of these displays. You can collect the r_d values into an array if you wish.

Obviously, this calculation of r_d is meaningful only if the i_D-v_D relationship is close to linear. You will be able to see whether this is so when you observe the XY plot.

Procedure:

Open the XY display and run the experiment with a bias of +10 V and Δv_{IN} = 2 V. Record the r_d value that you observe. Try several widely different values of Δv_{IN}, recording the r_d value and the appearance of the plot. Do any of them give an invalid value of r_d?

Use one of your r_d values that you trust to calculate the slope of the voltage-transfer curve (Experiment 2) in the forward-active region. Compare this slope with the one you measured from the curve in Experiment 2.

Run the experiment again with bias values of 0.3 V and -5 V (you will have to make a circuit change to achieve the negative value). You will also have to give some thought to an appropriate voltage swing when the bias is 0.3 V. Record the r_d value in each case, and comment on the shape of the plot. Use the negative-bias value to predict the slope of the voltage transfer function in this region. Again, compare your result with the value estimated in Experiment 2.

Comment on the accuracy of your r_d calculations for the different voltage scan ranges. The appearance of the plots should help you do this.

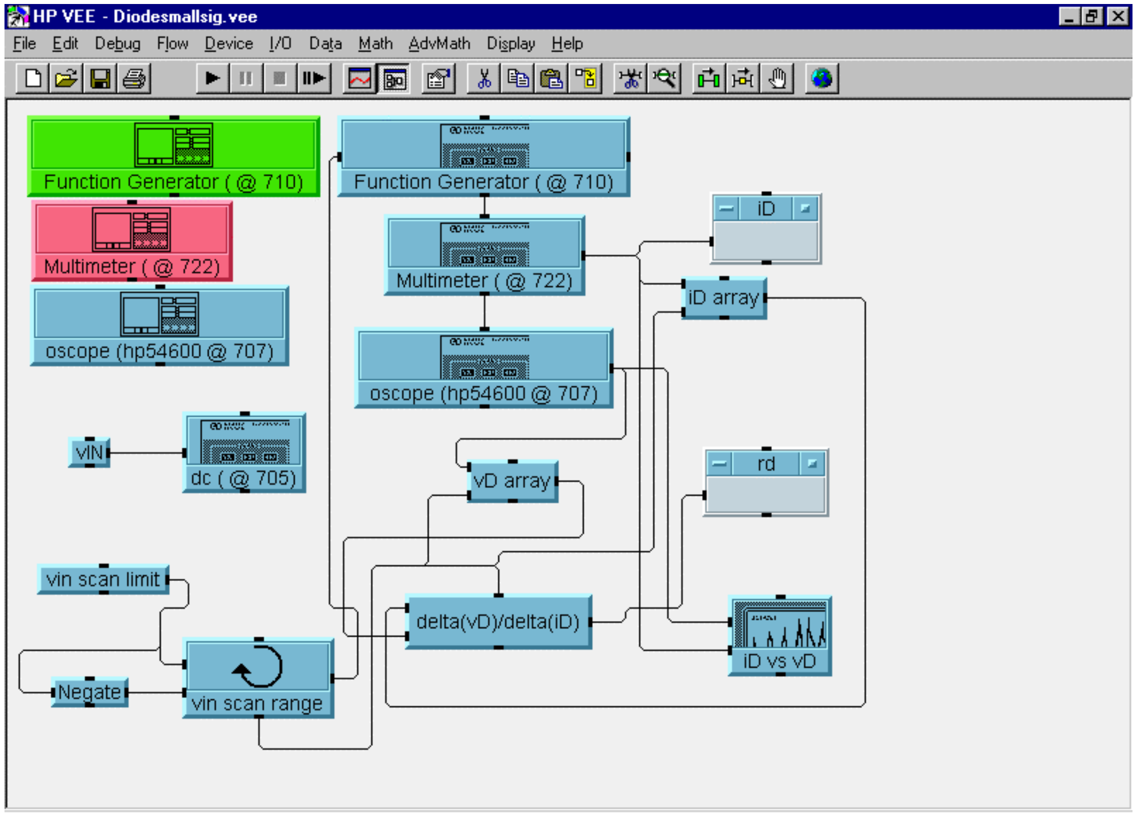


Fig. 3-2 Agilent VEE Setup