Experiment 7: Mosfet Transconductance

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Purpose:
To make a direct measurement of the transconductance of an NMOS transistor. This quantity is essential for determining the gain of MOSFET amplifiers.

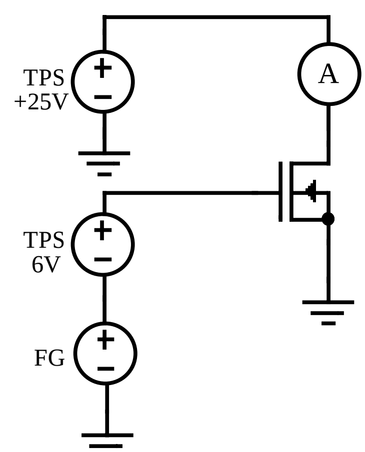
Method:
The procedure will be similar to that used for the small-signal behavior of the junction diode: An operating point in the constant-current region will be established, then the input voltage will be changed incrementally about this point, and the corresponding drain current will be measured.

An expression for the transconductance follows directly from differentiating the i_D - v_{GS} relationship:

$$g_m = \left.\frac{di_D}{dv_{GS}}\right|_{op.pt.} = \left.\frac{d}{dv_{GS}}\left[K\left(v_{GS} - V_{TR}\right)^2\right]\right|_{op.pt.} = 2K\left(V_{GS} - V_{TR}\right) = 2\sqrt{KI_D} \qquad (7\text{-}1).$$

This provides an independent way to determine K or V_{TR}. Since we know that the transconductance of a BJT is simply I_C/V_T, independent of device parameters, there is no need for an independent measurement of this quantity.

Hardware Setup:
Build the following circuit, using an NMOS transistor whose parameters you know:



Software Setup:
The function generator operates in DC mode, with its offset voltage determined by a For Range object. Its values should swing symmetrically about the operating point, which is set by the 6 V component of the triple power supply. The +25 V component sets V_{DD}. The Direct I/O driver thus

needs two inputs, each controlled by a knob or slider. You may use the method described in Experiment 3 for achieving a symmetrical voltage swing from the function generator with only one control element.

The i_D vs v_{GS} plot will be shown on an XY plot object, taking the outputs directly from the function generator and multimeter drivers in the usual way.

The remaining requirement is to calculate and display the value of g_m under various conditions. For an accurate measurement, the range of v_{GS} values around the operating point should be small to insure a good approximation to linearity. Here is a suggested way to insure this, which will acquaint you with some additional mathematical functions available in Agilent VEE.

Create arrays of the v_{GS} and i_D values with Collectors at the function generator and multimeter outputs, triggered by the sequence output pin of the For Range control. The number of elements in the arrays is determined by the v_{GS} range and increment that you chose; they may change from one run to another. Find the midpoint of the range by sending the v_{GS} array to a Formula object that contains the expression:

floor(maxIndex(a)/2) (assuming that the input variable to the Formula object is named **a**).

For example, if there are 20 elements in the array, the maximum index is 19 because in Agilent VEE the index of the first element of an array is 0, and not 1. Dividing by two gives 9.5, and taking the floor (the next lowest integer) gives 9. The slope $\Delta i_D/\Delta v_{GS}$ is calculated in a Formula object with three input terminals. If a represents the current, b the voltage, and c the index at the midpoint, then the expression can be

(a[c+1]-a[c-1])/(b[c+1]-b[c-1]).

Array indexes are enclosed in square brackets. The output can be presented in an alphanumeric display object.

Procedure:

Set V_{CC} to +15 V, and set the V_{GS} about 1 volt above threshold. Swing the signal by about ±0.5 V. Record the displayed value of g_m and observe the plot to see whether the curve is far from linear. Then try several higher operating points, recording the same information. Compare the displayed g_m values with the values calculated from equation (7-1).

Try increasing the swing range of v_{GS}, observing the plots. How far can you go before a pronounced nonlinearity is observed. When the curve becomes nonlinear, does the calculated g_m change? Explain why there was or was not a change.

Transconductance has meaning only when the MOSFET is in the constant-current range. How high can you set v_{GS} before this condition is violated? What do you expect to happen if you insert a 5 kΩ pullup resistor between the ammeter and the drain of the MOSFET?

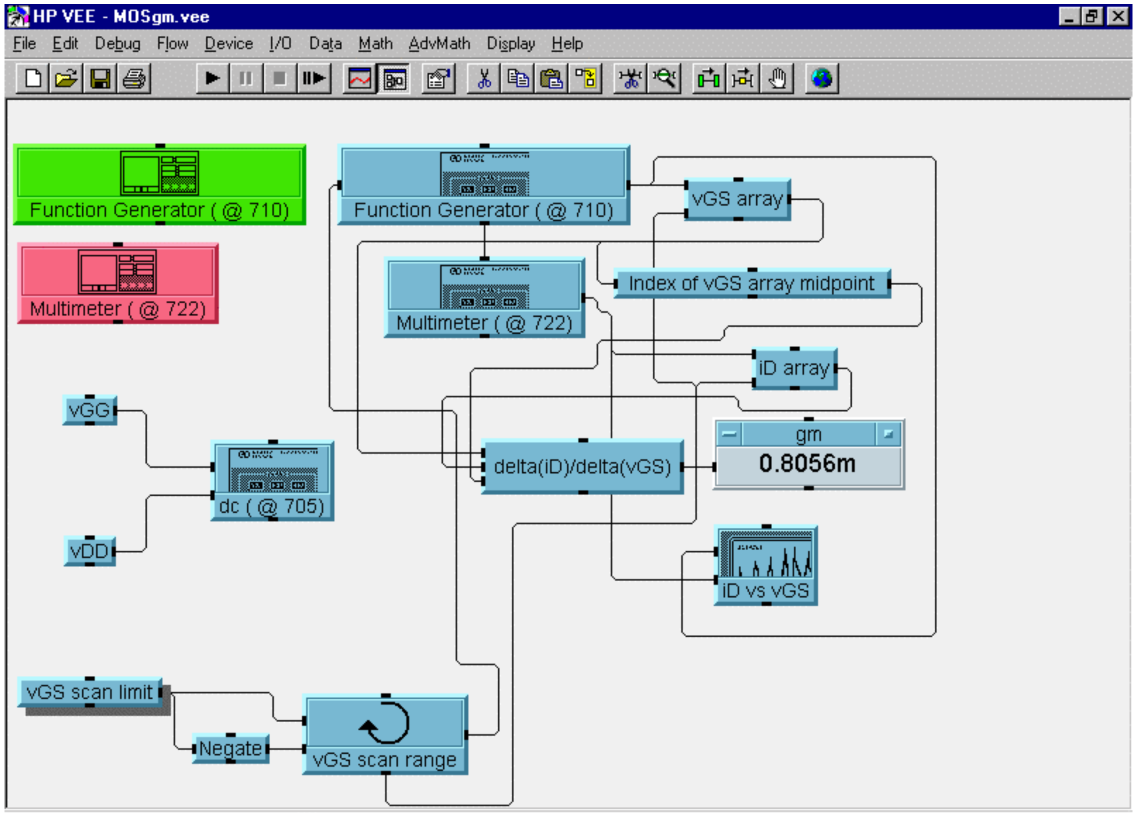


Fig. 7-2 Agilent VEE Setup