INCREMENTAL (SMALL SIGNAL) ANALYSIS

What it is
A method of analysis that allows us to get approximate analytic expressions (equations) for nonlinear circuits which can't be solved easily.
Concept: "Take derivative first"

Why you do it
Linear signal analysis is such a powerful tool, we're going to use it to analyze systems that aren't linear. Anything (even a nonlinear circuit element) looks linear if you look at small enough changes from an operating point.

PROCEDURE:

1. First, find the DC (large signal) operating point for each element in the nonlinear circuit.

Possible methods:

- Solve nonlinear equations (e.g. quadratic for active region MOSFET square-law model)
- Iteratively solve nonlinear equations (e.g. SPICE)
- Approximate analysis (e.g. for BJT, assume $V_{BE} = 0.7V$ in active region)
- Graphical technique

Small signal solution will "ride on" bias levels provided by large signal operating point solution

2. Redraw the circuit: replace each circuit element with its small-signal model

- **Linear elements (e.g. pure R, L, C) stay the same**
- **Constant V/I Sources: Gone! ("take derivative first"):**
  - DC voltage sources: replace with short circuit
  - DC current sources: replace with open circuit
- **Nonlinear element: Replace with small-signal model**
  - For each type of device, small-signal model is obtained by taking derivative of appropriate terminal characterstic to find linear approximation for behavior around operating point.
  - Usually just do this once for each type of device; small signal model parameters are a function of large signal operating point (e.g. small signal MOSFET model derived once; then for each application of model use operating point information to calculate small signal parameters).

3. Solve the small-signal circuit model using all the linear analysis tools you know and love:

Good Old Ohm's Law

- All V-I characteristics are linear in small-signal model

Can use Thevenin's theorem to simplify large circuits

- Attack them one block at a time
- Helps to understand functions of each block; how well actual circuit is performing function

Can use superposition to calculate response to different inputs

- Attack output behavior one signal at a time
- Helps to understand response (output) as caused by each input

Can use transfer functions to express frequency-dependent behavior

Can always use KVL, KCL, nodal analysis

- (apply to any circuit, linear or nonlinear)

4. Total behavior is sum of DC (large signal) operating point + small signal component "riding on" DC bias from large signal operating point solution

Cautions

Limitations

- If actual signal isn't "small", then "solution" won't be valid!
- How small is "small"? Depends on accuracy required. Need to look at derivation of model for individual devices used.

Common errors

- Don't get large signal, small signal quantities confused! For example:
  - There should be no DC sources (e.g. supply rails) in a small signal model.