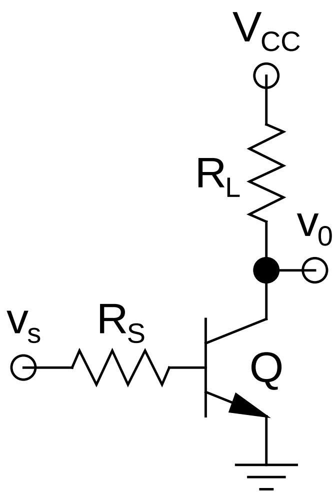
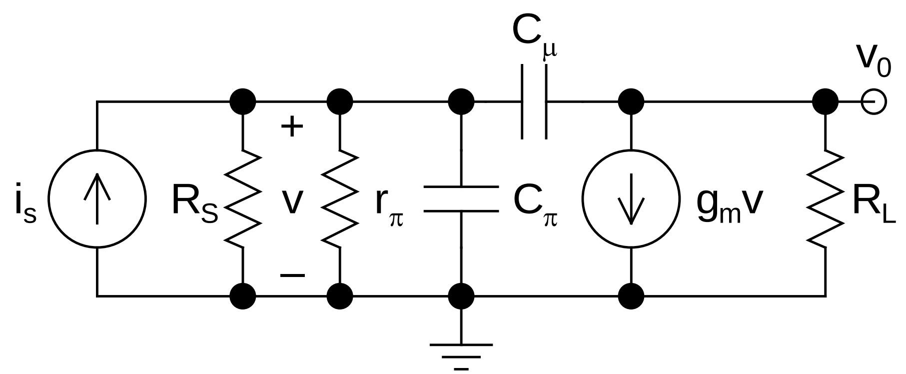
- ***Zero-Value Time Constant (ZVTC) Technique***:
  - ***The easiest one***
  - ***Information regarding only the DP***
  - ***Suppresses information about all other poles and zeros of the system***
  - ***Reasonable accuracy***
  - ***Underestimates f_H slightly*** (***better than overestimating and not achieving it***!)
  - ***Based on heuristic***
  - ***Similar to the IVTC technique***, ***based on an algorithm***

- ***Exact Analysis of a CE Stage*:**



ac Schematic



High-Frequency Equivalent

- ***Biasing circuits omitted for simplicity***
- ***Converted input v_s to its Norton equivalent***

- ***KCL at input node*** (using ***Laplace operator*** s = jω and $R = R_S || r_\pi$):

  $i_s = v/R + sC_\pi v + sC_\mu(v - v_0)$

  $= [1/R + s(C_\pi + C_\mu)]v - sC_\mu v_0$

- ***KCL at output node***:

  $sC_\mu(v_0 - v) + g_m v + v_0/R_L = 0$

$$\Rightarrow v = -\frac{1/R_L + sC_\mu}{g_m - sC_\mu} v_0$$

$$\Rightarrow \frac{v_0}{i_s}(s) = -\frac{R_L R\left(g_m - sC_\mu\right)}{1 + s\left(R_L C_\mu + RC_\mu + RC_\pi + g_m R_L RC_\mu\right) + s^2 R_L RC_\pi C_\mu}$$

- Thus, the ***voltage gain***:

$$A_v(s) = \frac{v_0}{v_s} = -\frac{g_m R_L R}{R_S} \frac{\left(1 - sC_\mu / g_m\right)}{1 + sa + s^2 R_L R C_\pi C_\mu} \qquad (1)$$

$$a = R_L C_\mu + R(C_\pi + C_\mu) + g_m R_L R C_\mu$$

- Hence, the circuit has ***one zero*** and ***two poles***

$$\Rightarrow A_v(s) = A_{v0} \frac{\left(1 - s/z_1\right)}{\left(1 - s/p_1\right)\left(1 - s/p_2\right)} \qquad (2)$$

$$A_{v0} = \textbf{\textit{midband gain}} = -\, g_m R_L R/R_S$$
$$= -\, g_m R_L r_\pi/(r_\pi + R_S)$$

- z_1 (= g_m/C_μ): ***positive real zero***
- The ***frequency*** corresponding to z_1 occurs at $z_1/(2\pi)$, which is ***extremely high***, and generally, is ***not of much consequence***
- ***Computation of the two poles p_1 and p_2 is slightly more tricky***
- From Eqs.(1) and (2), it is obvious that ***both p_1 and p_2 are real and negative***

- To find these, ***write the denominator*** of Eq.(1) as:

$$D(s) = (1 - s/p_1)(1 - s/p_2)$$
$$= 1 - s(1/p_1 + 1/p_2) + s^2/(p_1 p_2) \qquad (3)$$

- ***Matching coefficients*** with Eq.(2), we can get p_1 and p_2, however, the ***resulting algebra*** will become ***extremely tedious***
- Hence, we invoke the ***Dominant Pole Approximation*** (DPA)

- ***DPA***:
  - The ***smallest pole*** [***Dominant Pole*** (DP)] is ***at least 10 times away from its nearest pole***
  - This is an ***excellent approximation for practical analog circuits***
- ***Apply this approximation*** and ***assume p_1 to be the DP*** and ***at least 10 times away from p_2*** [***Non-Dominant Pole*** (NDP)]
- The ***pole frequencies*** are $|p_1|/(2\pi)$ and $|p_2|/(2\pi)$
- ***Note***: $|p_1|/(2\pi)$ is the ***Upper Cutoff Frequency*** (f_H)