

## 5.7 Frequency response of amplifiers

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 20 marks

**KEY WORDS** coupling capacitor • Miller capacitance • dominant pole

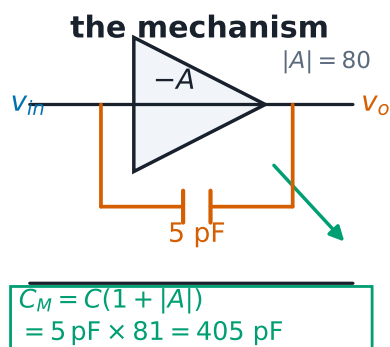
### Objective

Locate low- and high-frequency corners from coupling capacitors and internal poles, apply the Miller multiplication, and compute bandwidth and gain-bandwidth limits – each corner checked against its own RC.

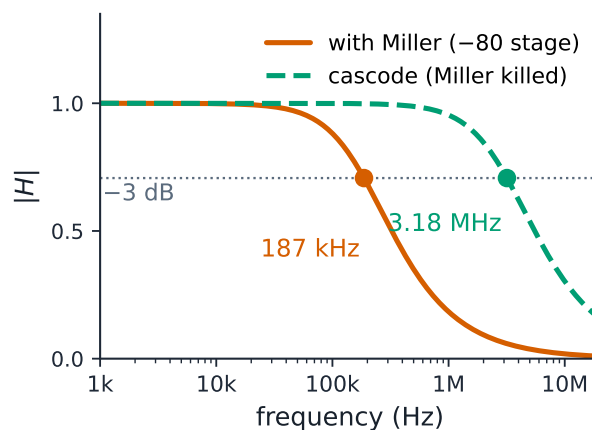
### 1 Key knowledge and worked examples

#### ■ Two families of corner

**Coupling capacitors** (series, between stages) set the LOW corner  $f_L = 1/(2\pi RC)$  per stage – the total low corner is the quadrature sum of stage corners. Internal capacitances set the HIGH corner via the **dominant pole** :  $f_H \approx 1/(2\pi R_{eq} \cdot C_{eq})$  at the input node.



#### what it costs (and the cascode cure: 17×)



*The Miller multiplication and the bandwidth it costs; the cascode reclaims 17×.*

### ■ Worked example: Miller multiplication

A stage with gain  $-80$  has  $C_{gb} = 5pF$  base-to-collector. The input sees the **Miller capacitance**  $C_M = C_{gb}(1 + |A_v|) = 5p \times 81 = 405pF$ . With  $R_{eq} = 2k\Omega$  and 20 pF stray:  $f_H = 1/(2\pi \times 2000 \times 425p) = 187kHz$ . The Miller effect explains why high-gain stages roll off first – and why the cascode (which holds the collector nearly still, killing the gain across  $C_{gb}$ ) extends bandwidth for free.

### ■ Gain-bandwidth closure

For an op-amp stage, once  $f_H$  is known, the **gain-bandwidth product** closes the design: gain  $\times$  bandwidth = constant. A discrete stage's own corners multiply the same way – two cascaded stages each  $-3$  dB at a frequency give  $-6$  dB total there, and the composite  $-3$  dB point is lower than either.

## 2 Practice

**2.1** A coupling capacitor 10  $\mu F$  into a 15  $k\Omega$  input resistance: compute  $f_L$ . [2]

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**2.2** An input node with  $R_{eq} = 4k\Omega$  and  $C_{eq} = 50pF$ : compute  $f_H$ . [2]

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**2.3** A stage of gain  $-50$  has 4 pF across it: compute the Miller capacitance the input sees. [2]

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### 3 Exam-style questions

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**3.1** A single-stage CE amplifier has: input coupling  $2.2\ \mu\text{F}$  into a  $20\ \text{k}\Omega$  total resistance; a bypass capacitor  $47\ \mu\text{F}$  looking into  $R_E \parallel (r_{\pi}/(\beta+1)) \approx 25\ \Omega$ ; and a high-frequency node of  $R_{eq} = 1.5\ \text{k}\Omega$  with  $C_{gb} = 4\ \text{pF}$  at stage gain  $-60$  plus  $25\ \text{pF}$  stray.

Compute each low corner (coupling, bypass) and the high corner (with Miller); state the amplifier's passband edges; and compute the bypass capacitor needed to push ITS corner a decade below the coupling corner. [7]

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**3.2** A two-stage amplifier has each stage at gain  $-40$  with input  $R_{eq} = 2\ \text{k}\Omega$ ,  $C_{gb} = 5\ \text{pF}$ , stray  $20\ \text{pF}$ .

Compute each stage's Miller capacitance and  $f_H$ ; compute the composite  $-3\ \text{dB}$  high corner of the cascade (quadrature combination:  $1/f_{\text{total}}^2 \approx 1/f_1^2 + 1/f_2^2$  for two identical stages – equivalently  $f_{\text{total}} = f_H \cdot \sqrt{2^{\{1/2\}} - 1}^{\{1/2\}} = 0.644\ f_H$ ); and state the gain-bandwidth product of one stage. Verify the composite against the per-stage corner. [7]

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