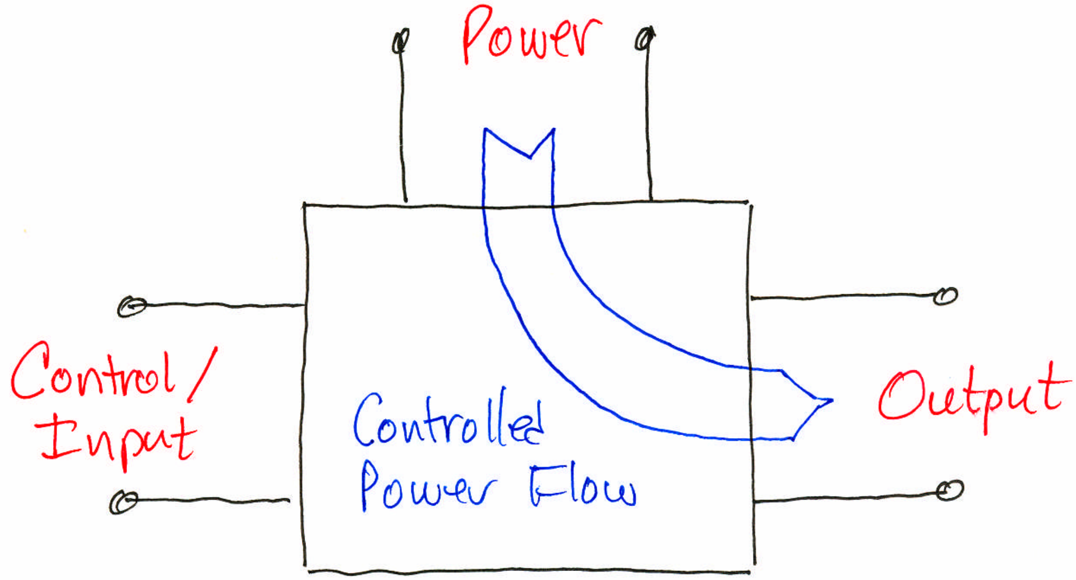
6.002 - Lecture 6

Amplifiers

- Amplifiers
- Review Of Digital Inverter
- Review Of MOSFET Characteristics
- Dependent Sources
- Amplifier Implementation

Amplifiers



- An amplifier is a three-port device.
- Ubiquitous use to improve signal strength, improve signal-to-noise ratio, and provide power gain.
- Examples found in electronics, mechanics, pneumatics, hydraulics, economics, society ...

Some Amplifier Properties

Gain: Voltage, Current, Power

Equivalence: Input, Output

Bandwidth

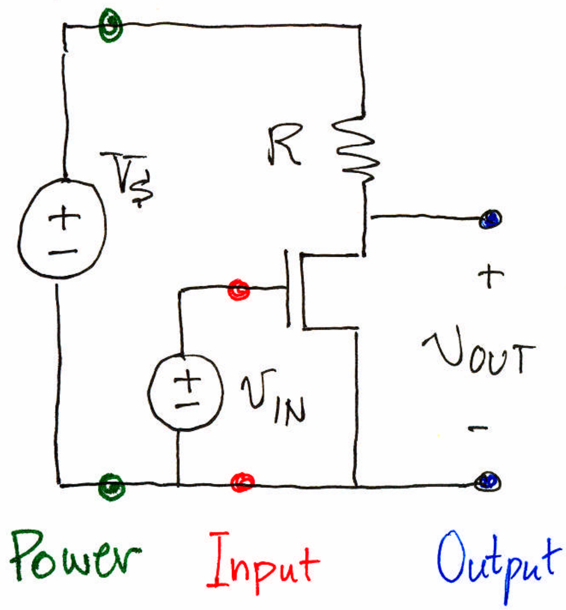
Noise

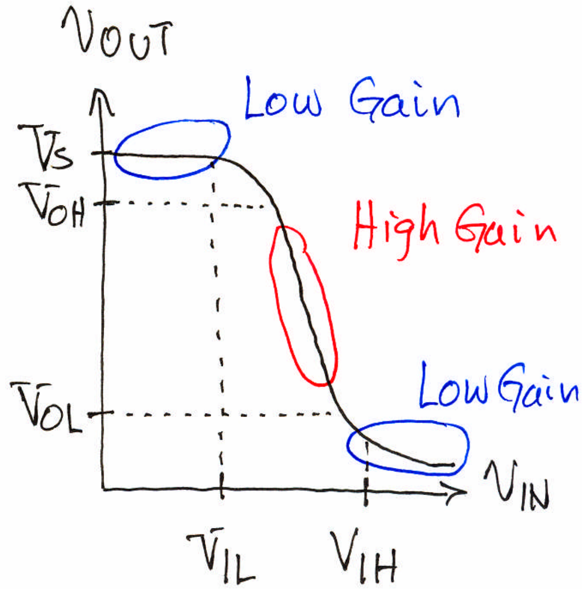
Stability

Dissipation

Load Dependence

NMOS Inverter

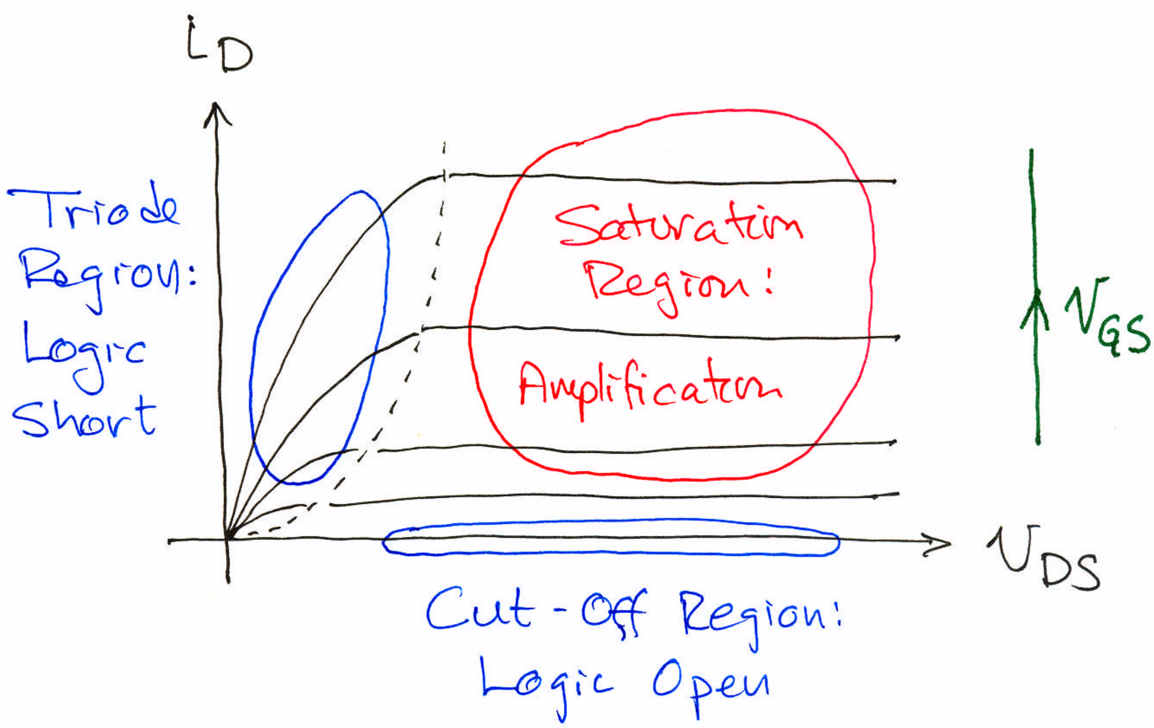




Low Gain ⇒ Output is insensitive to input. Perfect for digital logic operation.

High Gain ⇒ Output is very sensitive to input. Perfect for amplification.

MOSFET Characteristics



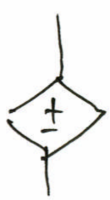
Saturation Region: i_D depends (to first order) only on v_{GS}, and not on v_{DS}! Model this region with a voltage-dependent current source.

Independent & Dependent Sources

Independent Sources ( ) are external inputs and are independent of all other signals.

Dependent Sources ( ) are internal sources having values that depend on other internal branch variables.

Dependent Voltage Source

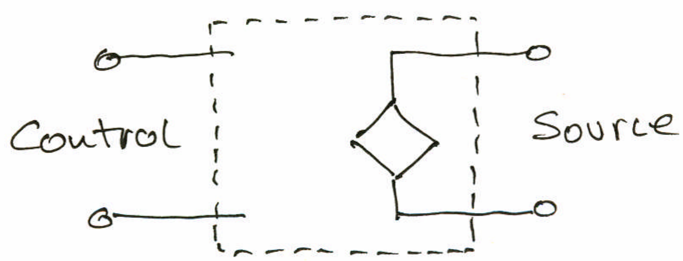


Label Indicates Dependence

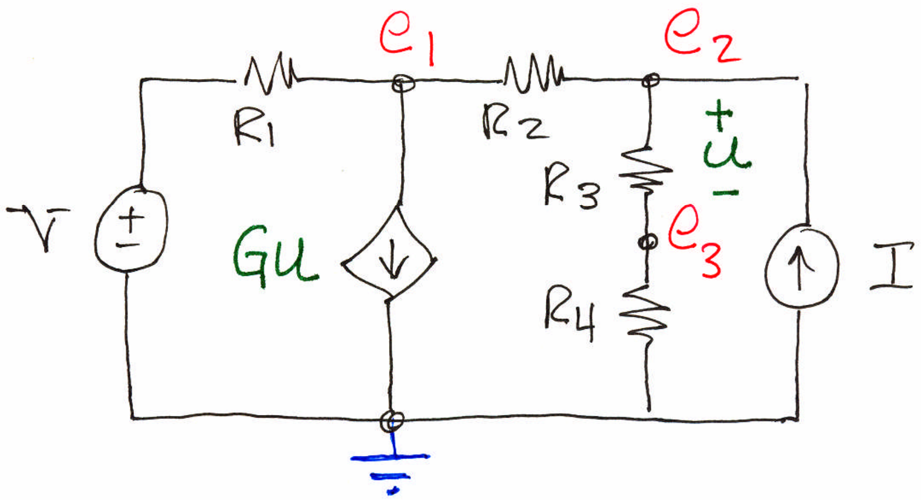
Dependent Current Source

Label Indicates Dependence

Dependent sources are atleast two-port devices, and are three-port devices if they can source power.



Network Example (Node Method)



Node 1: $G_1(e_1 - V) + G(e_2 - e_3) + G_2(e_1 - e_2) = 0$

Node 2: $G_2(e_2 - e_1) + G_3(e_2 - e_3) - I = 0$

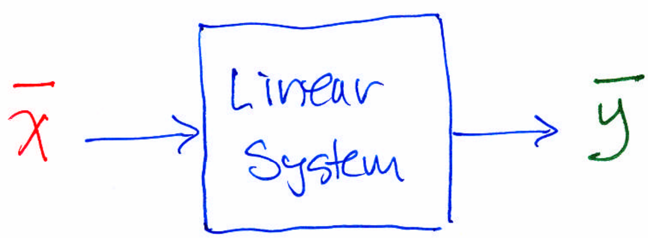
Node 3: $G_3(e_3 - e_2) + G_4(e_3) = 0$

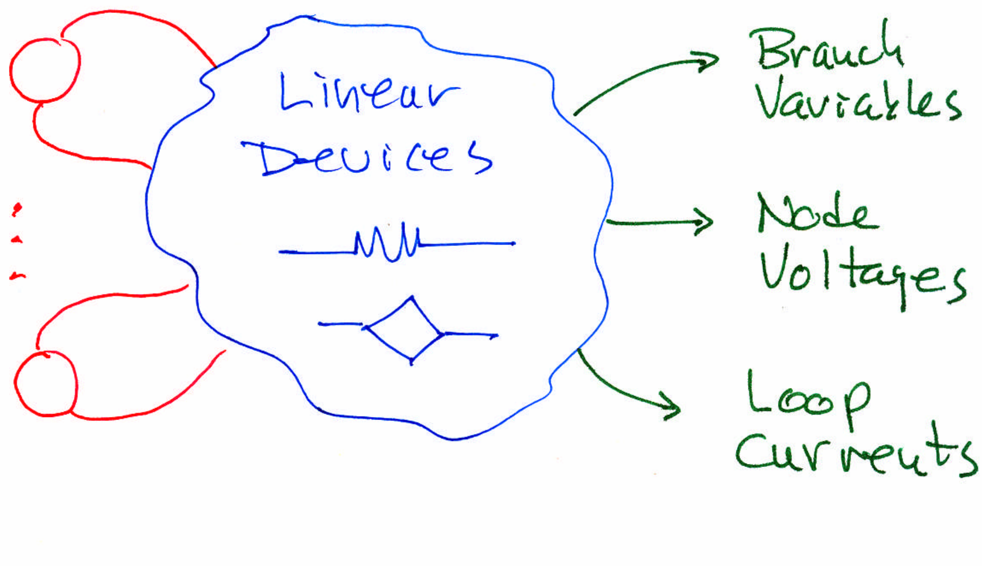
$$\begin{bmatrix} G_1 + G_2 & G - G_2 & -G \\ -G_2 & G_2 + G_3 & -G_3 \\ 0 & -G_3 & G_3 + G_4 \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} = \begin{bmatrix} G_1 & 0 \\ 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} V \\ I \end{bmatrix}$$

- Dependent source properties appear in coefficient matrices.
- The network remains linear if the dependent sources are linear.

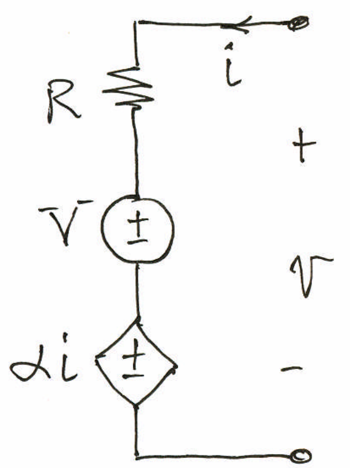
Superposition

Dependent sources are part of the network/system, not part of the independent inputs. Carry out superposition only over the independent sources.

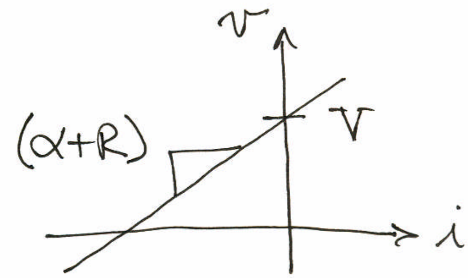




Thevenin & Norton Equivalence



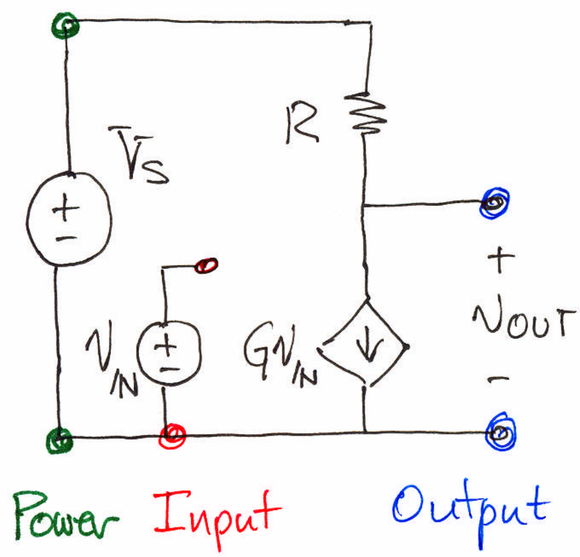
$$v = \alpha i + \bar{V} + Ri$$
$$= \bar{V} + (\alpha + R)\, i$$



The dependent source is acting like a resistor:

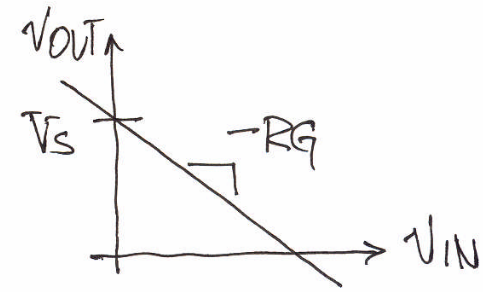
- Independent sources can only bias the i-v relation at a port.
- Dependent sources can also change the slope of the i-v relation.
- Dependent sources are part of the network, and so must be part of a Thevenin resistance calculation.

Amplifier Implementation

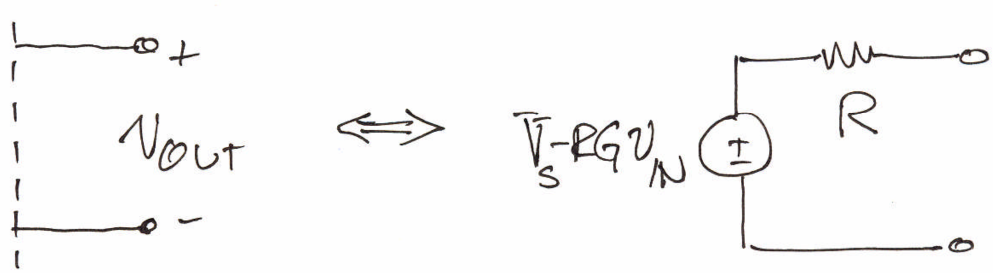


$$\frac{V_{OUT} - \bar{V}_S}{R} + G\,V_{IN} = 0$$

$$V_{OUT} = \bar{V}_S - RG\,V_{IN}$$



Thevenin Equivalent:

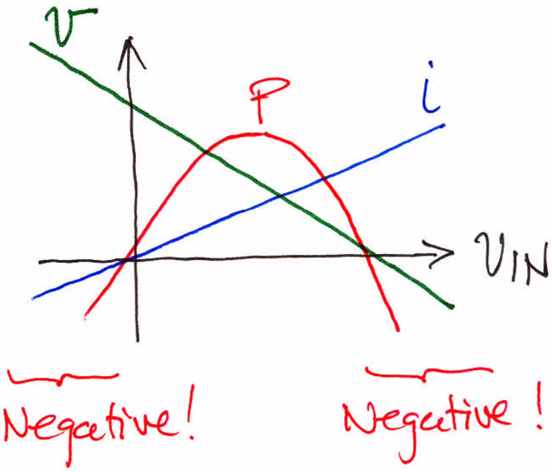


Dependent Source Power

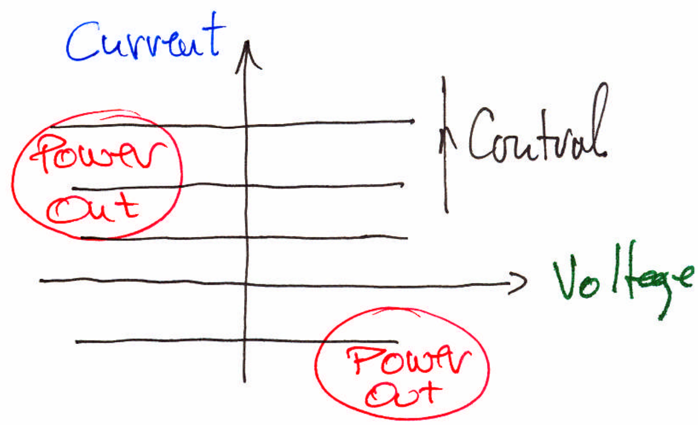
Voltage $= V_S - RG\,v_{IN}$

Current $= G\,v_{IN}$

Power In $=$ Voltage $\cdot$ Current



Dependent Source:



MOSFET: