Electronics 2

Active BPF using BJT

Marwan Bitar / 4110259

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- The Significanse
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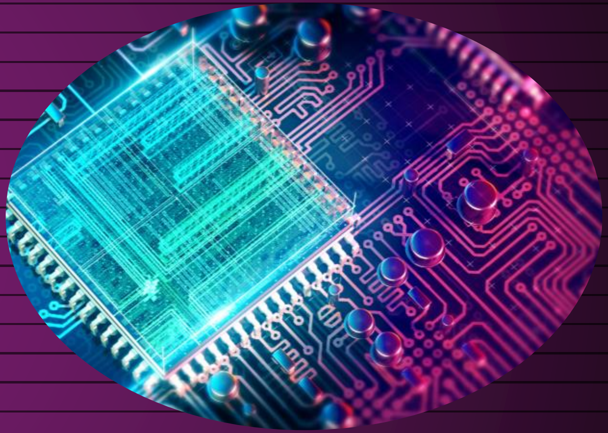
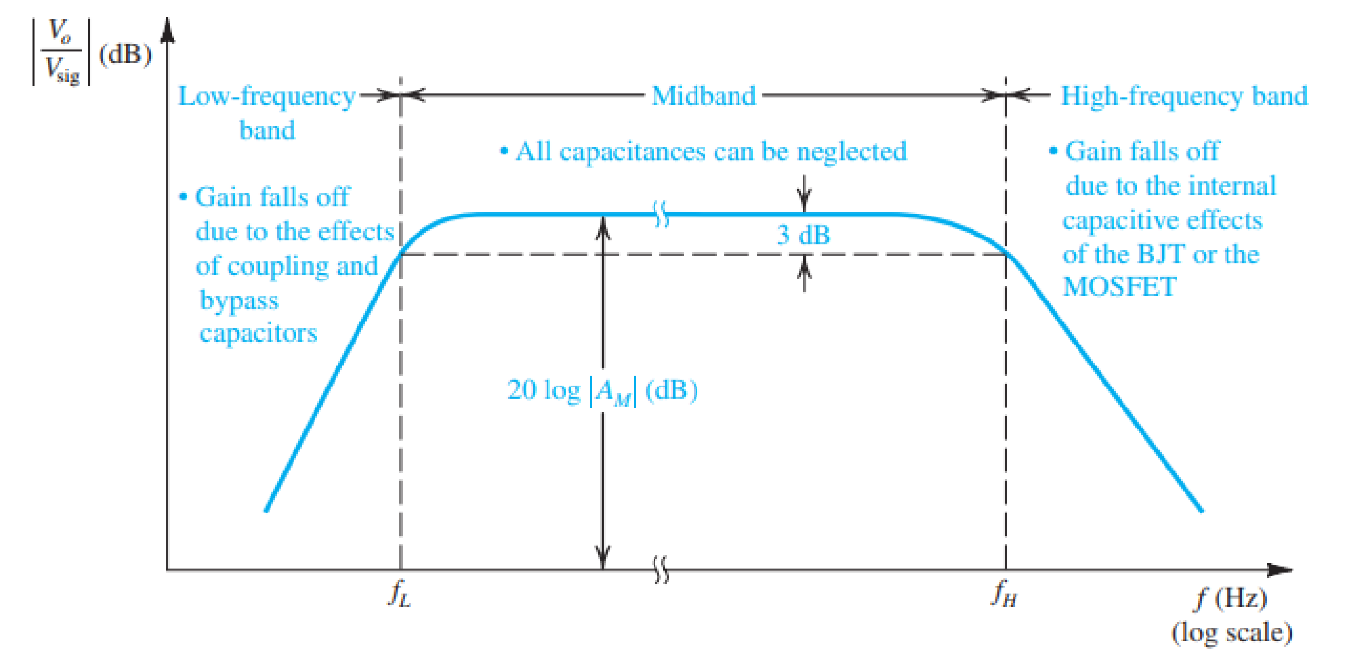


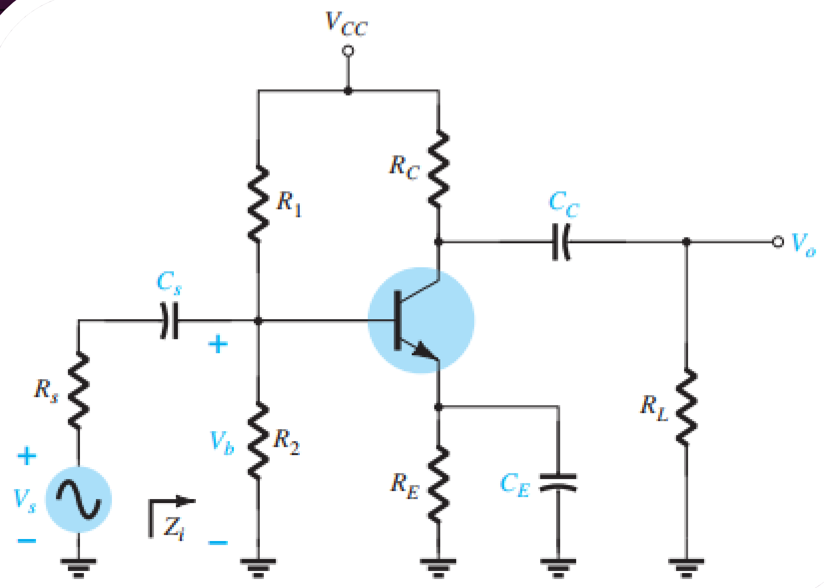
Theory

$$\text{bandwidth (BW)} = f_H - f_L$$

$$f = \frac{1}{2\pi RC}$$



Configuration



Voltage divider common-emitter BJT circuit

Low Frequency Response

Capacitor S

$$f_{L_s} = \frac{1}{2\pi(R_i + R_s)C_s}$$

$$R_i = R_1 \,||\, R_2 \,||\beta_{r_e}$$

Capacitor C

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C}$$

$$R_o = R_C \| r_o$$

Capacitor E

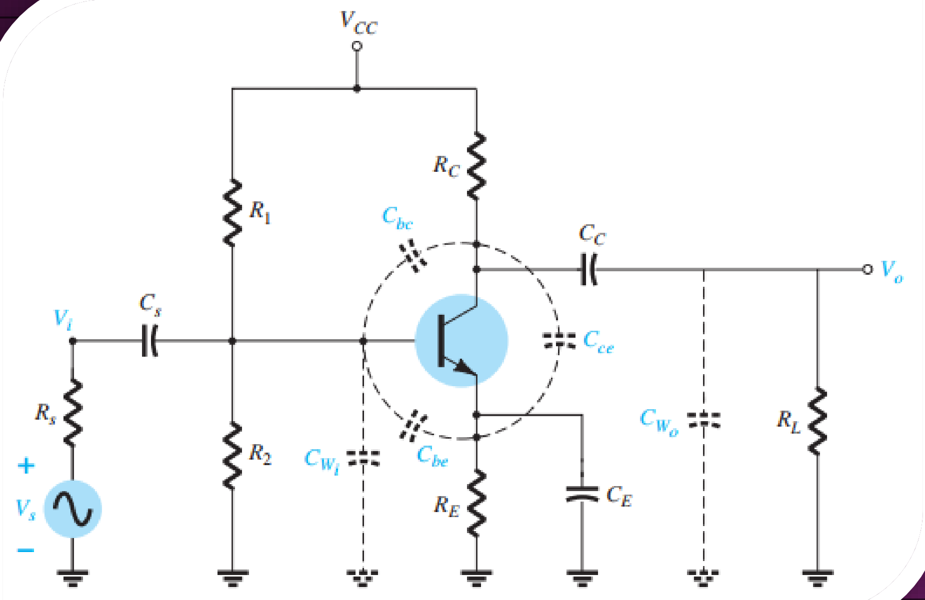
$$f_{L_E} = \frac{1}{2\pi R_e C_E}$$

$$R_e = R_E \| \left(\frac{R_s'}{\beta} + r_e\right)$$

and $R_s' = R_s \| R_1 \| R_2$

$$f_L = \max(f_S, f_C, f_E)$$

Configuration of High Frequency Response



Same BJT configuration with the effect of the output capacitance

High Frequency Response

$$f_{H_i} = \frac{1}{2\pi R_{Th_i} C_i}$$

$$R_{Th_i} = R_s \| R_1 \| R_2 \| \beta r_e$$

$$C_i = C_{W_i} + C_{be} + C_{M_i} = C_{W_i} + C_{be} + (1 - A_v)C_{bc}$$

Capacitance Ci

$f_H = \min(f_{Hi}, f_{Ho})$

Capacitance Co

$$f_{H_o} = \frac{1}{2\pi R_{Th_o} C_o}$$

$$R_{Th_o} = R_C \| R_L \| r_o$$

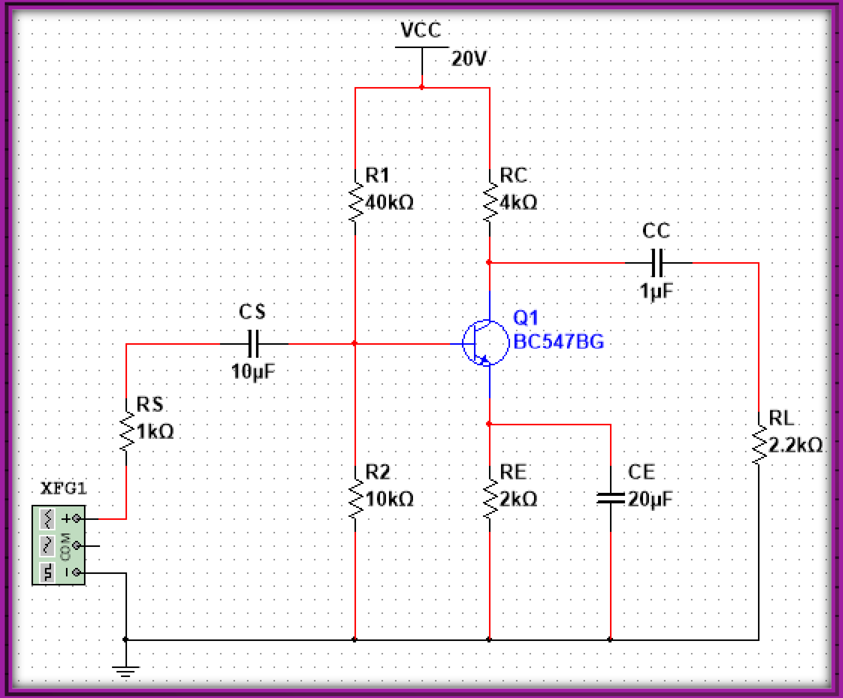
$$C_o = C_{W_o} + C_{ce} + C_{M_o}$$

$$C_o = C_{W_o} + C_{ce} + (1 - 1/A_v)C_{bc}$$

The Gain

- The total gain: $$A_{v_s} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_b}{V_s}$$
- The gain of the amplifier (without the effect of Rs) $$A_v = \frac{V_o}{V_i} = \frac{-R_C \| R_L}{r_e}$$
- The resulted gain: (after adding Rs) $$A_{v_{\text{mid}}} = \frac{\mathbf{V}_b}{\mathbf{V}_s} = \frac{R_i}{R_i + R_s}$$

Implementation



Circuit Simulation

Low Frequency Response

$$f_{L_s} = \frac{1}{2\pi(R_i + R_s)C_s}$$

$$R_i = R_1 \,||\, R_2 \,||\beta_{r_e}$$

Capacitor S

$$V_B \cong \frac{R_2 V_{CC}}{R_2 + R_1} = \frac{10\,\text{k}\Omega(20\,\text{V})}{10\,\text{k}\Omega + 40\,\text{k}\Omega} = \frac{200\,\text{V}}{50} = 4\,\text{V}$$

from (DC analysis)

$$I_E = \frac{V_E}{R_E} = \frac{4\,\text{V} - 0.7\,\text{V}}{2\,\text{k}\Omega} = \frac{3.3\,\text{V}}{2\,\text{k}\Omega} = 1.65\,\text{mA}$$

$$r_e = \frac{26\,\text{mV}}{1.65\,\text{mA}} \cong \mathbf{15.76\,\Omega}$$, $$\beta r_e = 120*15.76 = 1.891\text{ k}\Omega$$

$$R_i = R_1 \| R_2 \| \beta r_e = 10\text{k}//40\text{k}//1.891\text{k} = 1.529\text{ k}\Omega$$

$$f_{Ls} = \frac{1}{2\pi(1.529k+1k)10\mu} = \mathbf{6.29\ Hz}$$

Low Frequency Response

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C}$$

$$R_o = R_C \| r_o$$

Capacitor C

Using the following equations:

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C} \quad \text{with} \quad R_o = R_C \| r_o \cong R_C$$

Because r_O = 1 GΩ $\cong \infty$

$$f_{L_C} = \frac{1}{2\pi(R_o + R_L)C_C} = \frac{1}{2\pi(4k + 2.2k)1\mu} = \mathbf{25.67\,Hz}$$

Low Frequency Response

$$f_{L_E} = \frac{1}{2\pi R_e C_E}$$

$$R_e = R_E \| \left(\frac{R'_s}{\beta} + r_e\right)$$

and $R'_s = R_s \| R_1 \| R_2$

Capacitor E

$$f_{L_E} = \frac{1}{2\pi R_e C_E}, \quad R_e = R_E \| \left(\frac{R'_s}{\beta} + r_e\right) \text{ and } R'_s = R_s \| R_1 \| R_2$$

Rs' = 889 Ω, R_e = 24 Ω

$$f_{LE} = \frac{1}{2\pi(24)20\mu} = 331.57\ Hz$$

$f_L = \max(f_S, f_C, f_E) = 331.57$ Hz

High Frequency Response

$$f_{H_i} = \frac{1}{2\pi R_{\mathrm{Th}_i} C_i}$$

$$R_{\mathrm{Th}_i} = R_s \| R_1 \| R_2 \| \beta r_e$$

$$C_i = C_{W_i} + C_{be} + C_{M_i} = C_{W_i} + C_{be} + (1 - A_v)C_{bc}$$

Capacitance Ci

R_{Thi} = 605 Ω, C_i = 10 pF, $f_{Hi} = \frac{1}{2\pi(677)10p} = 26.31\ MHz$

High Frequency Response

$$f_{H_o} = \frac{1}{2\pi R_{Th_o} C_o}$$

$$R_{Th_o} = R_C \| R_L \| r_o$$

$$C_o = C_{W_o} + C_{ce} + C_{M_o}$$

$$C_o = C_{W_o} + C_{ce} + (1 - 1/A_v)C_{bc}$$

Capacitance Co

R_{Tho} = 1419 Ω (taking r_o = 1 GΩ $\cong \infty$), C_o = 1.7 pF, $f_{Ho} = \frac{1}{2\pi(1419)1.7p} = 65.98\ MHz$

$f_H = \min(f_{Hi}, f_{Ho})$ = 26.31 MHz

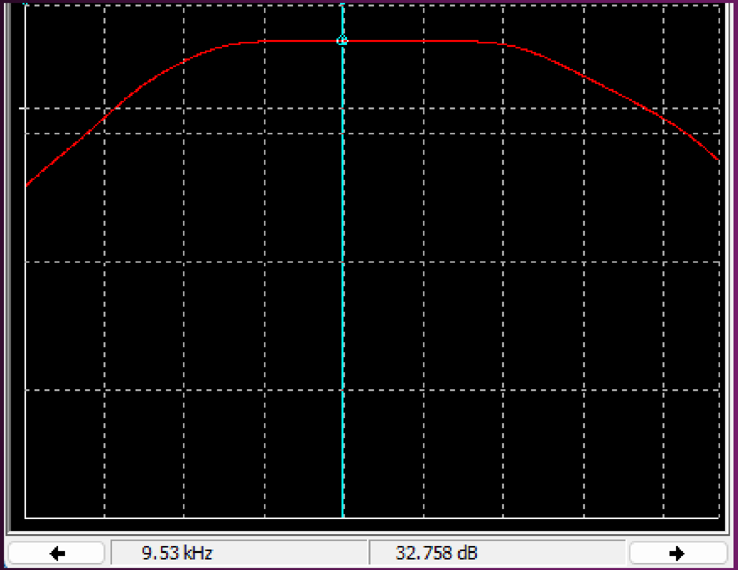
The Gain

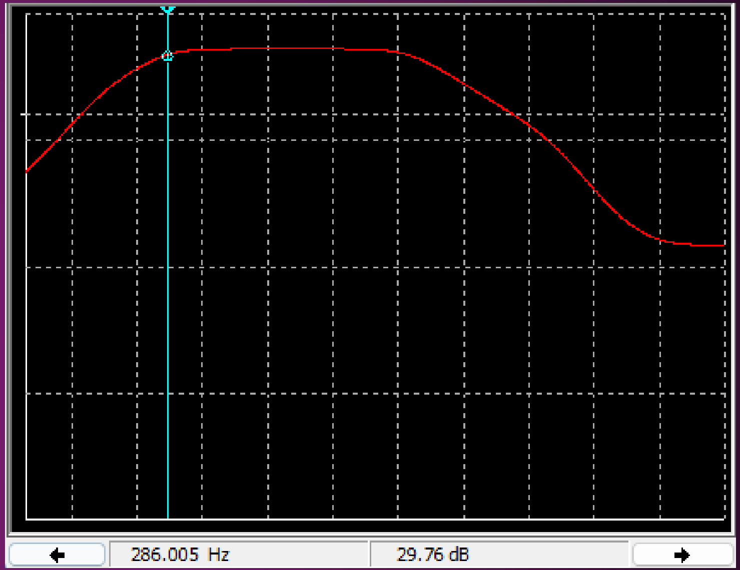
$$A_v = \frac{V_o}{V_i} = \frac{-R_C \| R_L}{r_e} = \frac{-1419}{15.76} = -90.04$$

$$A_{v_{\mathrm{mid}}} = \frac{\mathbf{V}_b}{\mathbf{V}_s} = \frac{R_i}{R_i + R_s} = \frac{1529}{1529 + 1000} = 0.60$$

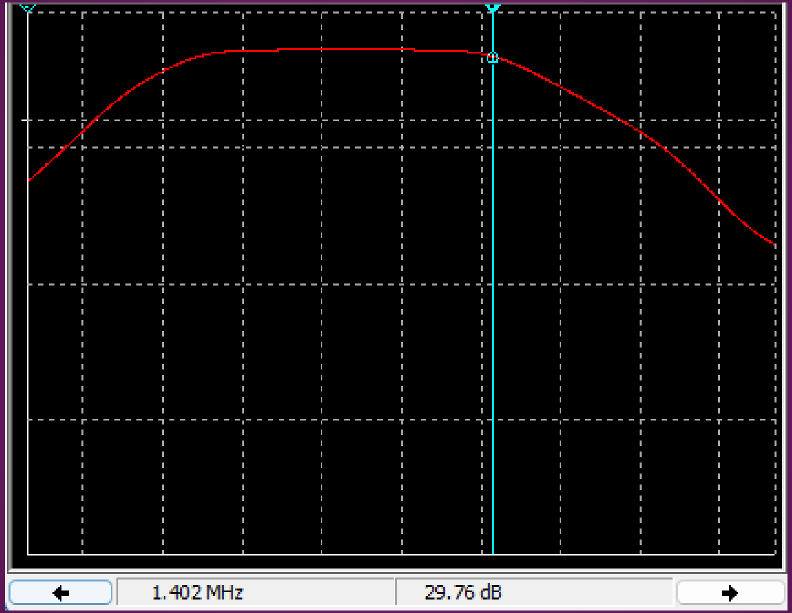
$$A_{v_s} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_b}{V_s} = -90.04 * 0.60 = -54.02$$

$$dB\ Gain = 20\,log(54.02) = 34.65\ dB$$

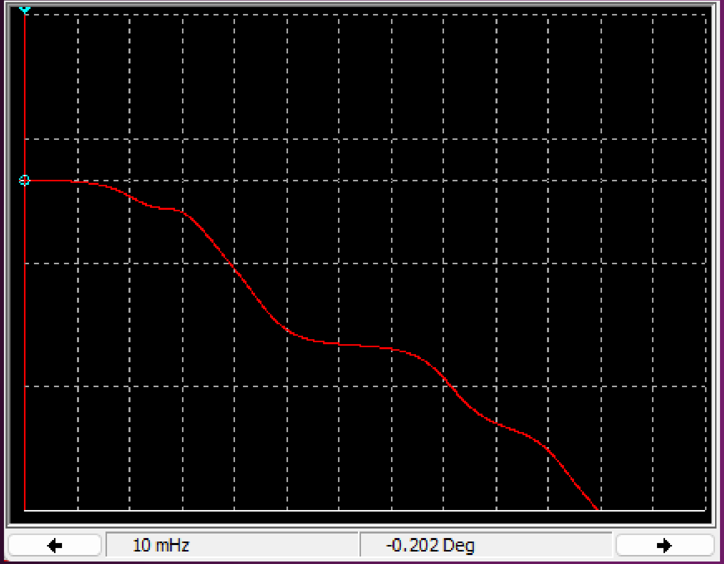




Bode Plot – Magnitude



Bode Plot – Magnitude



Bode Plot – Phase

Analysis

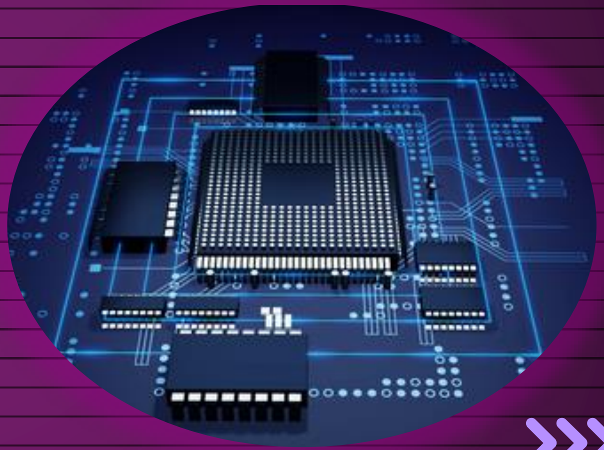
- Noise
- Approximations in the calculations

- Values are found and calculated on a logarithmic scale

Parameter	Theoretical	Particle	Error
Low Frequency	331.57 Hz	286.01 Hz	13.74%
High Frequency	26.31 MHz	1.40 MHz	High
Gain	34.65 dB	32.76 dB	5.45%

Conclusion

- Circuit Construction
- Analysis
- Course Knowledge



Thank you!

Questions?