

Experiment: TIA simple Z3 Z5 ZL

Filter 1

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, R_3, \infty, R_4, \frac{L_L s}{C_L L_L s^2 + 1} \right) \\ H(s): & \frac{C_L L_L R_3 R_4 R_{4g_m} s^2 + C_L L_L R_3 s^2 + 2 L_L R_3 R_{4g_m} s + L_L R_3 R_{4g_m} - 1}{\frac{L_L R_3 s (R_{4g_m} - 1)}{C_L L_L \sqrt{C_L^2 L_L^2} (R_{4g_m} + 1)}} \\ \mathbf{Q}: & \frac{C_L R_3 \sqrt{C_L^2 L_L^2} (R_{4g_m} + 1)}{2 R_{4g_m} + R_{4g_m} + 1} \\ \omega_0: & \sqrt{\frac{1}{C_L L_L}} \\ \text{Bandwidth:} & \frac{2 R_{4g_m} + R_{4g_m} + 1}{C_L R_3 (R_{4g_m} + 1)} \end{aligned}$$

Filter 2

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, R_3, \infty, R_4, \frac{1}{C_L s + \frac{1}{R_L} + \frac{1}{L_L s}} \right) \\ H(s): & \frac{L_L R_3 R_L s (R_{4g_m} - 1)}{C_L L_L R_3 R_4 R_{4g_m} s^2 + C_L L_L R_3 R_L s^2 + L_L R_3 R_{4g_m} s + 2 L_L R_3 R_{4g_m} s + L_L R_3 s + L_L R_4 R_{4g_m} s + L_L R_L s + R_3 R_4 R_{4g_m} + R_3 R_L} \\ \mathbf{Q}: & \frac{C_L R_3 R_L \sqrt{C_L^2 L_L^2} (R_{4g_m} + 1)}{R_3 R_{4g_m} + 2 R_3 R_{4g_m} + R_3 + R_4 R_{4g_m} + R_L} \\ \omega_0: & \sqrt{\frac{1}{C_L L_L}} \\ \text{Bandwidth:} & \frac{R_3 R_{4g_m} + 2 R_3 R_{4g_m} + R_3 + R_4 R_{4g_m} + R_L}{C_L R_3 R_L (R_{4g_m} + 1)} \end{aligned}$$

Filter 3

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{1}{C_3 s}, \infty, R_4, \frac{L_L s}{C_L L_L s^2 + 1} \right) \\ H(s): & \frac{L_L s (R_{4g_m} - 1)}{C_3 L_L R_{4g_m} s^2 + C_3 L_L s^2 + C_L L_L R_{4g_m} s^2 + C_L L_L R_{4g_m} s^2 + C_L L_L s^2 + 2 L_L R_{4g_m} s + R_{4g_m} + 1} \\ \mathbf{Q}: & \frac{\sqrt{L_L (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{2 g_m} \\ \omega_0: & \sqrt{\frac{1}{L_L (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{2 g_m}{C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L} \end{aligned}$$

Filter 4

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{1}{C_3 s}, \infty, R_4, \frac{1}{C_L s + \frac{1}{R_L} + \frac{1}{L_L s}} \right) \\ H(s): & \frac{L_L R_4 s (R_{4g_m} - 1)}{C_3 L_L R_4 R_{4g_m} s^2 + C_3 L_L R_4 s^2 + C_L L_L R_4 R_{4g_m} s^2 + C_L L_L R_4 s^2 + L_L R_4 R_{4g_m} s + 2 L_L R_4 R_{4g_m} s + L_L s + R_4 R_{4g_m} + R_L} \\ \mathbf{Q}: & \frac{R_L \sqrt{L_L (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{R_{4g_m} + 2 R_{4g_m} + 1} \\ \omega_0: & \sqrt{\frac{1}{L_L (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{R_{4g_m} + 2 R_{4g_m} + 1}{R_L (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)} \end{aligned}$$

Filter 5

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{R_3}{C_3 R_3 s + 1}, \infty, R_4, \frac{L_L s}{C_L L_L s^2 + 1} \right) \\ H(s): & \frac{L_L R_3 s (R_{4g_m} - 1)}{C_3 L_L R_3 R_{4g_m} s^2 + C_3 L_L R_3 s^2 + C_L L_L R_3 R_{4g_m} s^2 + C_L L_L R_3 R_{4g_m} s^2 + C_L L_L R_3 s^2 + 2 L_L R_3 R_{4g_m} s + L_L R_3 s + R_3 R_{4g_m} + R_3} \\ \mathbf{Q}: & \frac{R_3 \sqrt{L_L (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{2 R_{4g_m} + R_{4g_m} + 1} \\ \omega_0: & \sqrt{\frac{1}{L_L (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{2 R_{4g_m} + R_{4g_m} + 1}{R_3 (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)} \end{aligned}$$

Filter 6

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{R_3}{C_3 R_3 s + 1}, \infty, R_4, \frac{1}{C_L s + \frac{1}{R_L} + \frac{1}{L_L s}} \right) \\ H(s): & \frac{L_L R_3 R_L s (R_{4g_m} - 1)}{C_3 L_L R_3 R_4 R_{4g_m} s^2 + C_3 L_L R_3 R_L s^2 + C_L L_L R_3 R_4 R_{4g_m} s^2 + C_L L_L R_3 R_L s^2 + L_L R_3 R_{4g_m} s + 2 L_L R_3 R_{4g_m} s + L_L R_3 s + L_L R_4 R_{4g_m} s + L_L R_L s + R_3 R_4 R_{4g_m} + R_3 R_L} \\ \mathbf{Q}: & \frac{R_3 R_L \sqrt{L_L (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{R_3 R_{4g_m} + 2 R_3 R_{4g_m} + R_3 + R_4 R_{4g_m} + R_L} \\ \omega_0: & \sqrt{\frac{1}{L_L (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{R_3 R_{4g_m} + 2 R_3 R_{4g_m} + R_3 + R_4 R_{4g_m} + R_L}{R_3 R_L (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)} \end{aligned}$$

Filter 7

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{L_3 s}{C_3 L_3 s^2 + 1}, \infty, R_4, R_L \right) \\ H(s): & \frac{L_3 R_L s (R_{4g_m} - 1)}{C_3 L_3 R_4 R_{4g_m} s^2 + C_3 L_3 R_L s^2 + L_3 R_4 R_{4g_m} s + 2 L_3 R_L R_{4g_m} s + L_3 s + R_4 R_{4g_m} + R_L} \\ \mathbf{Q}: & \frac{C_3 R_L \sqrt{C_3^2 L_3^2} (R_{4g_m} + 1)}{R_{4g_m} + 2 R_{4g_m} + 1} \\ \omega_0: & \sqrt{\frac{1}{C_3 L_3}} \\ \text{Bandwidth:} & \frac{R_{4g_m} + 2 R_{4g_m} + 1}{C_3 R_L (R_{4g_m} + 1)} \end{aligned}$$

Filter 8

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{L_3 s}{C_3 L_3 s^2 + 1}, \infty, R_4, \frac{1}{C_L s} \right) \\ H(s): & \frac{L_3 s (R_{4g_m} - 1)}{C_3 L_3 R_{4g_m} s^2 + C_3 L_3 s^2 + C_L L_3 R_{4g_m} s^2 + C_L L_3 R_{4g_m} s^2 + C_L L_3 s^2 + 2 L_3 R_{4g_m} s + R_{4g_m} + 1} \\ \mathbf{Q}: & \frac{\sqrt{L_3 (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{2 g_m} \\ \omega_0: & \sqrt{\frac{1}{L_3 (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{2 g_m}{C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L} \end{aligned}$$

Filter 9

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{L_3 s}{C_3 L_3 s^2 + 1}, \infty, R_4, \frac{R_L}{C_L R_L s + 1} \right) \\ H(s): & \frac{L_3 R_L s (R_{4g_m} - 1)}{C_3 L_3 R_4 R_{4g_m} s^2 + C_3 L_3 R_L s^2 + C_L L_3 R_4 R_{4g_m} s^2 + C_L L_3 R_L s^2 + L_3 R_{4g_m} s + 2 L_3 R_L R_{4g_m} s + L_3 s + R_4 R_{4g_m} + R_L} \\ \mathbf{Q}: & \frac{R_L \sqrt{L_3 (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)}{R_{4g_m} + 2 R_{4g_m} + 1} \\ \omega_0: & \sqrt{\frac{1}{L_3 (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{R_{4g_m} + 2 R_{4g_m} + 1}{R_L (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)} \end{aligned}$$

Filter 10

Filter Type: BP

$$\begin{aligned} Z(s): & \left( \infty, \infty, \frac{L_3 s}{C_3 L_3 s^2 + 1}, \infty, R_4, \frac{L_L s}{C_L L_L s^2 + 1} \right) \\ H(s): & \frac{L_3 L_L s (R_{4g_m} - 1)}{C_3 L_3 L_L R_{4g_m} s^2 + C_3 L_3 L_L s^2 + C_L L_3 L_L R_{4g_m} s^2 + C_L L_3 L_L R_{4g_m} s^2 + C_L L_3 L_L s^2 + 2 L_3 L_L R_{4g_m} s + L_3 L_3 R_{4g_m} + L_3 + L_L R_{4g_m} + L_L} \\ \mathbf{Q}: & \frac{L_3 + L_L}{\sqrt{L_3 L_L (C_3 + C_L)} (C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L)} \\ \omega_0: & \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}} \\ \text{Bandwidth:} & \frac{2 g_m}{C_3 R_{4g_m} + C_3 + C_L R_{4g_m} + C_L} \end{aligned}$$

#### Filter 11

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{L_3 s}{C_3 L_3 s^2 + 1}, \infty, R_4, \frac{1}{C_L s + \frac{1}{R_L^* + \frac{1}{L_L^*}}} \right)$$

$$H(s): \frac{C_3 L_3 R_L R_4 R_L R_L R_L s^2 + C_3 L_3 L_L R_L R_L s^2 + C_L L_3 L_L R_4 R_L R_L R_L s^2 + C_L L_3 L_L R_L s^2 + L_3 L_L R_4 R_L s^2 + 2 L_3 L_L R_L R_L s + L_3 L_L s + L_3 R_L R_L R_L s + L_3 R_L + L_L R_4 R_L R_L + L_L R_L}{C_3 R_4 R_L \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}} (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$

$$\mathbf{Q}: \frac{R_L \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}}{R_4 g_m + 2 R_L g_m + 1}$$

$$\omega_0: \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}$$

$$\text{Bandwidth: } \frac{R_4 g_m + 2 R_L g_m + 1}{R_L (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$

#### Filter 12

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{1}{C_3 s + \frac{1}{R_3^* + \frac{1}{L_3^*}}}, \infty, R_4, R_L \right)$$

$$H(s): \frac{L_3 R_3 R_L s (R_4 g_m - 1)}{C_3 R_4 R_L \sqrt{\frac{1}{C_3 L_3}} (R_4 g_m + 1)}$$

$$\mathbf{Q}: \frac{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}$$

$$\omega_0: \sqrt{\frac{1}{C_3 L_3}}$$

$$\text{Bandwidth: } \frac{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}{C_3 R_3 R_L (R_4 g_m + 1)}$$

#### Filter 13

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{1}{C_3 s + \frac{1}{R_3^* + \frac{1}{L_3^*}}}, \infty, R_4, \frac{1}{C_L s} \right)$$

$$H(s): \frac{L_3 R_3 s (R_4 g_m - 1)}{C_3 L_3 R_3 R_4 R_L R_L s^2 + C_3 L_3 R_3 s^2 + C_L L_3 R_3 R_4 R_L s^2 + C_L L_3 R_3 s^2 + 2 L_3 R_3 g_m s + L_3 R_4 g_m s + L_3 s + R_3 R_4 g_m + R_3}$$

$$\mathbf{Q}: \frac{R_3 \sqrt{\frac{1}{L_3 (C_3 + C_L)}}}{2 R_3 g_m + R_4 g_m + 1}$$

$$\omega_0: \sqrt{\frac{1}{L_3 (C_3 + C_L)}}$$

$$\text{Bandwidth: } \frac{2 R_3 g_m + R_4 g_m + 1}{R_3 (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$

#### Filter 14

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{1}{C_3 s + \frac{1}{R_3^* + \frac{1}{L_3^*}}}, \infty, R_4, \frac{R_L}{C_L R_L s + 1} \right)$$

$$H(s): \frac{L_3 R_3 R_L s (R_4 g_m - 1)}{C_3 L_3 R_3 R_4 R_L R_L R_L s^2 + C_3 L_3 R_3 R_L s^2 + C_L L_3 R_3 R_4 R_L R_L s^2 + C_L L_3 R_3 R_L s^2 + L_3 R_3 R_4 g_m s + 2 L_3 R_3 R_L g_m s + L_3 R_3 s + L_3 R_L R_L g_m s + L_3 R_L s + R_3 R_4 R_L g_m + R_3 R_L}$$

$$\mathbf{Q}: \frac{R_3 R_L \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}}{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}$$

$$\omega_0: \sqrt{\frac{1}{L_3 (C_3 + C_L)}}$$

$$\text{Bandwidth: } \frac{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}{R_3 R_L (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$

#### Filter 15

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{1}{C_3 s + \frac{1}{R_3^* + \frac{1}{L_3^*}}}, \infty, R_4, \frac{L_L s}{C_L L_L s^2 + 1} \right)$$

$$H(s): \frac{L_3 L_L R_3 s (R_4 g_m - 1)}{C_3 L_3 L_L R_3 R_4 R_L R_L s^2 + C_3 L_3 L_L R_3 s^2 + C_L L_3 L_L R_3 R_4 R_L s^2 + C_L L_3 L_L R_3 s^2 + 2 L_3 L_L R_3 g_m s + L_3 L_L R_4 g_m s + L_3 R_3 s + L_L R_3 R_4 g_m + L_L R_3}$$

$$\mathbf{Q}: \frac{R_3 \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}}{2 R_3 g_m + R_4 g_m + 1}$$

$$\omega_0: \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}$$

$$\text{Bandwidth: } \frac{2 R_3 g_m + R_4 g_m + 1}{R_3 (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$

#### Filter 16

**Filter Type:** BP

$$Z(s): \left( \infty, \infty, \frac{1}{C_3 s + \frac{1}{R_3^* + \frac{1}{L_3^*}}}, \infty, R_4, \frac{1}{C_L s + \frac{1}{R_L^* + \frac{1}{L_L^*}}} \right)$$

$$H(s): \frac{L_3 L_L R_3 R_L s (R_4 g_m - 1)}{C_3 L_3 L_L R_3 R_4 R_L R_L R_L s^2 + C_3 L_3 L_L R_3 R_L s^2 + C_L L_3 L_L R_3 R_4 R_L R_L s^2 + C_L L_3 L_L R_3 R_L s^2 + L_3 L_L R_3 R_4 g_m s + 2 L_3 L_L R_3 R_L g_m s + L_3 L_L R_3 s + L_3 R_3 R_4 R_L g_m + L_3 R_3 R_L + L_L R_3 R_4 R_L g_m + L_L R_3 R_L}$$

$$\mathbf{Q}: \frac{R_3 R_L \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}}{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}$$

$$\omega_0: \sqrt{\frac{L_3 + L_L}{L_3 L_L (C_3 + C_L)}}$$

$$\text{Bandwidth: } \frac{R_3 R_4 g_m + 2 R_3 R_L g_m + R_3 + R_4 R_L g_m + R_L}{R_3 R_L (C_3 R_4 g_m + C_3 + C_L R_4 g_m + C_L)}$$