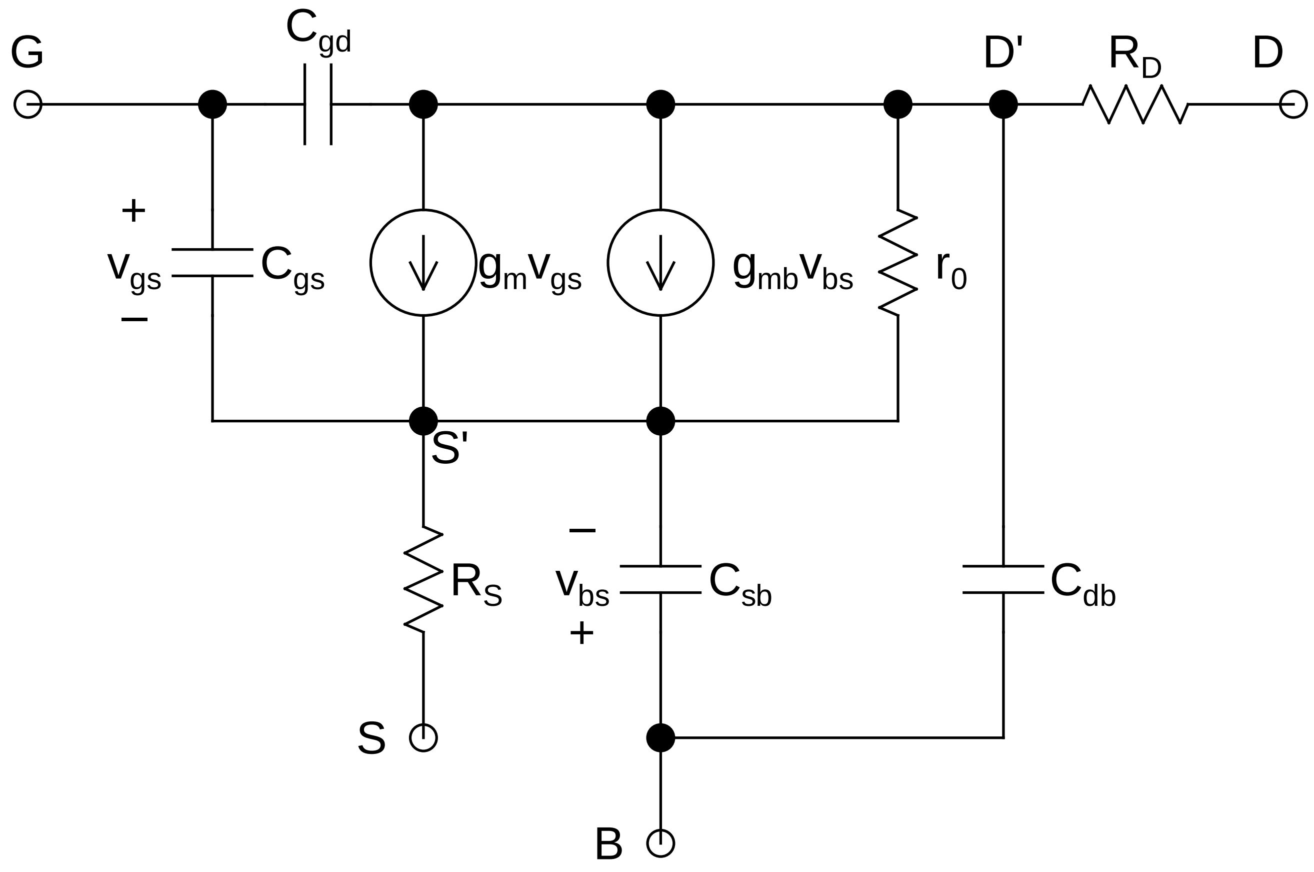
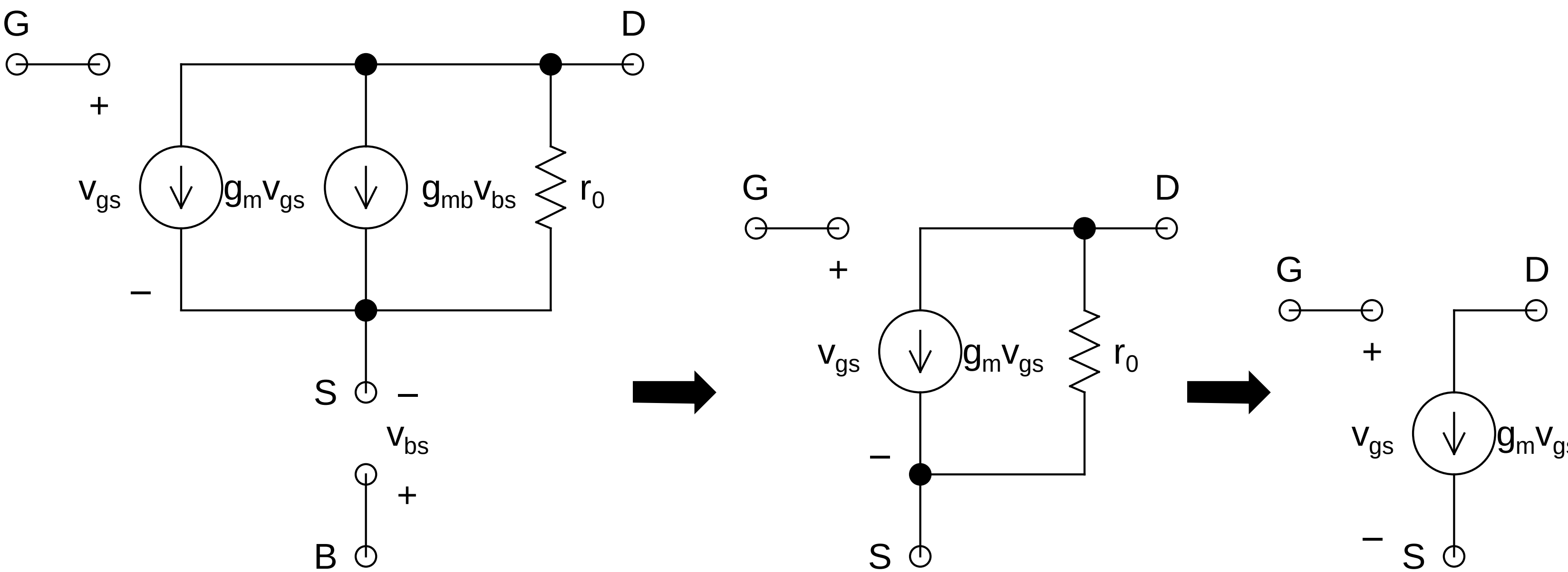
The Hybrid-π Model



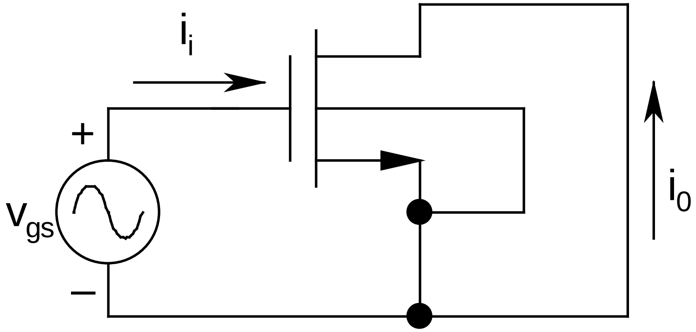
- ***Simplifications***:
  - ***R_S and R_D can be safely neglected***
  - For ***low to moderate frequencies***, the ***capacitive reactances*** of all the capacitances will be ***extremely large*** $\Rightarrow$ ***can be neglected***
  - ***If both B and S are connected to fixed DC potentials***, ***current source $g_{mb}v_{bs}$ disappears***
  - Leads to the ***Low-Frequency T-Model***, having only ***two components***: $g_m v_{gs}$ and r_0
  - ***Simplest possible equivalent results if r_0 is also neglected*** (***ideal current source***!)

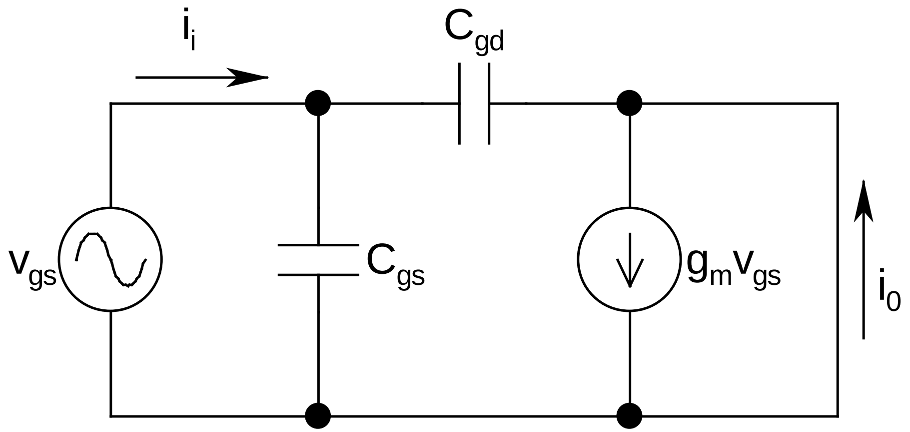


Low-Frequency **Without Body Effect** **Without CLM**

Frequency Specification of MOSFETs

- Only ***Unity-Gain Frequency*** (f_T)





- $i_0 \approx g_m v_{gs}$ (neglecting ***reverse transmission*** through C_{gd})
- $i_i = j\omega(C_{gs} + C_{gd})$

$$\Rightarrow \frac{i_0(j\omega)}{i_i(j\omega)} = \frac{g_m}{j\omega\left(C_{gs} + C_{gd}\right)}$$

$$\text{At } f = f_T, \ \left|i_0/i_i\right| = 1$$

$$\Rightarrow f_T = \frac{g_m}{2\pi\left(C_{gs} + C_{gd}\right)}$$

- ***Remarkable similarity with that for BJT***

- ***Maximum Operable Frequency*** (f_{max}):
  - ***Maximum possible f_T***
  - Noting that $C_{gs} >> C_{gd}$, ***neglecting C_{gst}***, and ***substituting the expressions for C_{gsi} and g_m***:

$$f_{max} = f_T\Big|_{max} = \frac{3\mu_n V_{GT}}{4\pi L^2}$$

  - $f_{max} \propto 1/L^2$
    - ***Thrust towards making L as small as possible***
  - $f_{max} \propto V_{GT}$
    - ***Making V_{GT} large may be detrimental***!

BIASING

- To find the ***DC operating point*** (***bias point***, ***Q-point***)
- Has to ***precede ac analysis***, since ***small-signal parameters depend on the bias point***
- For ***diodes***: (I_D, V_D)
- For ***BJTs***: (I_C, V_{CE})
- For ***MOSFETs***: (I_D, V_{DS})
- Also, $P_D = V_D \times I_D$ (***Diodes***), $V_{CE} \times I_C$ (***BJTs***), and $V_{DS} \times I_D$ (***MOSFETs***)

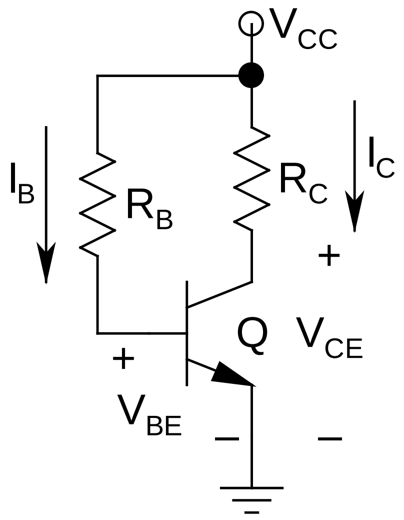
- ***DC power dissipated in a circuit*** = (***Supply Voltage***) × (***Supply Current***)
- Circuits may be ***biased*** by ***single supply*** (***positive/negative and ground***) or ***dual supply*** (***positive and negative***)
- Devices should be ***properly biased*** and ***ideally*** should be under the ***best biasing*** (BB)
- Also, need ***voltage references*** to provide ***fixed DC voltages*** at some ***circuit nodes***

- ***Two types***:
  - ***Discrete Stage Biasing***:
    - Uses ***power supplies*** and ***resistors*** along with the ***active devices***
    - Used for ***discrete circuits*** assembled in ***breadboards***
    - Also known as ***passive biasing***
  - ***IC (Integrated Circuit) Stage Biasing***:
    - ***Avoids resistors*** as much as possible and ***uses transistors*** as ***biasing elements***
    - Used for ***IC stages***
    - Also known as ***active biasing***

Discrete Stage Biasing: BJT

- Will be using ***quick estimate*** ($V_{BE} = 0.7$ V)
- **FA mode of operation** with $V_{CE} \geq 0.2$ V
- ***Error of ±5-10% quite acceptable***
- ***Common Schemes***:
  - ***Fixed Resistor Bias***
  - ***Emitter Feedback Bias***
  - ***Collector Feedback Bias***
  - ***Voltage Divider (or 4-Resistor) Bias***

- ***Fixed Resistor Bias***:
  - $I_B = (V_{CC} - V_{BE})/R_B$
  - $I_C = \beta I_B$
  - $I_E = (\beta + 1)I_B \approx I_C$
  - $V_{CE} = V_{CC} - I_C R_C$
    - For BB, $V_{CE} = V_{CC}/2$
  - P_D (circuit) $= V_{CC} \times I_E$
  - ***Note***: ***Need β to find the operating point***
  - The ***simplest biasing circuit***, but has ***severe β dependence***



- ***Emitter Feedback Bias***:
  - ***While writing KVL, never take CE or BC loops, since V_{CE} and V_{BC} are not known***
  - ***Consider only BE loops with V_{BE} = 0.7 V***
  - $V_{CC} = I_B R_B + V_{BE} + I_E R_E$

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1) R_E}$$