Small-Signal Concepts

ECE 3110
slope = $\frac{dI}{dV} = G$ (conductance) = $\frac{1}{R}$

$I = \frac{V}{R}$
The relationship between voltage, current, and conductance is described by the equation:

\[ I = V / R \]

The conductance, denoted by \( G \), is defined as the inverse of resistance, \( R \), so:

The slope of the graph is given by the derivative of current with respect to voltage, \( dI/dV \), which is equal to the conductance, \( G \), and equals the reciprocal of the resistance, \( 1/R \).
low conductance $G$ (high resistance $R$)

high conductance $G$ (low resistance $R$)

"input" voltage waveform

"output" current waveforms

\[ R = 1/G \]

\[ I = 1/V \]

"input" voltage waveform

"output" current waveforms
What if we replace the linear resistor with a nonlinear device like a transistor?
\[ I_C = I_S \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \]
The input voltage waveform is shown on the left, with the output current waveform resulting in distortion. The equation for the output current $I_C$ is given by:

$$I_C = I_S \cdot \exp\left(\frac{V_{BE}}{V_T}\right)$$
Distortion can be managed if signal swing is kept sufficiently small.

\[ I_C = I_s \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \]
The output current waveform is related to the input voltage waveform through the equation:

\[ I_C = I_S \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \]
slope $= \frac{dI_C}{dV_{BE}} = g_m$ (transconductance)

- high transconductance $g_m$
- low transconductance $g_m$

The curve is approximately linear for small signal swings.

input voltage waveform

output current waveform
output current waveform

small-signal amplitude \( i_c \)

slope = \( \frac{dI_C}{dV_{BE}} = g_m \) (transconductance)

bias voltage \( V_{BE} \)

bias current \( I_C \)

input voltage waveform

small-signal amplitude \( v_{be} \)

\( V_{BE} \)
output current waveform

slope = \frac{dI_C}{dV_{BE}} = g_m \text{ (transconductance)}

bias current \(I_C\)

bias voltage \(V_{BE}\)

small-signal amplitude \(v_{be}\)

input voltage waveform

ac small-signal linear approximation:

\[ i_c = g_m v_{be} \]

Important: \(I_C \neq g_m V_{BE} \) !!!

\[ I_C = I_S \cdot \exp\left(\frac{V_{BE}}{V_T}\right) \]

Don’t confuse ac and dc analysis!