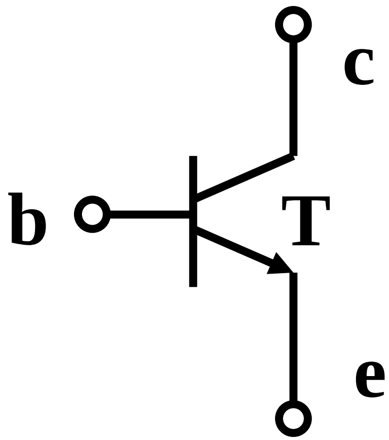
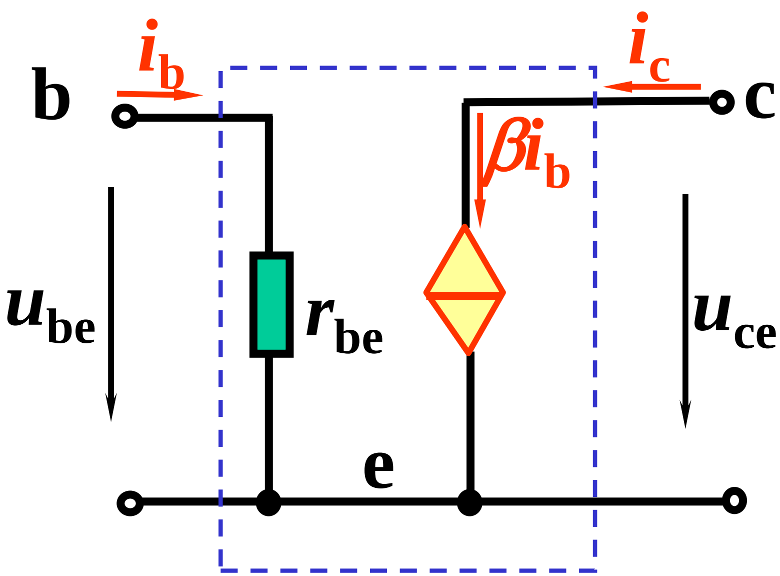
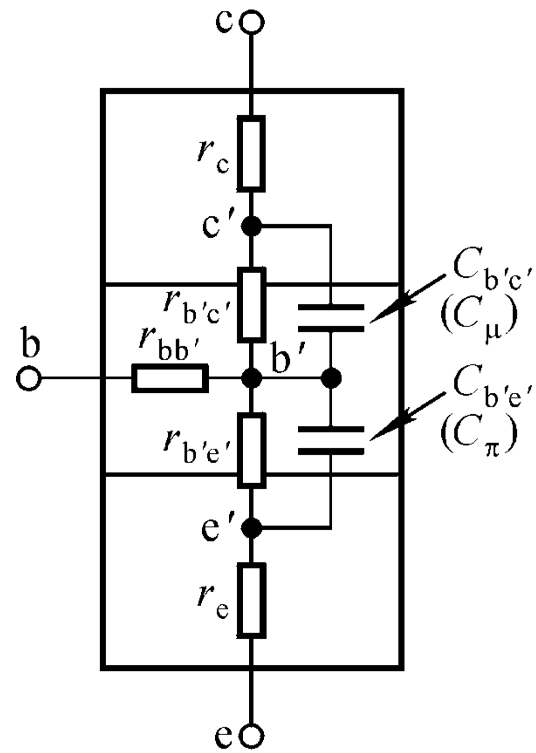
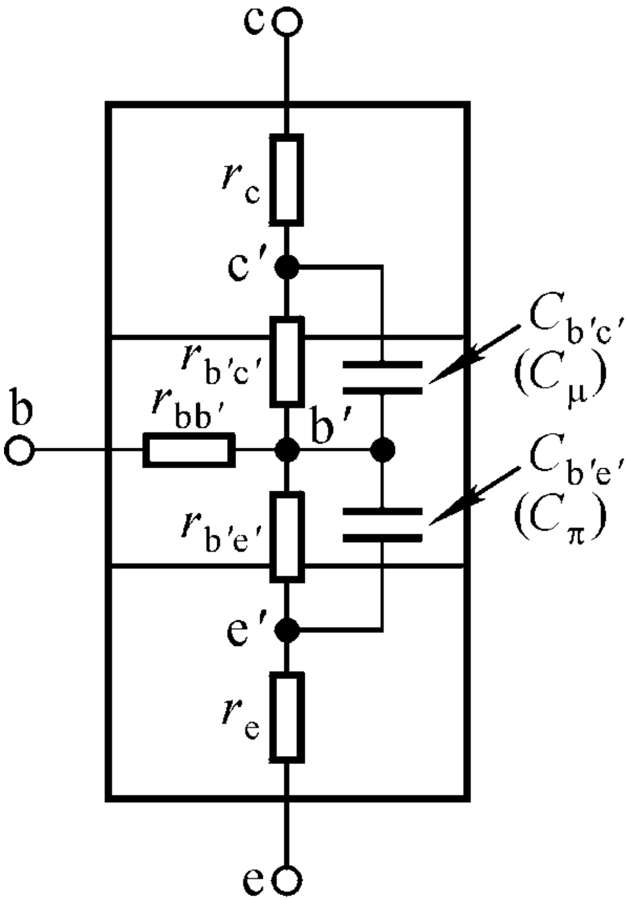
4.2 晶体管的高频等效模型

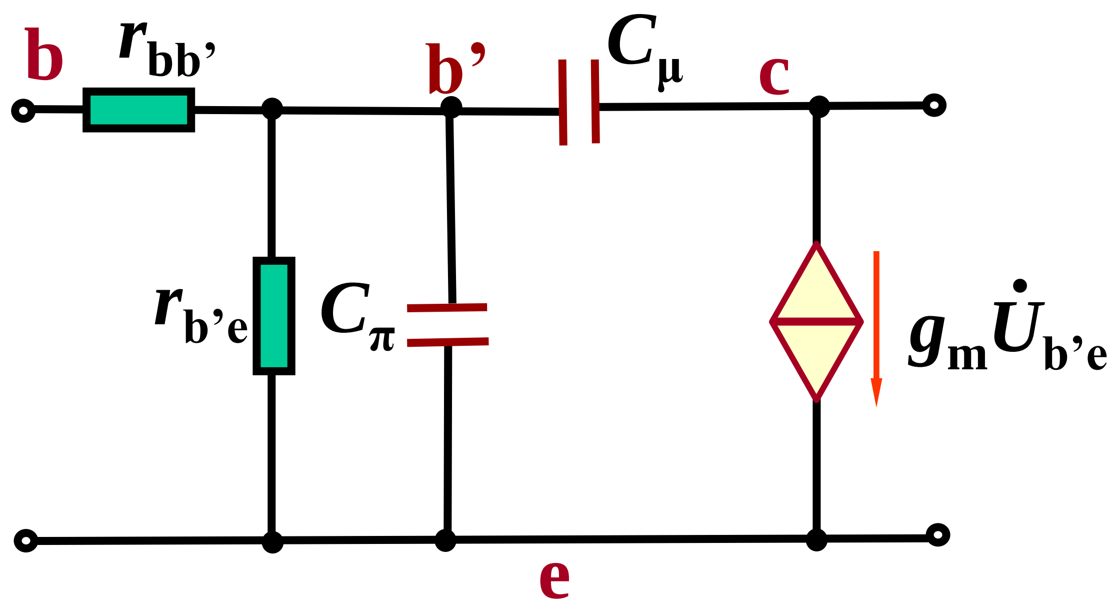






4.2 晶体管的高频等效模型





g_m为跨导，不随信号频率的化而变化

$$r_{be} = r_{bb'} + (1+\beta)\frac{U_T}{I_E} = r_{bb'} + r_{b'e}$$

4.2 晶体管的高频等效模型

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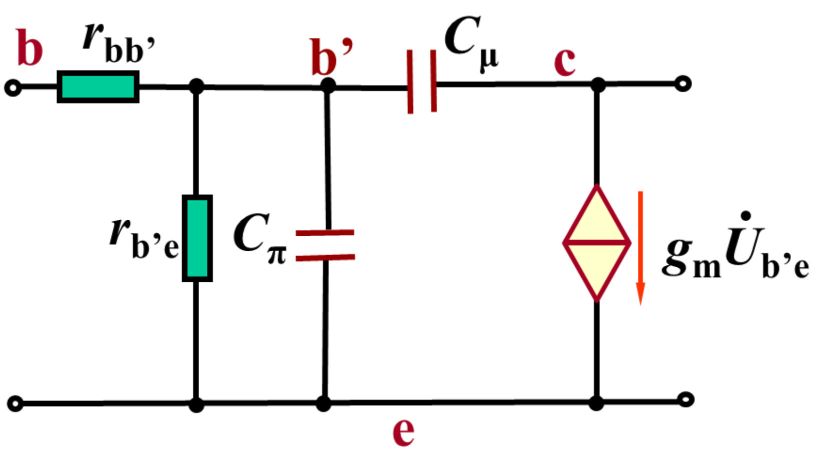

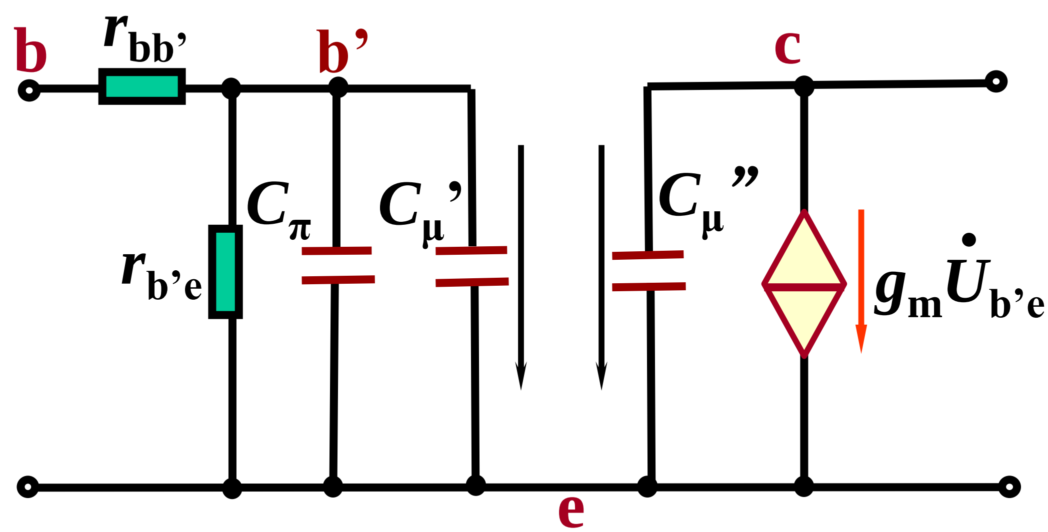

$$\frac{\dot{U}_{b'e}}{\frac{1}{j\omega C_\mu'}} = \frac{\dot{U}_{b'e} - \dot{U}_{ce}}{\frac{1}{j\omega C_\mu}}$$

$$C_\mu(\dot{U}_{b'e} - \dot{U}_{ce}) = C_\mu' \dot{U}_{b'e}$$

令 $K = \dfrac{\dot{U}_{ce}}{\dot{U}_{b'e}}$

$C_\mu' = (1-K)C_\mu$　　密勒效应

$C_\mu'' = \dfrac{K-1}{K}C_\mu$　　电容小，容抗大可忽略

4.2 晶体管的高频等效模型

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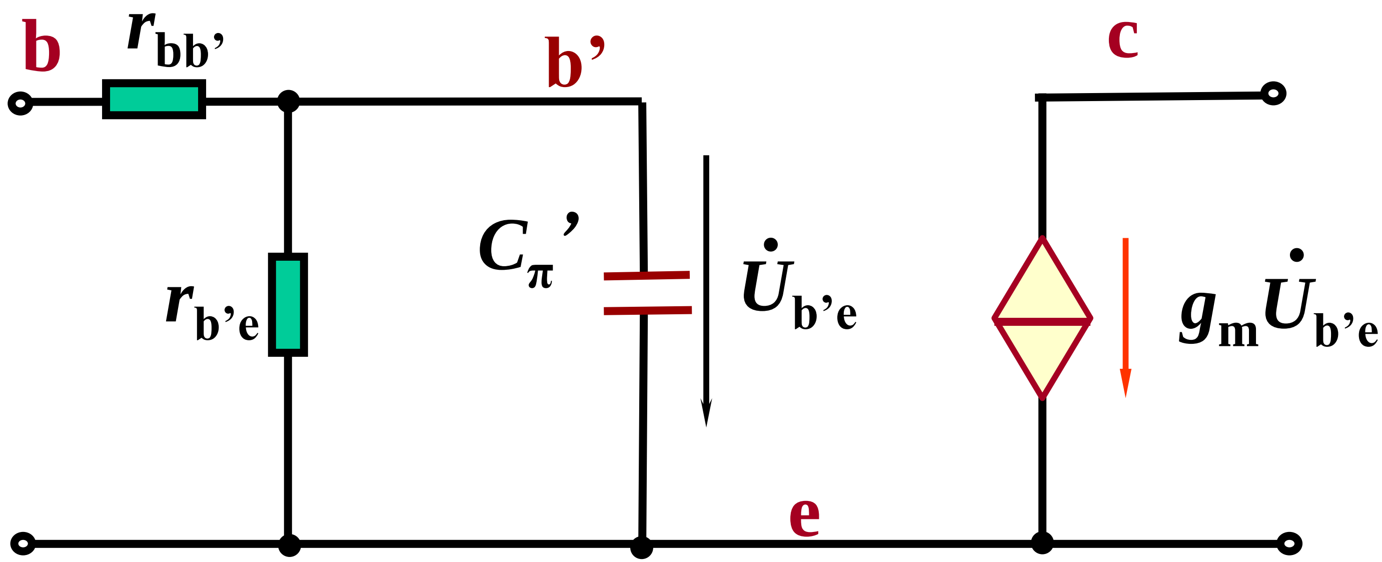
高频下简化三极管等效电路



$r_{bb'}$ 查手册

$$r_{b'e} = (1+\beta_0)\frac{U_T}{I_{EQ}}$$

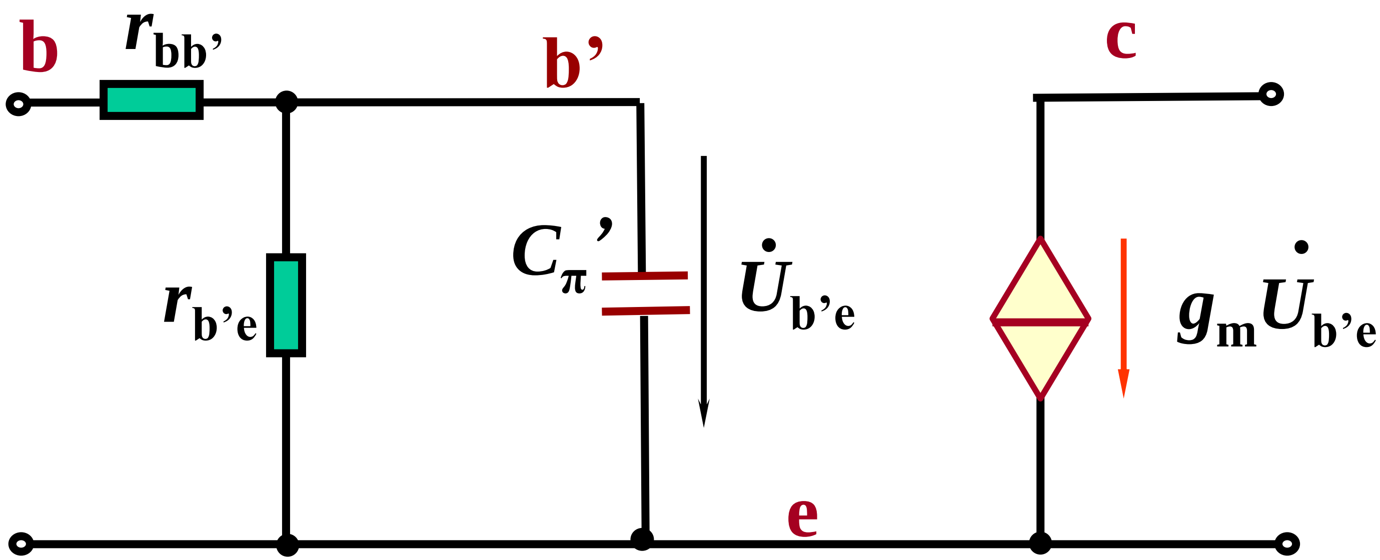
$$C_{\pi}' = C_{\pi} + C_{\mu}'$$

$$C_{\mu}' = (1-K)C_{\mu}$$

C_{μ}近似为C_{Ob}:查手册

C_{π}, g_m ？

g_m的求解

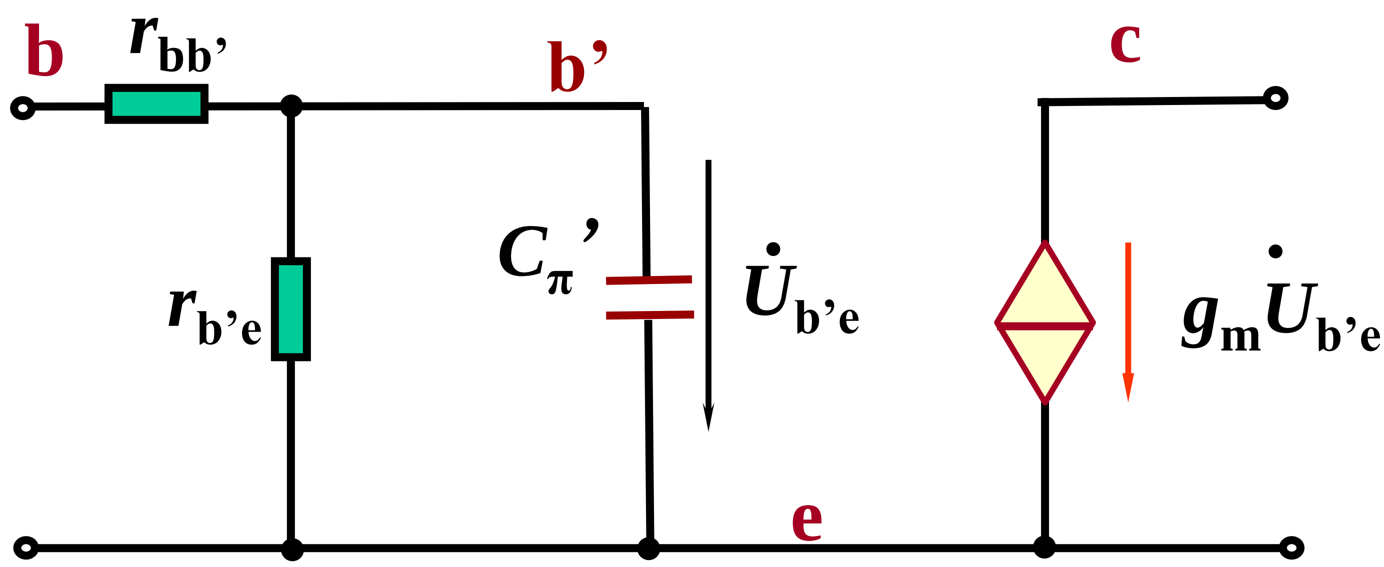


低频段 $\beta_0 \dot{I}_b = g_m \dot{U}_{b'e}$

$$g_m = \beta_0 \frac{\dot{I}_b}{\dot{U}_{b'e}} = \beta_0 \frac{1}{r_{b'e}} = \frac{\beta_0}{(1+\beta_0)\dfrac{U_T}{I_E}} \approx \frac{I_E}{U_T}$$

4.2 晶体管的高频等效模型

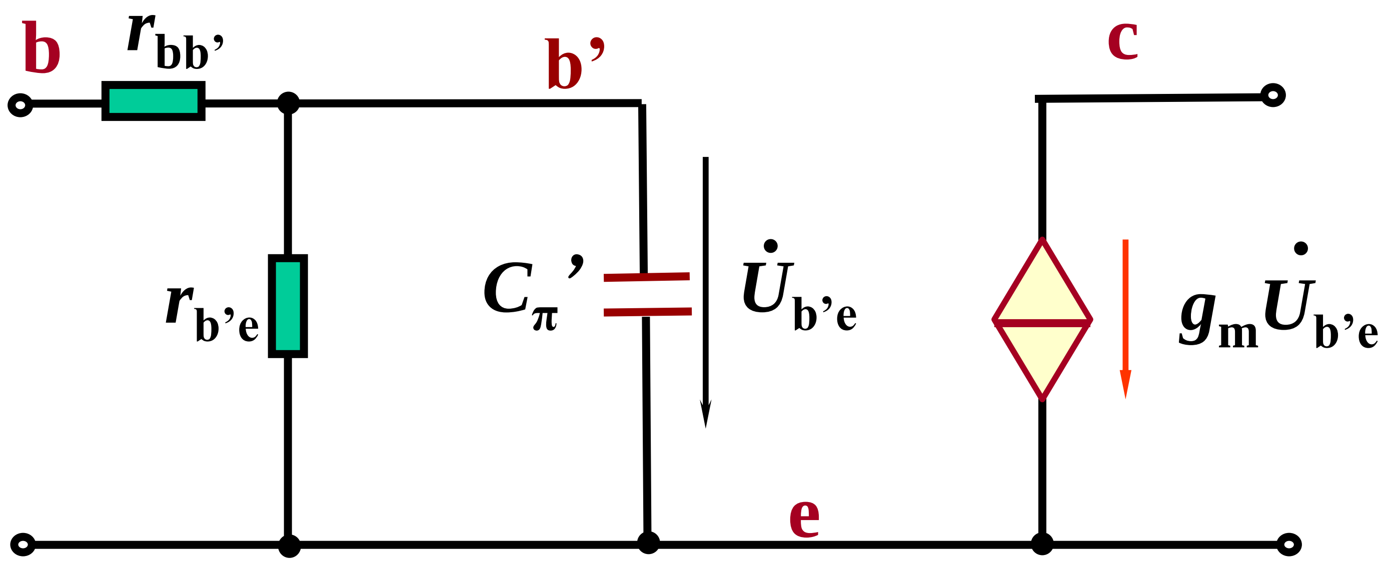
C_π的求解



高频段　求$\beta(f)$，然后求C_π

根据定义 $\beta(f)=\left.\dfrac{\dot{I}_c}{\dot{I}_b}\right|_{U_{CE}=\text{常数}}$ $\Rightarrow$ $\dot{U}_{ce}=0$

4.2 晶体管的高频等效模型



$$\beta(f)=\frac{\dot{I}_c}{\dot{I}_b}=\frac{g_m\dot{U}_{b'e}}{\dfrac{\dot{U}_{b'e}}{r_{b'e}}+\dfrac{\dot{U}_{b'e}}{\dfrac{1}{j\omega C_\pi'}}}=\frac{g_m r_{b'e}}{1+j\omega r_{b'e}C_\pi'}=\frac{\beta_0}{1+j\omega r_{b'e}C_\pi'}$$

令

$$f_\beta=\frac{1}{2\pi r_{b'e}C_\pi'}$$

$$\beta(f)=\frac{\beta_0}{1+j\omega r_{b'e}C_\pi'}=\frac{\beta_0}{1+j\dfrac{\omega}{\omega_\beta}}=\frac{\beta_0}{1+j\dfrac{f}{f_\beta}}$$

4.2 晶体管的高频等效模型

$$\beta(f) = \frac{\beta_0}{1 + j\dfrac{f}{f_\beta}}$$

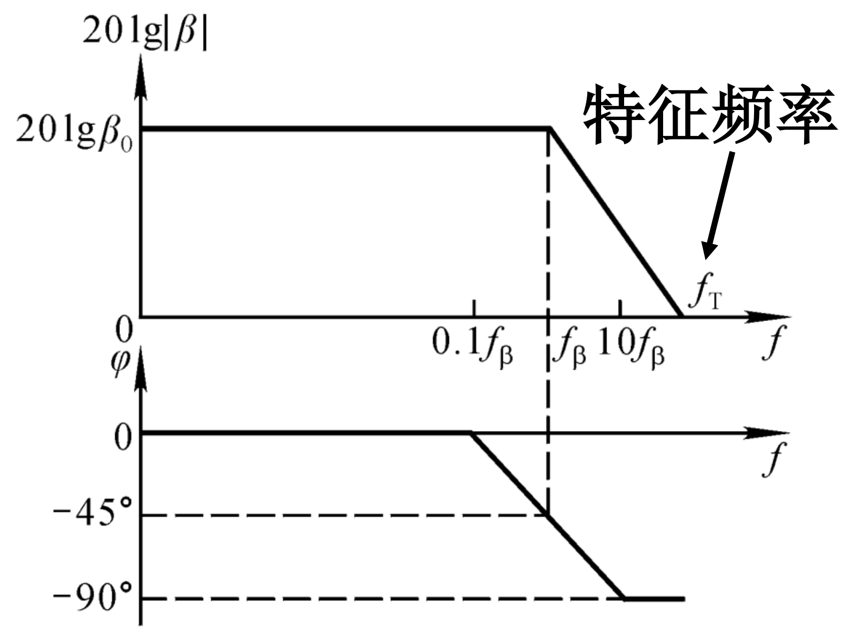
$$f_\beta = \frac{1}{2\pi r_{b'e} C_\pi'}$$ 共射截止频率 手册

当 $f=0$时 $\beta = \beta_0$ $\varphi=0$

当 $f = f_\beta$时

$$\beta = \frac{1}{\sqrt{2}}\beta_0 \approx 0.707\beta_0 \qquad \varphi=45^o$$

当 $f >> f_\beta$时 $\beta \to 0$ $\varphi \to 90^o$



4.2 晶体管的高频等效模型

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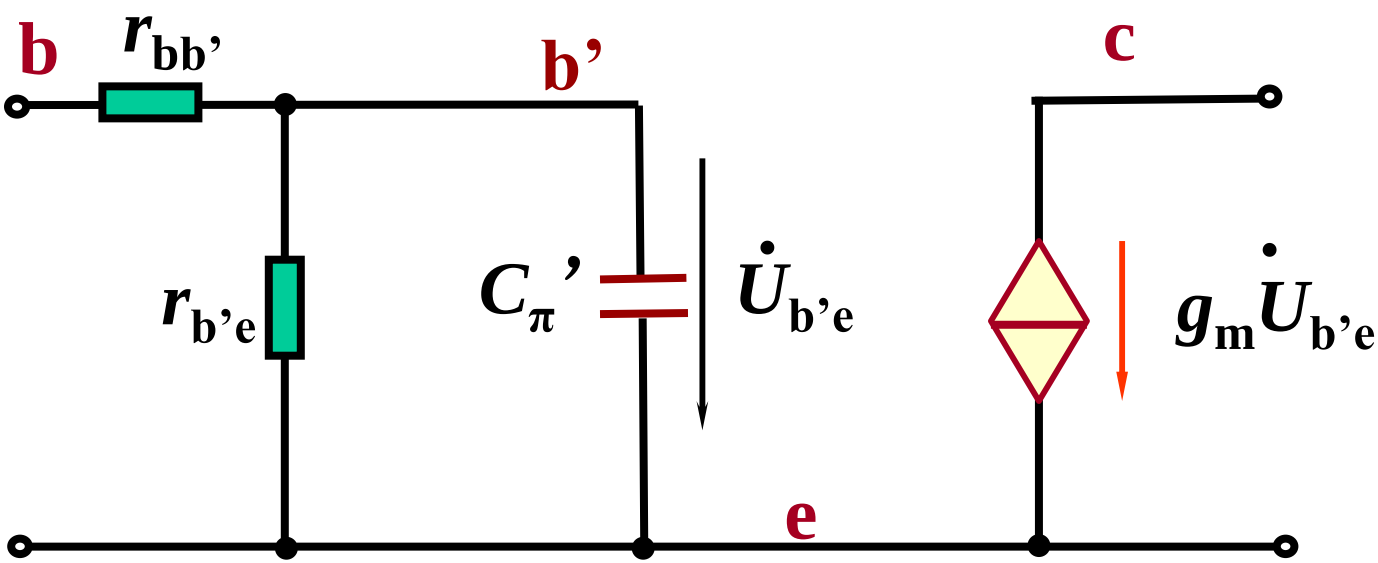


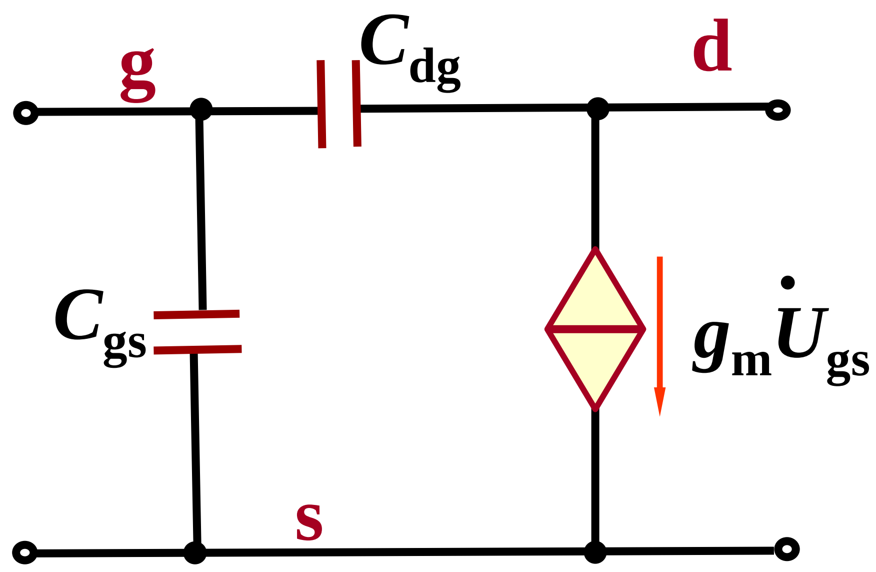
$$f_\beta = \frac{1}{2\pi r_{b'e} C_\pi'}$$

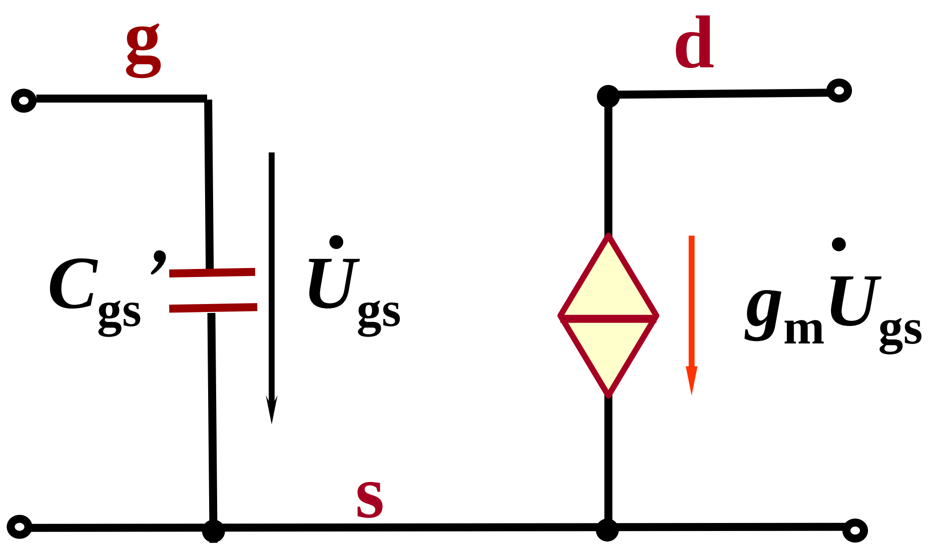
$$C_\pi' = C_\pi + C_\mu'$$

$$C_\mu' = C_\mu(1-K) \qquad K = \frac{\dot{U}_{ce}}{\dot{U}_{b'e}} \qquad \dot{U}_{ce}=0 \Rightarrow K=0 \Rightarrow C_\mu' = C_\mu$$

$$f_\beta = \frac{1}{2\pi r_{b'e}(\boxed{C_\pi} + C_\mu)}$$

4.3 场效应管的高频等效模型

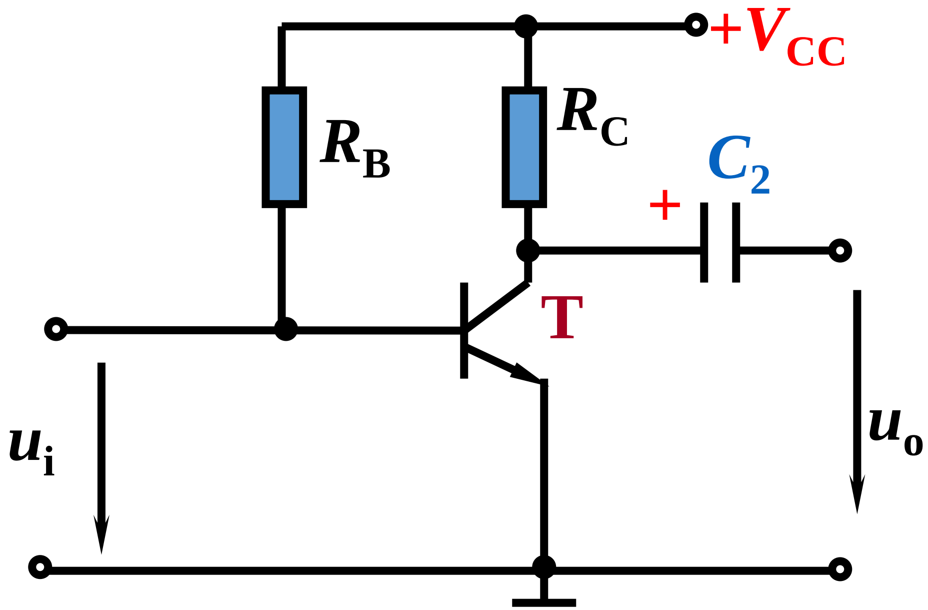


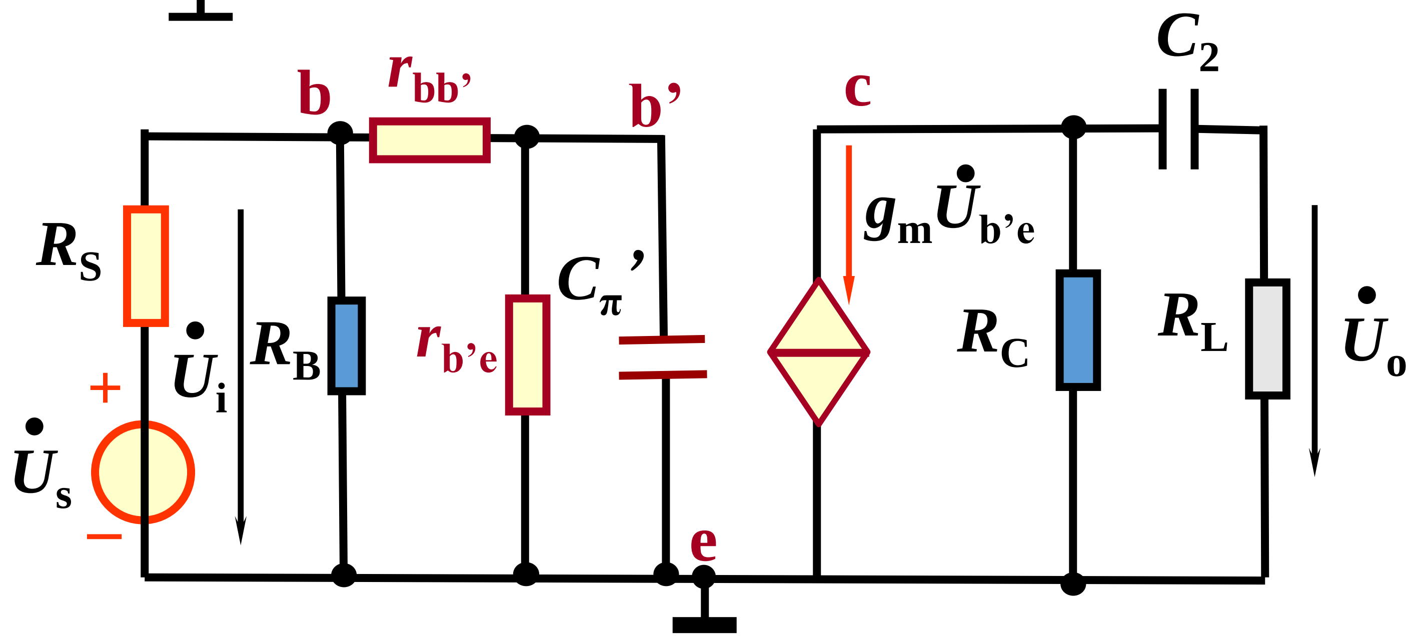


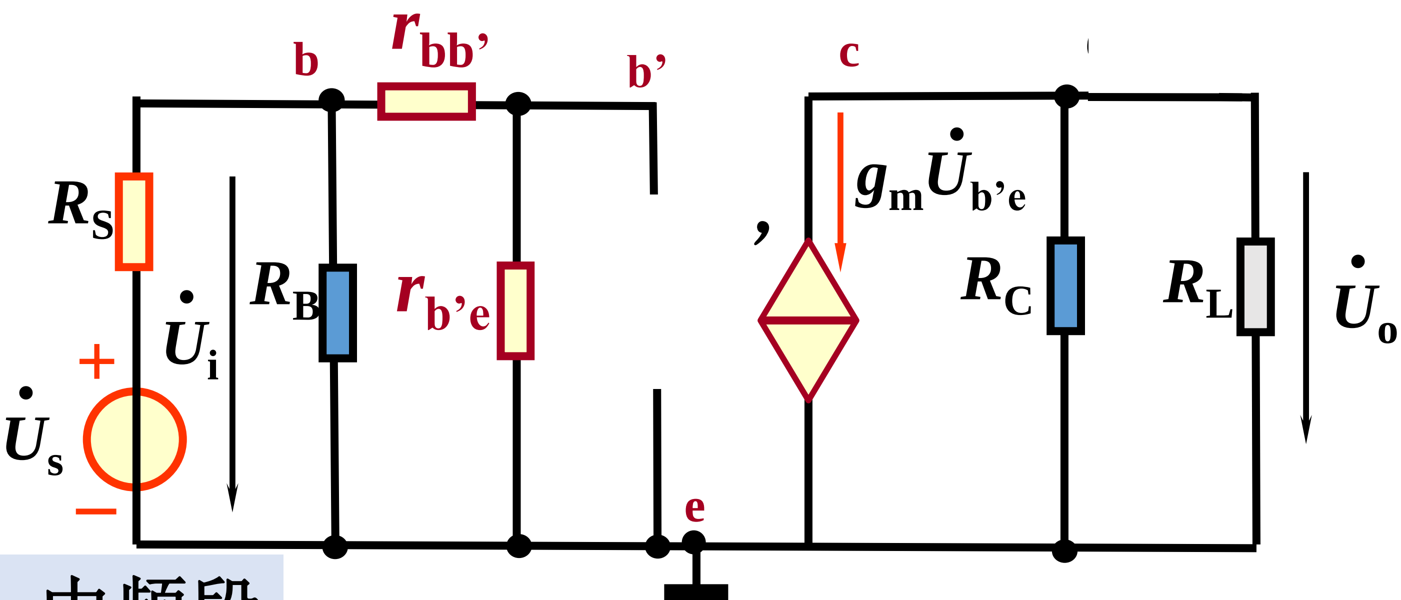
$$K \approx -g_m R_L'$$

$$C_{gs}' = C_{gs} + (1-K)C_{gd}$$

4.4 单管放大电路的频率响应



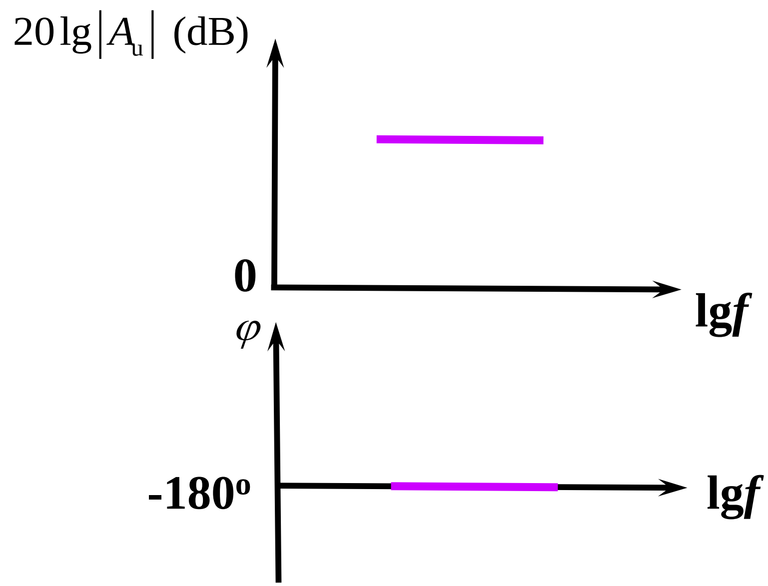




一、中频段

$$A_{um}=\frac{\dot{U}_o}{\dot{U}_i}=\frac{-g_m\dot{U}_{b'e}(R_C//R_L)}{\dot{U}_{b'e}\left(\frac{r_{be}}{r_{b'e}}\right)}$$

$$=-g_m\frac{r_{b'e}\;R_C//R_L}{r_{be}}=-\beta_0\frac{R_C//R_L}{r_{be}}$$



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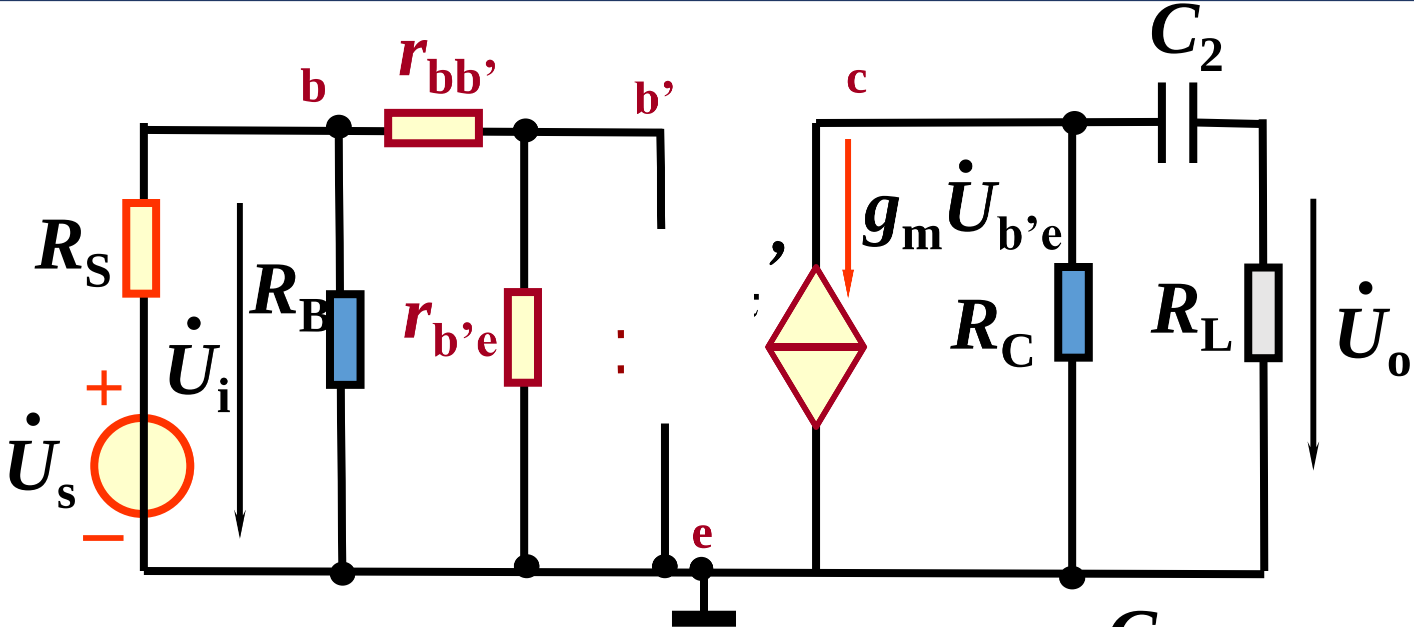
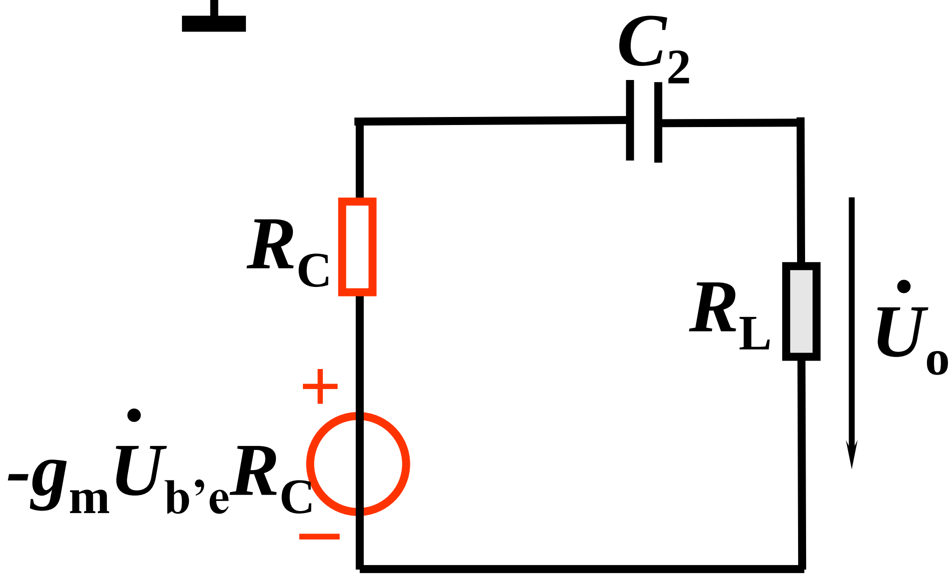
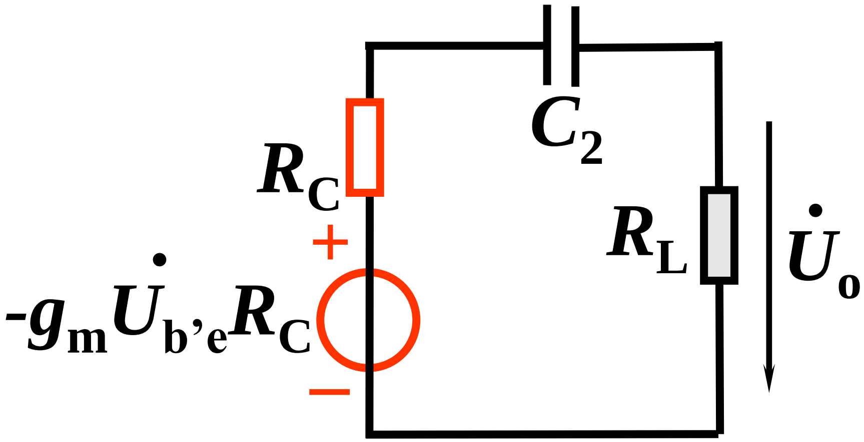


二、低频段



4.4 单管放大电路的频率响应



$$\dot{U}_o = -g_m \dot{U}_{b'e} R_C \frac{R_L}{R_C + R_L + \frac{1}{j\omega C_2}}$$

$$= -g_m \frac{r_{b'e}}{r_{be}} \frac{R_C R_L}{R_C + R_L + \frac{1}{j\omega C_2}} \dot{U}_i$$

$$= -g_m \frac{r_{b'e}}{r_{be}} \frac{R_C // R_L}{1 + \frac{1}{j\omega C_2 (R_C + R_L)}} \dot{U}_i$$

$$A_{uL} = -g_m \frac{r_{b'e}}{r_{be}} \frac{R_C // R_L}{1 + \frac{1}{j\omega C_2 (R_C + R_L)}}$$

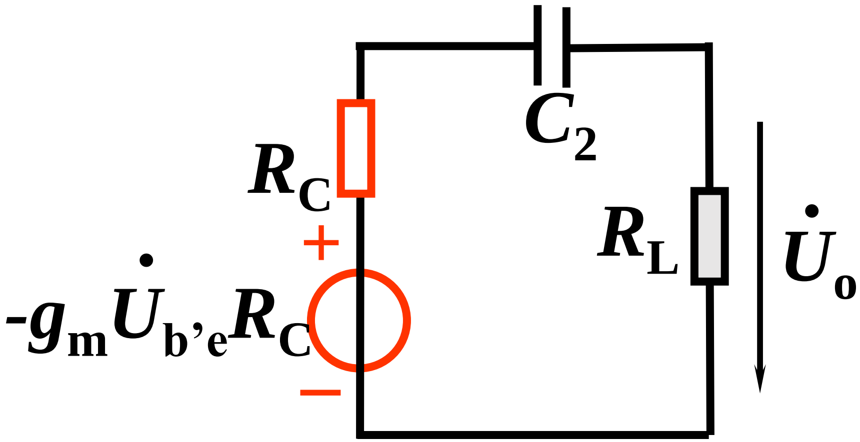
$$A_{um} = \frac{\dot{U}_o}{\dot{U}_i} = -g_m \frac{r_{b'e}\ R_C // R_L}{r_{be}}$$

$$A_{uL} = \frac{A_{um}}{1 + \frac{1}{j\omega C_2 (R_C + R_L)}}$$

令 $f_L = \dfrac{1}{2\pi (R_C + R_L) C_2}$

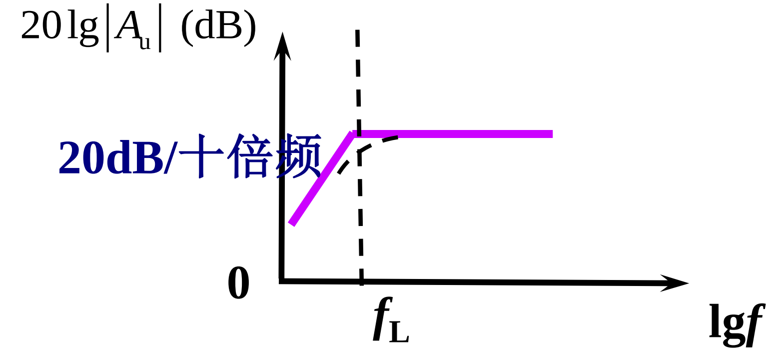
$$\boxed{A_{uL} = A_{um} \bullet \frac{j\frac{f}{f_L}}{1 + j\frac{f}{f_L}}}$$

4.4 单管放大电路的频率响应

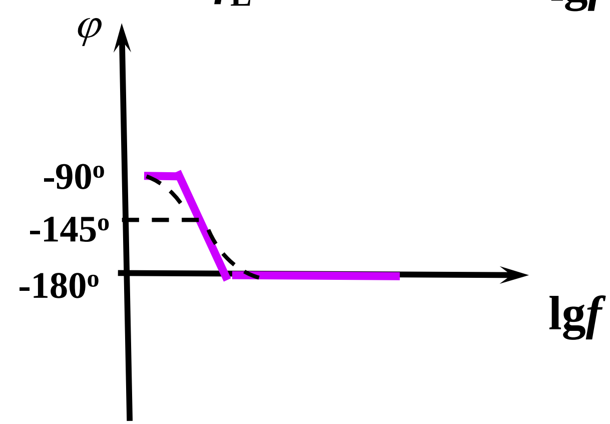


$$\dot{A}_{uL}=\dot{A}_{um}\bullet\frac{j\frac{f}{f_L}}{1+j\frac{f}{f_L}}$$

$$\boxed{f_L=\frac{1}{2\pi(R_C+R_L)C_2}}$$



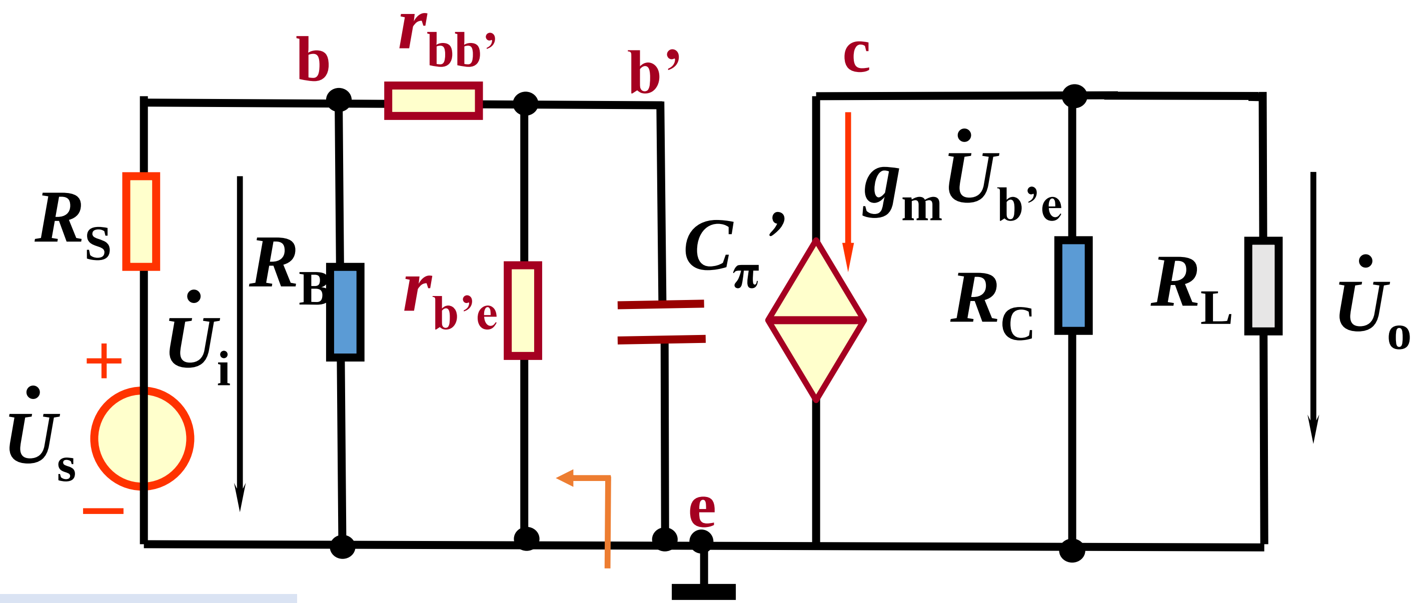
$$|\dot{A}_{uL}|=|\dot{A}_{um}|\bullet\frac{\frac{f}{f_L}}{\sqrt{1+(\frac{f}{f_L})^2}}$$



$$\varphi=-180^o+\boxed{90^o-arctg\frac{f}{f_L}}$$

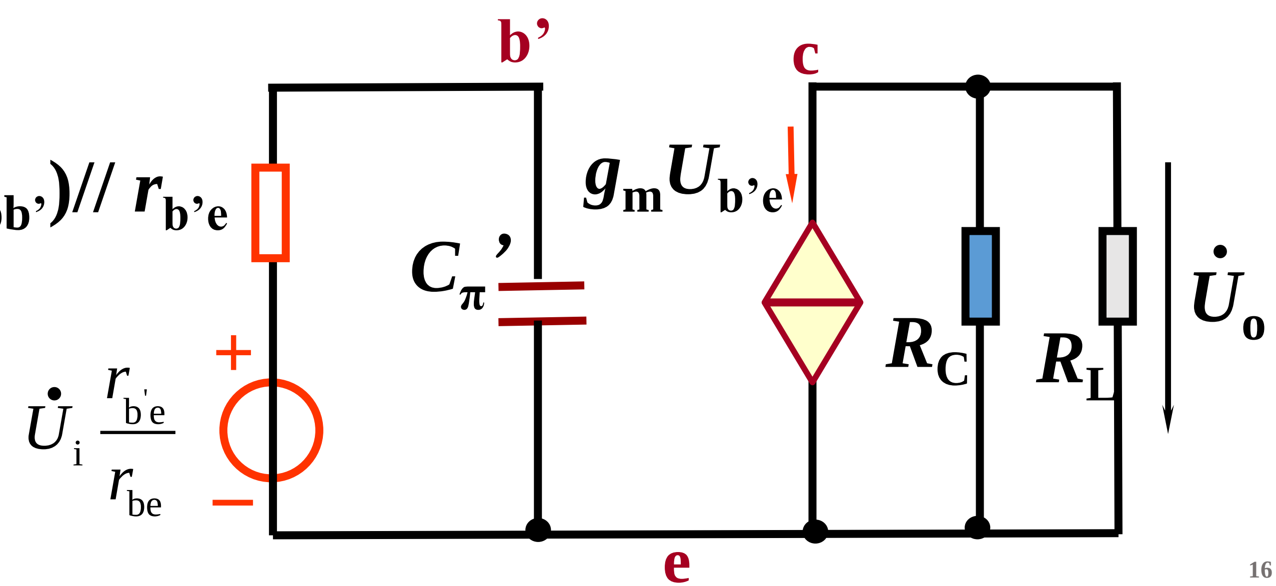
附加相移

4.4 单管放大电路的频率响应



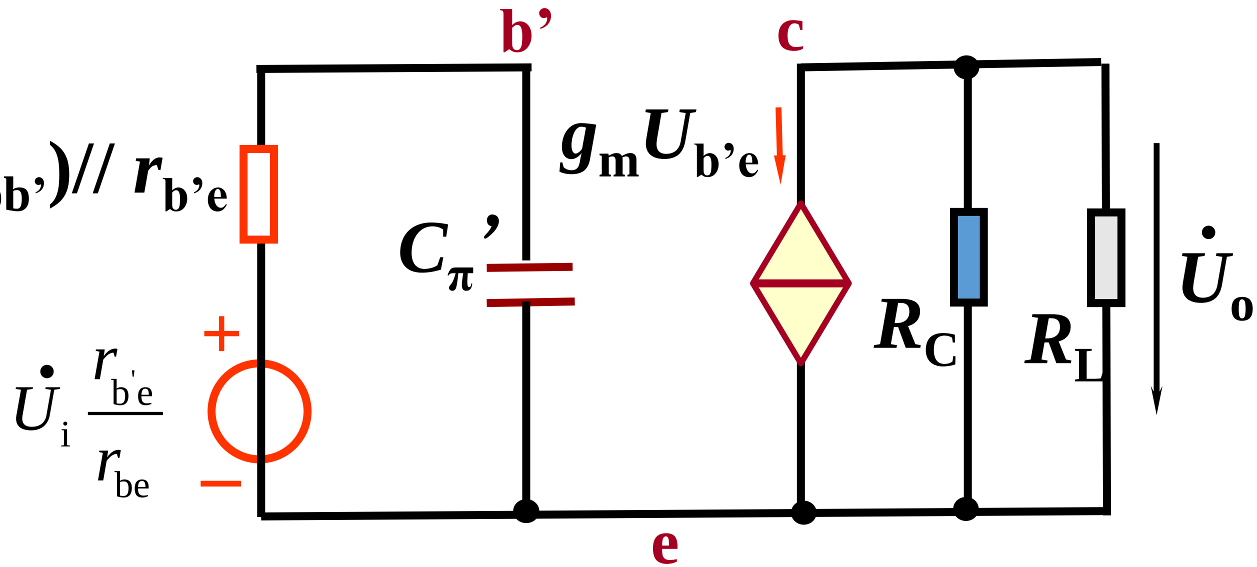
三、高频段

$$R=(R_S//R_{B+}\ r_{bb'})//\ r_{b'e}$$



4.4 单管放大电路的频率响应

$R=(R_S//R_{B+}\ r_{bb'})//\ r_{b'e}$

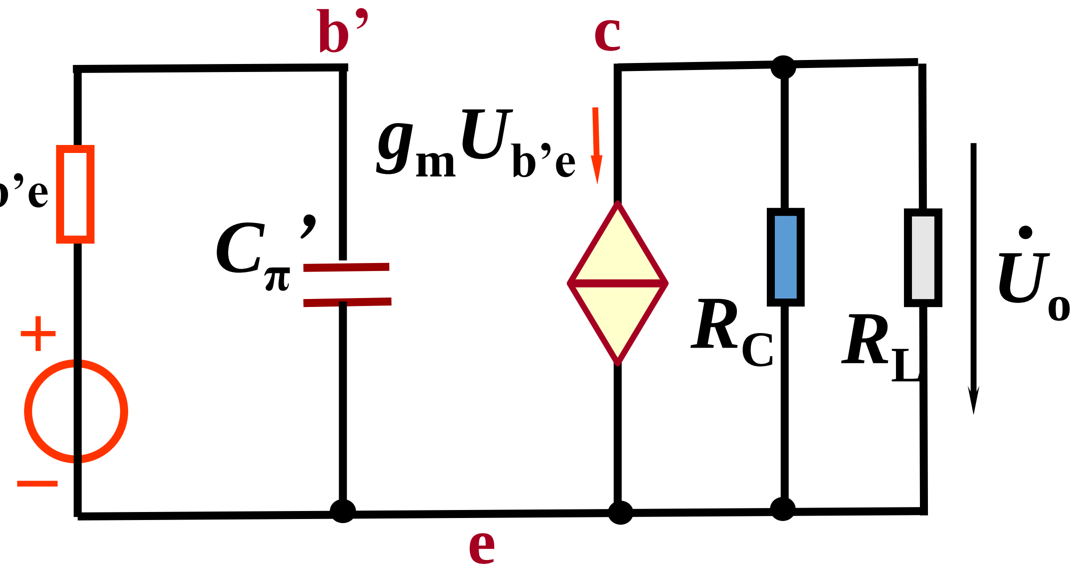


$$\dot{U}_o = -g_m \dot{U}_{b'e}(R_C // R_L)$$

$$A_{uH} = \frac{\dot{U}_o}{\dot{U}_i} = -g_m \frac{r_{b'e}}{r_{be}} \bullet \frac{\frac{1}{j\omega C_\pi'}}{R + \frac{1}{j\omega C_\pi'}} \bullet (R_C // R_L)$$

4.4 单管放大电路的频率响应

$$R=(R_S//R_B+r_{bb'})//r_{b'e}$$



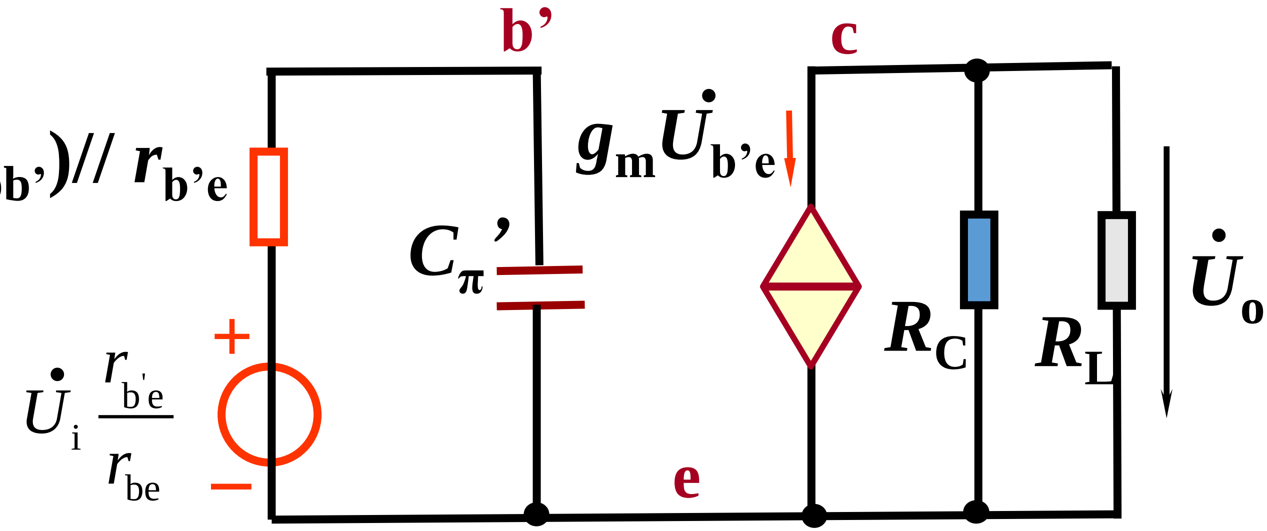
$$\dot{U}_i \frac{r_{b'e}}{r_{be}}$$

$$A_{uH}=\frac{\dot{U}_o}{\dot{U}_i}=-g_m\frac{r_{b'e}}{r_{be}}\bullet\frac{\frac{1}{j\omega C_\pi'}}{R+\frac{1}{j\omega C_\pi'}}\bullet(R_C//R_L)$$

令 $f_H=\dfrac{1}{2\pi R C_\pi'}$

$$A_{uH}=\frac{\dot{U}_o}{\dot{U}_i}=A_{um}\frac{1}{1+j\omega R C_\pi'}=A_{um}\frac{1}{1+j\dfrac{f}{f_H}}$$

R=(R_S//R_{B+} $r_{bb'}$)// $r_{b'e}$

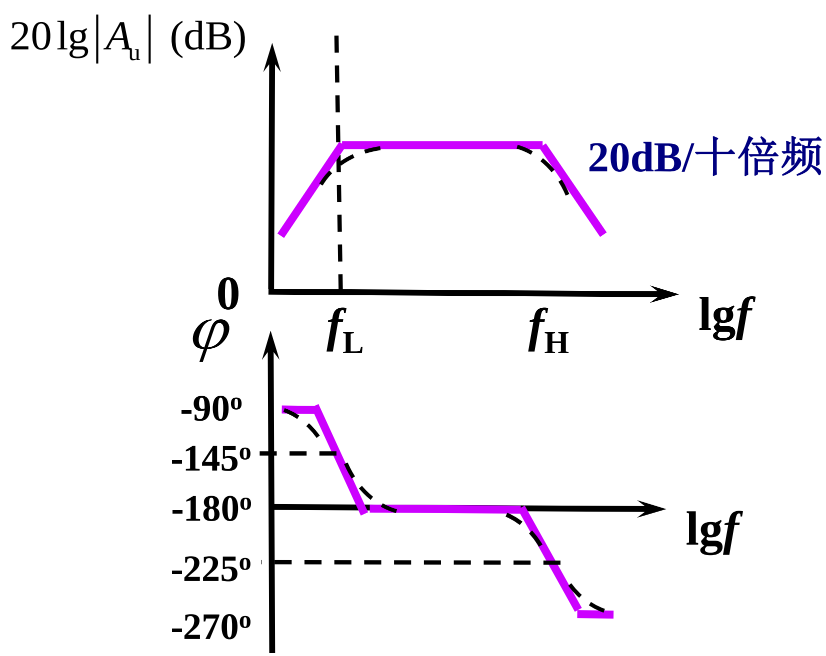


$$A_{uH}=\frac{\dot{U}_o}{\dot{U}_i}=A_{um}\frac{1}{1+j\frac{f}{f_H}}$$

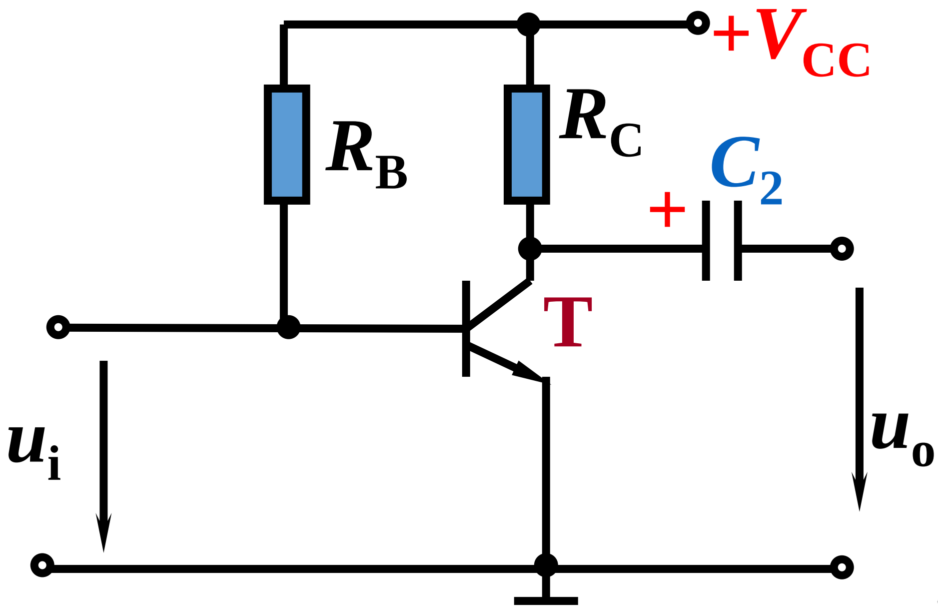
$$f_H=\frac{1}{2\pi RC_\pi'}$$

$$\varphi=-180^o\boxed{-arctg\frac{f}{f_L}}$$

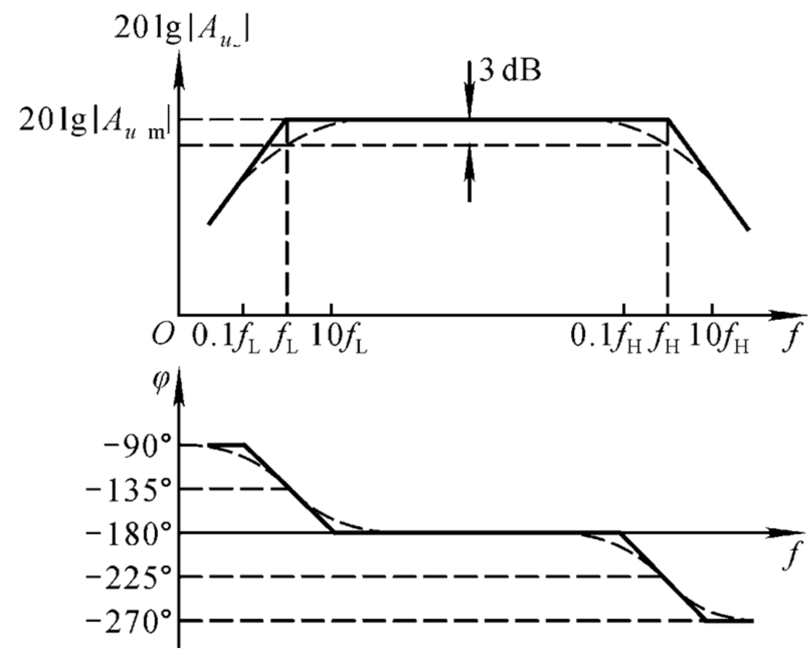
附加相移



4.4 单管放大电路的频率响应



外加耦合电容影响低频特性，极间电容影响高频特性



$$f_{\mathrm{H}}=\frac{1}{2\pi RC_{\pi}'}\qquad f_{\mathrm{L}}=\frac{1}{2\pi(R_{\mathrm{C}}+R_{\mathrm{L}})C_{2}}$$

$$f_{\mathrm{BW}}=f_{\mathrm{H}}-f_{\mathrm{L}}$$

全频段放大倍数

$$\dot{A}_u = \frac{\dot{U}_o}{\dot{U}_i}$$

$$= \dot{A}_{um} \frac{j\dfrac{f}{f_L}}{(1+j\dfrac{f}{f_L})(1+j\dfrac{f}{f_H})}$$