EECS 312 – Electronic Circuits I – Notes
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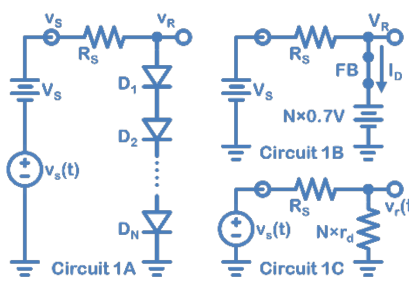
The Small Signal Analysis Process and Examples

Process: Draw the large-signal circuit (LSC) with only large-signal DC sources.
Solve the LSC (maybe using the CVD model) to find the operating point, I_D, for all the diodes.
Use I_D to find the small signal resistances, r_d, for all the diodes.
Draw the small signal circuit (SSC) with only small-signal sources and replace diodes with r_d.
Solve the SSC to find the small-signal relationship, such as $v_{out}(v_{in})$.

<u>Large-Signal (DC) and Small-Signal (Time-Varying) Models for Common Devices.</u>

Device	**Large-Signal Model (ω=0)**	**Small-Signal Model (ω>0)**
Resistor, (R)	R	R
DC Voltage Source	DC Voltage Source	Short
Time Varying Voltage Source	Short	Time Varying Voltage Source
DC Current Source	DC Current Source	Open
Time Varying Current Source	Open	Time Varying Current Source
Large Inductor, (jωL)	Short	Open
Large Capacitor, (1/jωC)	Open	Short
Diode	Diode (maybe CVD model)	$r_d = nV_T/I_D$

Example: Voltage Regulator



Circuit 1A show a regulator constructed using N diodes in series. The source voltage, v_S, is comprised of a DC component, V_S, as well as an unwanted noisy signal, $v_s(t)$, in series. The large signal circuit is shown in Circuit 1B (using the diode CVD model). The regulated voltage and diode bias current become: $V_R = N\times0.7$ [V]

$I_D = (V_S-N\times0.7)/R_S$ [A]

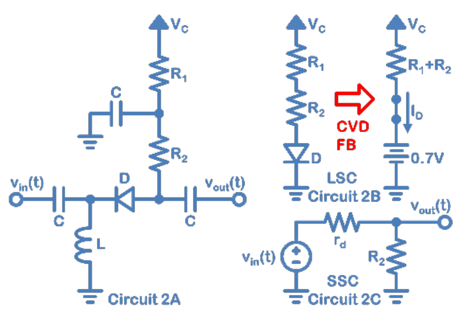
And the small signal resistance: $r_d = nV_T/I_D$

$r_d = nV_TR_S/(V_S-N\times0.7)$ [Ω]

The small signal circuit is shown in Circuit 1C, with the line regulation calculated as:

$$\Delta v_r/\Delta v_s = N\times r_d/(N\times r_d + R_S) = N\times nV_T/(V_S - N\times(0.7 - nV_T))$$

Example: Voltage-Controlled Attenuator



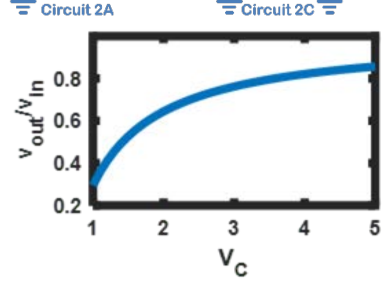
Circuit 2A shows a simple example of a voltage-controlled attenuator. The transfer function or small signal relationship, $v_{out}(t)/v_{in}(t)$, is found using small signal analysis. First, the large-signal circuit in 2B is analyzed to find the bias current and diode small signal resistance: $I_D = (V_C-0.7)/(R_1+R_2)$ [A]

$r_d = nV_T/I_D = nV_T(R_1+R_2)/(V_C-0.7)$ [Ω]

The small signal circuit is shown in 2C, with the small signal relationship calculated as:

$$v_{out}/v_{in} = R_2/(R_2+r_d)$$

$$v_{out}/v_{in} = R_2/(R_2+nV_T(R_1+R_2)/(V_C-0.7))$$



The plot shows the small-signal gain, v_{out}/v_{in}, as a function of the DC control voltage, V_C, for R_1=400 Ω, R_2=30 Ω, and n=2.