

$$H(j\omega) = \frac{V_{out}}{V_{in}} = \begin{cases} -R_2/R_1 & \omega = 0 \\ 0 & \omega \rightarrow \infty \end{cases}$$

1990-2000



100%



$$\frac{Z_2}{Z_1} = \frac{R_2 \parallel (1/j\omega C)}{R_1 R_2 + 1/j\omega C} = \frac{R_2}{R_1 j\omega R_2 C + 1}$$

$$-H(0) \frac{1}{1 + j\omega\tau}$$

[illegible]

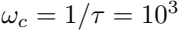


we are 100%

THESE ARE THE







$$H(j\omega) = \frac{V_{out}}{V_{in}} = \begin{cases} 0 & \omega \rightarrow 0 \\ -R_2/R_1 & \omega \rightarrow \infty \end{cases}$$

1990-00

$$\frac{Z_2(j\omega)}{Z_1(j\omega)} = \frac{R_2}{R_1 + 1/j\omega C} = \frac{R_2}{R_1} \frac{1}{1 + 1/j\omega R_1 C}$$

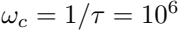
$$-H(\infty) \frac{1}{1 + 1/j\omega\tau}$$

we are 100%

Handwritten text in a stylized, pixelated font, likely representing a signature or name. The text is split into two lines by a horizontal separator consisting of two parallel lines. The top line reads "Handwritten" and the bottom line reads "Text".

2020

100%





HELLO = 1





$$H_{lp}(j\omega) = \frac{\omega_c}{j\omega + \omega_c} = \frac{1}{j\omega\tau + 1}, \quad H_{hp}(j\omega) = \frac{j\omega}{j\omega + \omega_c} = \frac{j\omega\tau}{j\omega\tau + 1}$$

$$H(j\omega) = \frac{V_{out}}{V_{in}} = \begin{cases} 0 & \omega = 0 \\ 0 & \omega \rightarrow \infty \end{cases}$$

$$Z_1(w) = R_1 + 1/w, \quad Z_2(w) = R_2 + 1/w$$

ABP@w

$$\frac{Z_2(\omega)}{Z_1(\omega)} = \frac{R_2 || (1/j\omega C_2)}{R_1 + 1/j\omega C_1} = \frac{R_2/j\omega C_2}{(R_1 + 1/j\omega C_1)(R_2 + 1/j\omega C_2)}$$

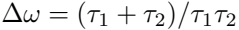
$$-\frac{j\omega R_2 C_1}{(j\omega R_1 C_1 + 1)(j\omega C_2 R_2 + 1)} = -\frac{j\omega \tau_3}{(1 + j\omega \tau_1)(1 + j\omega \tau_2)} = -(j\omega \tau_3) \left(\frac{1}{1 + j\omega \tau_1} \right) \left(\frac{1}{1 + j\omega \tau_2} \right)$$

$$= -j\omega\tau_3 \left(\frac{1/\tau_1\tau_2}{(j\omega)^2 + j\omega(\tau_1 + \tau_2)/\tau_1\tau_2 + 1/\tau_1\tau_2} \right) = -j\omega\tau_3 \frac{\omega_n^2}{\omega^2 + j\omega\Delta\omega + \omega_n^2}$$

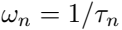
we are 1234567890

www.1234567890

we are 1/2 of 1/2



W = 1 2 3 4









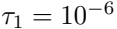
$$\tau_n = \sqrt{\tau_1 \tau_2} = (\tau_1 \tau_2)^{1/2}, \quad \log \tau_n = \frac{1}{2} (\log \tau_1 + \log \tau_2)$$

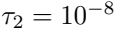
$$\log w_n = \frac{1}{2} (\log w_1 + \log w_2)$$

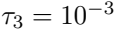














$$-Im_{BP}(j\omega) = -20 \log |H_{BP}(j\omega)| = -20 \log \left| \frac{Z_2(\omega)}{Z_1(\omega)} \right| = 20 \log \left| \frac{Z_1(\omega)}{Z_2(\omega)} \right| = Im_{BS}(j\omega)$$

A pixelated, grayscale image of the number 12345. The digits are rendered in a blocky, low-resolution style with varying shades of gray, giving it a retro or digital appearance. The number is centered horizontally and occupies most of the frame.



ABEWE

$$\frac{Z_1(\omega)}{Z_2(\omega)} = \frac{R_2 + 1/j\omega C_2}{R_1 || 1/j\omega C_1} = \frac{R_2 + 1/j\omega C_2}{R_1/j\omega C_1 / (R_1 + 1/j\omega C_1)}$$

$$\frac{(1 + j\omega C_1 R_1)(1 + j\omega C_2 R_2)}{j\omega R_1 C_2} = \frac{(1 + j\omega \tau_1)(1 + j\omega \tau_2)}{j\omega \tau_3}$$

W

o

Woo

$$\frac{V_a - V_{in}}{Z_1} + \frac{V_a - V_{out}}{Z_3} + \frac{V_a - V_{out}}{Z_2} = \frac{V_a - V_{in}}{Z_1} + (V_a - V_{out}) \left(\frac{1}{Z_3} + \frac{1}{Z_2} \right) = 0$$

$$\frac{V_{out} - V_a}{Z_2} + \frac{V_{out}}{Z_4} = 0,$$



$$V_a = V_{out} \frac{Z_2 + Z_4}{Z_4}$$

$$V_{out} \left(\frac{Z_2 + Z_4}{Z_1 Z_4} + \frac{Z_2}{Z_3 Z_4} + \frac{Z_2}{Z_2 Z_4} \right) = \frac{V_{in}}{Z_1}$$

A pixelated, grayscale image of the word "love" in a stylized, blocky font. The letters are composed of various shades of gray, giving it a textured, digital appearance. The "l" is on the left, followed by "o", "v", and "e" on the right. The image has a low-resolution, 8-bit aesthetic.





$$\frac{V_{out}}{V_{in}} = \frac{Z_3 Z_4}{Z_1 Z_2 + Z_1 Z_3 + Z_2 Z_3 + Z_3 Z_4}$$





A pixelated, black and white representation of the text "100%". The characters are composed of various shades of gray and black pixels, giving it a retro, digital appearance. The "1" is a simple vertical bar with a base. The "0" is a circle with a small dot in the center. The "0" is a circle with a small dot in the center. The "%" is a standard percentage symbol.

$$H(j\omega) = \frac{\omega_p^2}{(j\omega)^2 + \Delta\omega j\omega + \omega_p^2}$$

$$\omega_n = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}, \quad \Delta\omega = \frac{1}{(R_1 || R_2) C_1} = \frac{1}{R_p C_1}, \quad R_p = R_1 || R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

$$Q = \frac{\omega_n}{\Delta\omega} = \frac{\sqrt{R_1 R_2 C_1 C_2}}{(R_1 + R_2) C_2}, \quad \zeta = \frac{1}{2Q} = \frac{(R_1 + R_2) C_2}{2\sqrt{R_1 R_2 C_1 C_2}}$$















$$\omega_n = \frac{1}{\sqrt{C_1 C_2}},$$

$$\Delta \omega = \frac{1}{C_1}$$

1 = 1001

A pixelated, black and white representation of the text "100%". The characters are composed of various shades of gray and black pixels, giving it a retro, digital appearance. The "1" is a simple vertical bar with a horizontal base. The "0"s are formed by a series of connected pixels, with the top and bottom curves being more solid black. The "." is a small cluster of black and gray pixels. The "%" sign is a complex shape made of many small, dark gray and black pixels, with a distinct loop and a tail.





$$H(j\omega) = \frac{(j\omega)^2}{(j\omega)^2 + \Delta\omega j\omega + \omega_n^2}$$

$$\omega_n = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}, \quad \Delta \omega = \frac{1}{C_s R_2}, \quad C_s = \frac{C_1 C_2}{C_1 + C_2}$$

$$Q \equiv \frac{\sqrt{R_1 R_2 C_1 C_2}}{(C_1 + C_2) R_1}, \quad \zeta \equiv \frac{1}{2Q} = \frac{(C_1 + C_2) R_1}{2\sqrt{R_1 R_2 C_1 C_2}}$$

$$V_2 = \frac{R_a}{R_a + R_b} V_{out} = k V_{out}, \quad \left(k = \frac{R_a}{R_a + R_b} \right)$$



$$\frac{V_1 - V_2}{Z_2} = \frac{V_2}{Z_4}, \quad \text{i.e.} \quad V_1 = V_2 \left(1 + \frac{Z_2}{Z_4} \right)$$



$$\frac{V_{in} - V_1}{Z_1} + \frac{V_{out} - V_1}{R_f} + \frac{V_2 - V_1}{Z_2} = \frac{V_1}{Z_3}$$

2021 + 2021

$$\frac{V_{in}}{Z_1} + \frac{V_{out}}{R_f} + \frac{V_2}{Z_2} = V_1 \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right)$$

$$v_2 \left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right)$$

WAVE

$$\frac{V_{in}}{Z_1} + \frac{V_{out}}{R_f} = kV_{out} \left[\left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right) - \frac{1}{Z_2} \right]$$

Van



21

$$K V_{out} \left[\left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right) - \frac{1}{Z_2} \right] - \frac{V_{out}}{R_f}$$

$$v_{out} \left\{ k \left[\left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right) - \frac{1}{Z_2} \right] - \frac{1}{R_f} \right\}$$

A $=$

$$\frac{V_{out}}{V_{in}}$$

$$1$$

$$Z_1 \left\{ k \left[\left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right) - \frac{1}{Z_2} \right] - \frac{1}{R_f} \right\}$$

$$1/k$$

$$Z_1 \left[\left(1 + \frac{Z_2}{Z_4} \right) \left(\frac{1}{Z_1} + \frac{1}{R_f} + \frac{1}{Z_2} + \frac{1}{Z_3} \right) - \frac{1}{Z_2} \right] - \frac{Z_1}{kR_f}$$

$$1/k$$

$$1 + \frac{Z_1}{R_f} + \frac{Z_1}{Z_3} + \frac{Z_2}{Z_4} + \frac{Z_1 Z_2}{Z_4 R_f} + \frac{Z_1}{Z_4} + \frac{Z_1 Z_2}{Z_3 Z_4} - \frac{Z_1}{k R_f}$$

$$Z_1 = R_1, \quad Z_4 = R_2, \quad Z_2 = \frac{1}{j\omega C_2}, \quad Z_3 = \frac{1}{j\omega C_1}$$

$$\left(1 + \frac{R_b}{R_a}\right) \frac{1}{R_1 C_1} j\omega$$

$$(j\omega)^2 + \left(\frac{1}{R_2 C_1} + \frac{1}{R_2 C_2} + \frac{1}{R_1 C_1} - \frac{R_b}{R_a R_f C_1} \right) j\omega + \frac{R_1 + R_f}{R_f R_1 R_2 C_1 C_2}$$

$$\frac{A j \omega}{(j \omega)^2 + \Delta \omega j \omega + \omega_n^2},$$

$$A = (1 + R_b / R_a) / R_1 C_1$$

$$\omega_n = \sqrt{\frac{R_1 + R_f}{R_f R_1 R_2 C_1 C_2}}$$

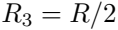
$$\Delta w = \frac{1}{R_2 C_1} + \frac{1}{R_2 C_2} + \frac{1}{R_1 C_1} - \frac{R_b}{R_a R_f C_1}$$















$$\frac{v_{out}}{v_{in}} = \frac{(j\omega)^2 + \omega_n^2}{(j\omega)^2 + 4\omega_n j\omega + \omega_n^2}$$

$$(j\omega)^2 + \omega_n^2$$

$$\omega^2 - \omega_n^2$$

$$=$$

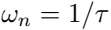
$$(j\omega)^2 + j\omega\omega_n/Q + \omega_n^2$$

$$\omega^2 - j\omega\Delta\omega - \omega_n^2$$

$$w_n = \frac{1}{RC} = \frac{1}{\tau}$$

Q1415025





$$|H(j\omega)| = \begin{cases} H(0) = \omega_n^2/\omega_n^2 = 1 & \omega = 0 \\ H(j\omega_n) = 0 & \omega = \omega_n = 1/\tau \\ H(\infty) = \lim_{\omega \rightarrow \infty} H(j\omega) = \omega^2/\omega^2 = 1 & \omega \rightarrow \infty \end{cases}$$



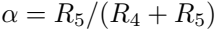






$$V_1 = \frac{R_5}{R_4 + R_5}$$

$$V_{out} = 0V_{out}$$



[illegible]



QWERTY

ASDFGH

JKL

100%

For all $x \in \mathbb{R}^n$

Vorlesung

How do we

$$V_{out} + (H(j\omega) - 1)V_1 = V_{out} + (H(j\omega) - 1) \frac{R_5}{R_4 + R_5} V_{out}$$

$$\left(1 + (H(j\omega) - 1) \frac{R_5}{R_4 + R_5}\right) V_{out} = \frac{R_4 + H(j\omega) R_5}{R_4 + R_5} V_{out}$$

$$H_{\text{active}}(j\omega) = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{H(j\omega)(R_4 + R_5)}{R_4 + H(j\omega)R_5}$$

$$E(v) = (v^2 + v + 1) / (v^2 + v + 1)$$

How do we know?

$$(\omega_n^2 - \omega^2)(R_4 + R_5)$$

$$R_4(\omega_n^2 - \omega^2 + 1\omega_n j\omega) + (\omega_n^2 - \omega^2)R_5$$

$$(\omega_n^2 - \omega^2)(R_4 + R_5)$$

$$4\omega_n R_4 j\omega + (\omega_n^2 - \omega^2)(R_4 + R_5)$$

$$\omega_n^2 - \omega^2$$

$$j\omega R_4 \omega_n R_4 / (R_4 + R_5) + \omega_n^2 - \omega^2$$

$$\frac{\omega_n^2 - \omega^2}{\omega_n^2 - \omega^2 + \omega_n / Q_{\text{active}} j\omega} = \frac{\omega^2 - \omega_n^2}{\omega^2 - \Delta\omega_{\text{active}} j\omega - \omega_n^2}$$

$$Q_{\text{active}} = \frac{R_4 + R_5}{4R_4}, \quad \Delta\omega_{\text{active}} = \frac{\omega_n}{Q_{\text{active}}}$$

$$\omega_n^2 - \omega^2$$

$$\omega_n^2 + 4j\omega\omega_n R_4 / (R_4 + R_5) - \omega^2$$

$$\frac{\omega_n^2 - \omega^2}{\omega_n^2 - \omega^2 + \omega_n / Q_{\text{active}} j\omega} = \frac{\omega_n^2 - \omega^2}{\omega_n^2 - \omega^2 + \Delta\omega_{\text{active}} j\omega}$$



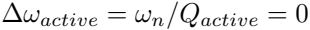
















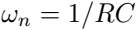
2014-2015

$$Z_3 = Z_3' \parallel Z_3'' = \frac{Z_3' Z_3''}{Z_3' + Z_3''} = \frac{2R(1 + j\omega RC)}{1 + j\omega RC + (j\omega RC)^2}$$

$$\frac{Z_2}{Z_2 + Z_3} = \frac{R + 1/j\omega C}{R + 1/j\omega C + 2R(1 + j\omega RC)/(1 + j\omega RC + (j\omega RC)^2)}$$

$$\frac{1/C}{1/j\omega C + 2R/(1 + j\omega RC + (j\omega RC)^2)} = \frac{1}{1 + 2j\omega RC/(1 + j\omega RC + (j\omega RC)^2)}$$

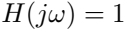
$$\frac{1 + j\omega RC + (j\omega RC)^2}{1 + 3j\omega RC + (j\omega RC)^2} = \frac{(j\omega)^2 + j\omega/RC + 1/(RC)^2}{(j\omega)^2 + 3j\omega/RC + 1/(RC)^2}$$



$$H(j\omega) = \frac{(j\omega)^2 + \omega_n j\omega + \omega_n^2}{(j\omega)^2 + 3\omega_n j\omega + \omega_n^2} = \frac{(j\omega)^2 + \Delta\omega_n j\omega + \omega_n^2}{(j\omega)^2 + \Delta\omega_d j\omega + \omega_n^2} = \frac{\omega_n^2 - \omega^2 + \Delta\omega_n j\omega}{\omega_n^2 - \omega^2 + \Delta\omega_d j\omega}$$



THE WORLD IS 1



1990

1995-1996

$$\frac{R_3}{R_4} = \frac{R_2 + 1/j\omega C_2}{R_1 || 1/j\omega C_1} = \frac{(j\omega R_1 C_1 + 1)(j\omega R_2 C_2 + 1)}{j\omega R_1 C_2} = \frac{1 - \omega^2 R_1 R_2 C_1 C_2 + j\omega(R_1 C_1 + R_2 C_2)}{j\omega R_1 C_2}$$

$$1 - \omega^2 R_1 R_2 C_1 C_2 = 0, \text{ i.e., } \omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

$$\frac{R_3}{R_4} = \frac{R_1 C_1 + R_2 C_2}{R_1 C_2} = \frac{C_1}{C_2} + \frac{R_2}{R_1}$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} = \frac{1}{\sqrt{R^2 C^2}} = \frac{1}{RC}$$

$$\frac{R_3}{R_4} = \frac{C_1}{C_2} + \frac{R_2}{R_1} = 1 + 1 = 2, \text{ i.e. } R_4 = 2R_3$$

$$\frac{V_{in}}{R_4} + \frac{V_{out}}{R_3} + \frac{V_1}{R_2} = 0 \quad (1)$$

$$V_2 = \frac{R + 1/j\omega C}{R + 1/j\omega C + R/j\omega C / (R + 1/j\omega C)} V_1 = \frac{(j\omega\tau + 1)^2}{(j\omega\tau + 1)^2 + j\omega\tau} V_1,$$



$$V_1 = \left(1 + \frac{j\omega\tau}{(j\omega\tau + 1)^2} \right) V_2, \quad (2)$$

$$\frac{V_1 - V_2}{R_1} + \frac{V_{out} - V_2}{2R_1} = 0, \quad \text{i.e.} \quad V_{out} = 3V_2 - 2V_1, \quad (3)$$

$$V_{out} = 3V_2 - 2V_1 = 3V_2 - 2 \left(1 + \frac{j\omega\tau}{(j\omega\tau + 1)^2} \right) V_2 = V_2 - \frac{j\omega 2\tau}{(j\omega\tau + 1)^2} V_2 = \frac{(j\omega\tau)^2 + 1}{(j\omega\tau + 1)^2} V_2$$

$$V_2 = \frac{(j\omega\tau + 1)^2}{(j\omega\tau)^2 + 1} V_{out}$$

$$V_1 = \left(1 + \frac{j\omega\tau}{(j\omega\tau + 1)^2} \right) V_2 = \left(1 + \frac{j\omega\tau}{(j\omega\tau + 1)^2} \right) \frac{(j\omega\tau + 1)^2}{(j\omega\tau)^2 + 1} V_{out} = \frac{(j\omega\tau)^2 + 3j\omega\tau + 1}{(j\omega\tau)^2 + 1} V_{out}$$

$$\frac{V_{in}}{R_1} + \frac{V_{out}}{R_3} + \frac{(j\omega\tau)^2 + 3j\omega\tau + 1}{(j\omega\tau)^2 + 1} \frac{V_{out}}{R_2} = 0$$

$$\frac{V_{in}}{R_4} = - \left(\frac{1}{R_3} + \frac{(j\omega\tau)^2 + 3j\omega\tau + 1}{(j\omega\tau)^2 + 1} \frac{1}{R_2} \right) v_{out}$$

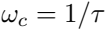
$$\frac{R_2}{R_4} = - \left(\frac{R_2}{R_3} + \frac{(j\omega\tau)^2 + 3j\omega\tau + 1}{(j\omega\tau)^2 + 1} \right) \frac{V_{out}}{V_{in}}$$

$$H(j\omega) = \frac{V_{out}}{V_{in}} = \frac{R_2 R_3}{R_4 (R_2 + R_3)} \frac{(j\omega\tau)^2 + 1}{(j\omega\tau)^2 + 3j\omega\tau R_3 / (R_2 + R_3) + 1}$$

$$H(j\omega) = A \frac{(j\omega)^2 + \omega_n^2}{(j\omega)^2 + \Delta\omega/Q j\omega + \omega_n^2} = \begin{cases} A & \omega = 0 \\ 0 & \omega = \omega_n = 1/\tau \\ A & \omega \rightarrow \infty \end{cases}$$

A R₂R₃/R₂+R₃R₂/R₂





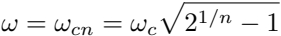


$$H(j\omega) = \frac{1}{j\omega\tau + 1} = \frac{1}{j\omega/\omega_c + 1} = \frac{\omega_c}{j\omega + \omega_c}$$

$$H(j\omega) = \left(\frac{\omega_c}{\omega_c + j\omega} \right)^n$$



$$\left| \frac{\omega_c}{\omega_c + j\omega} \right|^n = \left| \frac{\omega_c}{\sqrt{\omega_c^2 + \omega^2}} \right|^n = \frac{1}{\sqrt{2}} = 2^{-1/2}$$



wp4 2π1000=0.292x10³

$$\omega_c = \frac{\omega_{c4}}{\sqrt{2^{1/4} - 1}} = \frac{6.2832 \times 10^3}{0.435} = 1.445 \times 10^4$$

7-10-1910-5



$$R = \frac{\omega_c}{C} = \frac{6.92 \times 10^{-5}}{10^{-7}} = 6.92 \times 10^2 = 692 \, \Omega$$



$$|H_{lp}(j\omega)| = \frac{1}{\sqrt{1 + (\omega/\omega_c)^{2n}}} = \begin{cases} 1 & \omega = 0 \\ 1/\sqrt{2} & \omega = \omega_c \\ 0 & \omega = \infty \end{cases}$$

1992-1993





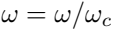


1992-1993

$$|H_p(j\omega)| = \frac{1}{\sqrt{1 + (\omega/\omega_c)^2}} = \frac{\omega_c}{\sqrt{\omega^2 + \omega_c^2}} = \left| \frac{\omega_c}{j\omega + \omega_c} \right|$$

$$|H_p(j\omega)| = \frac{1}{\sqrt{1 + (\omega/\omega_c)^2}} = \begin{cases} 1 & \omega < \omega_c \\ 0 & \omega > \omega_c \end{cases}$$

$$|H_{hp}(j\omega)| = \frac{1}{\sqrt{1 + (\omega_c/\omega)^{2n}}} = \frac{(\omega/\omega_c)^n}{\sqrt{1 + (\omega/\omega_c)^{2n}}} = \begin{cases} 0 & \omega = 1 \\ 1/\sqrt{2} & \omega = \omega_c \\ 1 & \omega = \infty \end{cases}$$

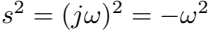




$$|H(j\omega)|^2 = H(j\omega)H(-j\omega) = \frac{1}{1 + (\omega/\omega_c)^{2n}} = \frac{1}{1 + \omega^{2n}} = \frac{1}{1 + (\omega^2)^n}$$







$$|H(j\omega)|^2 = H(j\omega)H(-j\omega) = \frac{1}{1 + (\omega^2)^n} = \frac{1}{1 + (-s^2)^n} = \frac{1}{1 + (-1)^n s^{2n}} = |H(s)|^2 = H(s)H(-s)$$



$$1 + (-1)^n s^{2n} = 0, \quad \text{i.e.} \quad \begin{cases} 1 + s^{2n} = 0 & n \text{ is even} \\ 1 - s^{2n} = 0 & n \text{ is odd} \end{cases}$$



$$\begin{cases} s = (-1)^{1/2n} = (e^{j(2k+1)\pi})^{1/2n} = e^{j(2k+1)\pi/2n} & n \text{ is even} \\ s = 1^{1/2n} = (e^{j2k\pi})^{1/2n} = e^{jk\pi/n} & n \text{ is odd} \end{cases} \quad (k = 0, \dots, 2n-1)$$

$$s_k = e^{i(2k+1)\pi/2n}, \quad s_k = 0, \quad s_k = e^{i(2k-1)\pi/2n}$$

94211721

A pixelated, grayscale representation of the word "HELLO" in a stylized, blocky font. The letters are composed of various shades of gray and black pixels, giving it a retro, digital appearance. The background is white.



$$s_{2n-1-k} = e^{j(2(2n-1-k)+1)\pi/2n} = e^{j\pi(4n-2k-1)/2n} = e^{j2\pi} e^{-j(2k+1)\pi/2n} = s_k$$

$$\frac{(2k+1)\pi}{2n} > \frac{\pi}{2}, \quad \text{i.e.} \quad k > \frac{n-1}{2}$$



$$\frac{1}{\prod_{k=\lceil (n-1)/2 \rceil}^{n-1}(s-s_k)(s-s_{2n-1-k})}}=\frac{1}{\prod_{k=\lceil (n-1)/2 \rceil}^{n-1}(s-s_k)(s-s_k^*)}}$$

$$\frac{1}{\prod_{k=1}^{n-1} (s^2 - (s_k + s_k^*)s + s_k s_k^*)} = \frac{1}{\prod_{k=1}^{n-1} (s^2 - 2 \cos((2k+1)\pi/2n) + 1)}$$





$$s_k + s_k^* = e^{j(2k+1)\pi/2n} + e^{-j(2k+1)\pi/2n} = 2\cos((2k+1)\pi/2n), \quad s_k s_k^* = 1$$

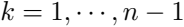
$$g_k = e^{i2k\pi/2n} = e^{ik\pi/n}, \quad (k = 0, \dots, 2n-1)$$













$$e^{2n-k} = e^{j(2n-k)\pi/n} = e^{-jk\pi/n} = e^{-k}$$



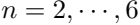
$$\frac{k\pi}{n} \geq \frac{\pi}{2},$$

i.e.

$$k \geq \frac{n}{2}$$

$$\frac{1}{(s-s_n)\prod_{i=\lceil n/2\rceil}^{n-1}(s-s_k)(s-s_{2n-k})}}=\frac{1}{(s+1)\prod_{i=\lceil n/2\rceil}^{n-1}(s-s_k)(s-s_k^*)}}$$

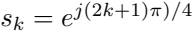
$$\frac{1}{(s+1)\prod_{i=\lceil n/2 \rceil}^{n-1}(s^2-(s_k+s_k^*)s+s_k s_k^*)}=\frac{1}{(s+1)\prod_{i=\lceil n/2 \rceil}^{n-1}(s^2-2\cos(k\pi/n)+1)}$$







341 = 324 + 14





$$s_0 = e^{j\pi/4} = \frac{1+j}{\sqrt{2}}, \quad s_1 = e^{j3\pi/4} = \frac{-1+j}{\sqrt{2}}, \quad s_2 = e^{j5\pi/4} = \frac{-1-j}{\sqrt{2}}, \quad s_3 = e^{j7\pi/4} = \frac{1-j}{\sqrt{2}}$$





$$\frac{1}{(s - s_1)(s - s_2)} = \frac{1}{(s - (-1 + j)/\sqrt{2})(s - (-1 - j)/\sqrt{2})}$$

1



s^2

+

$\sqrt{2}s$

+

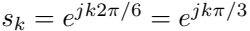
1

2023-2024





2021-2022





$$s_0 = e^{j0} = 1, \quad s_1 = e^{j\pi/3} = \frac{1 + j\sqrt{3}}{2}, \quad s_2 = e^{j2\pi/3} = \frac{-1 + j\sqrt{3}}{2}$$

$$s_3 = e^{j3\pi/3} = e^{j\pi} = -1, \quad s_4 = e^{j4\pi/3} = \frac{-1 - j\sqrt{3}}{2}, \quad s_5 = e^{j5\pi/3} = \frac{1 - j\sqrt{3}}{2}$$







$$\frac{1}{(s-s_2)(s-s_3)(s-s_4)} = \frac{1}{(s+1)(s-(-1+j\sqrt{3})/2)(s-(-1-j\sqrt{3})/2)}$$

$$1$$



$$(s + 1)(s^2 + s + 1)$$

2023-2024





921 = 921 + 1

2021-11-29



2009-10-20





2005-05-01

2009-09-19

$$H(s) = \frac{1}{(s^2 + 0.765s + 1)(s^2 + 1.848s + 1)}$$





[illegible]

$$g_k = e^{i(2k\pi)/10} = e^{i(k\pi)/5}, \quad g_k = 0, \quad , \quad 0)$$

2020-2021

2023-05-10

2009-05-16

$$H(s) = \frac{1}{(s+1)(s^2+0.618s+1)(s^2+1.618s+1)}$$





912 12 11 21 + 11

$$g_k = e^{i(2k+1)\pi/12}, \quad k = 0, \dots, 11$$





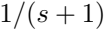
2009/12/5 17:00

2009-12-14

2009-12-29

$$H(s) = \frac{1}{(s^2 + 0.5176s + 1)(s^2 + 1.4142s + 1)(s^2 + 1.9319s + 1)}$$

1992 + 92 + 19



$$H(s) = \frac{1/\tau}{s + 1/\tau} = \frac{\omega_c}{s + \omega_c} = \frac{1}{s + 1}$$

we are 123456789





$$H(s) = \frac{1/R_1C_1R_2C_2}{s^2 + s(R_1 + R_2)/R_1R_2C_1 + 1/R_1C_1R_2C_2} = \frac{1}{s^2 + \Delta\omega s + \omega_n^2} = \frac{1}{s^2 + as + 1}$$

WORLDWIDE

$$\frac{201}{201} = \frac{101}{101} = 1$$

Q1 = 20, Q2 = 100, Q3 = 200

$$H(s) = \frac{s}{s + \omega_c} = \frac{s}{s + 1}, \quad H(s) = \frac{s^2}{s^2 + \Delta\omega s + \omega_c^2} = \frac{s^2}{s^2 + as + 1}$$

$$H(s) = \begin{cases} s^n / (1 + s^{2n}) & n \text{ is even} \\ s^n / (1 - s^{2n}) & n \text{ is odd} \end{cases}$$









A pixelated, black and white graphic of the text "1. RINGE". The characters are rendered in a blocky, digital font style. The "1" is a simple vertical bar with a small horizontal base. The "R" and "I" are composed of thick, dark strokes with some lighter gray shading to give them a three-dimensional appearance. The "N" is formed by two thick diagonal strokes meeting at the top. The "G" is a thick, curved stroke. The "E" is a simple horizontal bar with three vertical strokes. The "R" and "I" are composed of thick, dark strokes with some lighter gray shading to give them a three-dimensional appearance. The "N" is formed by two thick diagonal strokes meeting at the top. The "G" is a thick, curved stroke. The "E" is a simple horizontal bar with three vertical strokes.

Q1

—
—

Q1

Q1



100% Approved

$$\left\{ \begin{array}{l} Y_3(s) = Y_2(s)/s \Rightarrow Y_2(s) = Y_3(s)s \\ Y_2(s) = Y_1(s)/s \Rightarrow Y_1(s) = Y_2(s)s = Y_3(s)s^2 \\ Y_1(s) = Y_0(s)/s \Rightarrow Y_0(s) = Y_1(s)s = Y_3(s)s^3 \end{array} \right.$$

$$V_0(s) = X(s) + K_1 V_1(s) + K_2 V_2(s)$$

$$Y(s) = Y_0(s) + K_1 Y_1(s) + K_2 Y_2(s) + K_3 Y_3(s) = (s^3 + K_1 s^2 + K_2 s + K_3) Y_3(s)$$

$$H(s) = \frac{Y_3(s)}{X(s)} = \frac{1}{s^3 + k_1 s^2 + k_2 s + k_3}$$

$$\begin{cases} Y_2(s) = -c_2 Y_1(s)/s \Rightarrow Y_1(s) = -s Y_2(s)/c_2 \\ Y_1(s) = -c_1 Y_0(s)/s \Rightarrow Y_0(s) = -s Y_1(s)/c_1 = s^2 Y_2(s)/c_1 c_2 \\ Y_0(s) = k_0 X(s) + k_1 Y_1(s) + k_2 Y_2(s) \end{cases}$$

$$\frac{s^2}{c_1 c_2} Y_2(s) = k_0 X(s) + k_1 \left(-\frac{s}{c_2} \right) Y_2(s) + k_2 Y_2(s)$$

$$H(s) = \frac{Y_2(s)}{X(s)} = \frac{k_o}{\frac{s^2}{c_1 c_2} + \frac{s}{c_2} - k_2} = \frac{k_o c_1 c_2}{s^2 + k_1 c_1 s - c_1 c_2 k_2}$$



$$H(s) = k_0 \frac{c^2}{s^2 + ck_1s - k_2c^2}$$

$$H(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$









$$v = v + jv = |v|e^{jv}$$

2023 + 2024 = 2024

$$\begin{cases} |v| = \sqrt{u^2 + v^2}, & \angle v = \tan^{-1}(v/u) \\ |z| = \sqrt{x^2 + y^2}, & \angle z = \tan^{-1}(y/x) \end{cases}$$

$$vz = (v + jv)(x + jy) = |v|e^{j\angle v}|z|e^{j\angle z}$$

$$|vz| = |v|z, \quad e^j \angle v e^j \angle z = e^j \angle (v + z), \quad \text{or } \angle(vz) = \angle v + \angle z$$

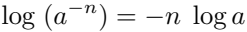
$$\frac{w}{z} = \frac{x + jv}{x + jy} = \frac{|w|e^{j\angle w}}{|z|e^{j\angle z}}$$

$$\left| \frac{w}{z} \right| = \frac{|w|}{|z|}, \quad \frac{e^{j\angle w}}{e^{j\angle z}} = e^{j(\angle w - \angle z)}, \quad \text{or} \quad \angle \left(\frac{w}{z} \right) = \angle w - \angle z$$

$$\log_{10} \left(\frac{100}{100} \right) = \log_{10} 1$$

log₁₀ = log₁₀

100% 100% 100%













$$Z = \frac{V}{I} = \frac{v_m e^{j\phi}}{i_m e^{j\psi}} = \frac{v_m}{i_m} e^{j(\phi - \psi)}$$







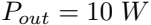


$$V e^{j\omega t} = L \frac{d}{dt} [I e^{j\omega t}] = j\omega L I e^{j\omega t} \text{ i.e. } Z_L = \frac{V}{I} = \frac{j\omega L I}{I} = j\omega L$$



$$Ie^{j\omega t} = C \frac{d}{dt} [Ve^{j\omega t}] = j\omega CVe^{j\omega t} \quad \text{i.e.} \quad Z_C = \frac{V}{I} = \frac{V}{j\omega CV} = \frac{1}{j\omega C}$$

$$Z_R = \frac{V}{I} = \frac{v_m e^{j\phi}}{i_m e^{j\phi}} = \frac{v_m}{i_m} = R$$



$$L_B = \log_{10} \frac{P_{out}}{P_{in}} = \log_{10} \frac{10}{0.1} = \log_{10} 100 = 2 \text{ bel}(B)$$

$$L_B = \log_{10} \frac{P_{out}}{P_{in}} = \log_{10} 100 = 2 \text{ } B = 20 \text{ } dB, \quad \text{or} \quad L_{dB} = 10 \log_{10} \frac{P_{out}}{P_{in}} = 20 \text{ } dB$$

$$L_B = \log_{10} \frac{P_{out}}{P_{in}} = \log_{10} 10000 = 3 \text{ } B = 30 \text{ } dB, \quad \text{or} \quad L_{dB} = 10 \log_{10} \frac{P_{out}}{P_{in}} = 30 \text{ } dB$$



1990-2020

$$\frac{P_{out}}{P_{in}} = 10^{L_{dB}/10} = 10^{30/10} = 10^3, \text{ i.e. } P_{out} = 10^3 P_{in} = 1,000 P_{in}$$

W 202

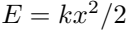
10-12 WPA 2



102 WPA 2

THE UNIVERSITY OF CHICAGO

123456789



$$L_{dB} = 10 \log_{10} \frac{V_{out}^2}{V_{in}^2} = 20 \log_{10} \frac{V_{out}}{V_{in}} \text{ dB}$$

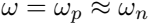
$$20 \log_{10} \frac{V_{out}}{V_{in}} = 20 \log_{10} \frac{1,0000}{10} = 40 \text{ dB}$$

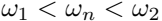
$$20 \log_{10} \frac{V_{out}}{V_{in}} = 20 \log_{10} \frac{10,000}{10} = 60 \text{ dB}$$

1990-2020

$$\frac{V_{out}}{V_{in}} = 10^{L_{dB}/20} = 10^{60/20} = 10^3, \text{ i.e., } V_{out} = 10^3 V_{in} = 1,000 V_{in}$$

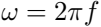






$$|H(j\omega_1)|^2 = |H(j\omega_2)|^2 = \frac{1}{2} |H(j\omega_p)|^2 \text{ i.e., } |H(j\omega_{1,2})| = 0.707 |H(j\omega_p)|$$

$$20 \log_{10} \left(\frac{|H(j\omega_{1,2})|}{|H(j\omega_p)|} \right) = 20 \log_{10} 0.707 = -3.01 \text{ dB} \approx -3 \text{ dB}$$



$$H(\omega) = |H(\omega)| \angle H(\omega) = |H(\omega)| \angle H(\omega)$$

1960





1992-2001



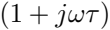


$$\left\{ \begin{array}{ll} Lm(H_1 H_2) = Lm H_1 + Lm H_2, & \angle(H_1 H_2) = \angle H_1 + \angle H_2 \\ Lm(H_1 / H_2) = Lm H_1 - Lm H_2, & \angle(H_1 / H_2) = \angle H_1 - \angle H_2 \\ Lm H^n = n Lm H, & \angle H^n = n \angle H \\ Lm(1/H) = -Lm H, & \angle(1/H) = -\angle H \end{array} \right.$$









$$\begin{aligned}
 & \left(\frac{1}{2} \frac{d^2}{dt^2} + \frac{1}{2} \frac{d^2}{dx^2} \right) \psi = 0 \\
 & \left(\frac{1}{2} \frac{d^2}{dt^2} + \frac{1}{2} \frac{d^2}{dx^2} \right) \psi = 0
 \end{aligned}$$

$$H(j\omega) = \frac{N(j\omega)}{1 + j\omega T}$$

$$H(j\omega) = \frac{N(j\omega)}{(j\omega)^2 + 2\zeta\omega_n j\omega + \omega_n^2} = \frac{N(j\omega)}{(\omega_n^2 - \omega^2) + j(2\zeta\omega_n\omega)}$$

$$\begin{cases} \text{If } k > 0, & k = |k|e^{j0}, & \operatorname{Lm} k = 20 \log_{10} |k|, & \angle k = 0 \\ \text{If } k < 0, & k = -|k| = |k|e^{j\pi}, & \operatorname{Lm} k = 20 \log_{10} |k|, & \angle k = \pi \end{cases}$$

$$\operatorname{Im} e^{j\omega T} = 20 \log_{10} |e^{j\omega T}| = 20 \log_{10} 1 = 0, \quad \angle e^{j\omega T} = \pm \omega T$$



$$\operatorname{Im}(j\omega) = 20 \log_{10} \omega \text{ dB}, \quad \angle(j\omega) = \frac{\pi}{2}$$



1m1=20101=011

$$\ln(w) = 20 \log_{10} w = 20 \log_{10} w = 20 \log_{10} w = \ln(w)$$



www.mma2

120px



$\ln v^2 = 40 \log_{10} v, \quad \ln v^2 = \pi$







1992-1993

$$\operatorname{Im}(j\omega)^{-1} = -\operatorname{Im}(j\omega) = -20 \log_{10} \omega \text{ dB}, \quad \angle(j\omega)^{-1} = -\angle(j\omega) = -\frac{\pi}{2}$$

1234



$$1 + j\omega\tau = \sqrt{1 + (\omega\tau)^2} e^{j \tan^{-1}(\omega\tau)} = \sqrt{1 + (\omega\tau)^2} \angle \tan^{-1}(\omega\tau)$$

$$\text{Im}(1+j\omega\tau) = 20 \log_{10} \sqrt{1+(\omega\tau)^2} = 20 \log_{10}(1+(\omega\tau)^2)^{1/2} = 10 \log_{10}(1+(\omega\tau)^2)$$

$$\frac{d}{dx} \left(x^2 + \frac{1}{x} \right) = 2x - \frac{1}{x^2}$$

$$\angle m(1+j) = 20 \log_{10} \sqrt{1^2 + 1^2} = 20 \log_{10} 0.707 \approx 3.01 \text{ dB}, \quad \angle(1+j) = \frac{\pi}{4}$$





$$\ln(1+jv) \approx 10 \lg_{10}(1) = 0, \quad \angle(1+jv) \approx \angle(1) = 0$$



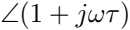


$$\angle m(1+j\omega\tau) \approx 20 \log_{10}(\omega\tau), \quad \angle(1+j\omega\tau) \approx \angle(j\omega\tau) = \frac{\pi}{2}$$

$x^2 + x + 1$













$$\frac{1}{1 + \exp(-x)} = \frac{1}{1 + \exp(-x)}$$

$$\ln(1+j\omega\tau)^{-1} = \ln(1+j\omega\tau) = -10 \log_{10}(1+(\omega\tau)^2)$$

$$\angle(1 + j\omega) - 1 = \angle(1 + j\omega) - 1$$

1.1 + 2.2 = 3.3





$$H(j\omega) = \frac{1}{(j\omega)^2 + 2\zeta\omega_n j\omega + \omega_n^2} = \frac{1}{(\omega_n^2 - \omega^2) + 2\zeta\omega_n j\omega} = \frac{\frac{1}{\omega_n^2}}{1 - \left(\frac{\omega}{\omega_n}\right)^2 + j2\zeta\frac{\omega}{\omega_n}}$$

$$\Delta = b^2 - 4ac = 2^2 - 4 \cdot 1 \cdot (-1) \geq 0$$



$$p_1, p_2 = \left(\pm \sqrt{p_2^2 - 1} \right) \omega \pi \omega 0$$

$$H(j\omega) = \frac{1}{(j\omega - p_1)(j\omega - p_2)} = \frac{1/p_1 p_2}{(j\omega/p_1 - 1)(j\omega/p_2 - 1)} = \frac{\tau_1}{1 + j\omega\tau_1} \frac{\tau_2}{1 + j\omega\tau_2} = H_1(j\omega)H_2(j\omega)$$

1234567890

12345678

$$I_m(A_1A_2) = I_m(A_1) + I_m(A_2), \quad I(A_1A_2) = I(A_1) + I(A_2)$$

we are 121

A pixelated, grayscale image of the text "w e 1". The characters are rendered in a blocky, digital font style. The 'w' and 'e' are on the left, followed by a space, then the number '1' on the right. The image has a low-resolution, dithered appearance.

A pixelated, grayscale illustration of a stylized, abstract shape resembling a lowercase 'e' or a similar character. The shape is composed of many small squares, creating a jagged, blocky appearance. It features a horizontal bar at the top and a vertical stem on the right side, with a small loop at the bottom. The overall style is reminiscent of early digital art or video game graphics.

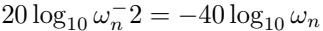
Figure 1 consists of two horizontal bar charts. The top chart is titled 'How often do you use the Internet?' and shows the distribution of responses for 'Daily', 'Weekly', 'Monthly', and 'Never'. The bottom chart is also titled 'How often do you use the Internet?' and shows the distribution of responses for 'Daily', 'Weekly', 'Monthly', and 'Never'.

How often do you use the Internet?	Percentage
Daily	75%
Weekly	15%
Monthly	5%
Never	5%

How often do you use the Internet?	Percentage
Daily	75%
Weekly	15%
Monthly	5%
Never	5%

A pixelated, black and white graphic of a stylized 'P' and 'A'. The 'P' is on the left, and the 'A' is on the right. Both letters are composed of a grid of black and white pixels, giving them a blocky, digital appearance. The 'P' has a thick vertical stem and a curved top. The 'A' has a triangular shape with a horizontal crossbar. The overall style is reminiscent of early computer graphics or video game sprites.

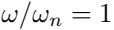




$$|H(j\omega)| = \left[\left(1 - \left(\frac{\omega}{\omega_n} \right)^2 \right)^2 + \left(2\zeta \frac{\omega}{\omega_n} \right)^2 \right]^{-1/2}$$

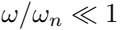
$$\text{Im} H(j\omega) = 20 \log_{10} |H(j\omega)| = -10 \log_{10} \left[\left(1 - \left(\frac{\omega}{\omega_n} \right)^2 \right)^2 + \left(2\zeta \frac{\omega}{\omega_n} \right)^2 \right]$$

$$\angle H(j\omega) = -\tan^{-1} \frac{2\zeta\omega/\omega_n}{1 - (\omega/\omega_n)^2}$$



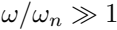
1920-1920

$$\operatorname{Im} H(j\omega) = -20 \log_{10} 2\zeta, \quad \angle H(j\omega) = -\frac{\pi}{2}$$





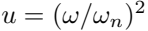
$$\ln A(\omega) - 10 \log_{10}(1) = 0, \quad \angle A(\omega) = 0^\circ$$



$$\operatorname{Im} H(j\omega) \approx -10 \log_{10} \left[\left(\frac{\omega}{\omega_n} \right)^4 \right] = -40 \log_{10} \frac{\omega}{\omega_n}$$

$$\angle H(j\omega) \approx -\tan^{-1} 2\omega/\omega \approx -\tan^{-1}(-0) = -\pi = -180^\circ$$

$$|H(j\omega)| = \frac{1}{\sqrt{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + 4\zeta^2 \frac{\omega^2}{\omega_n^2}}} = \frac{1}{\sqrt{(1-u)^2 + 4\zeta^2 u}}$$







$$|H(j\omega_n)| = \frac{1}{2\zeta} = Q$$





$$\frac{d}{dv} [v^2 + (4c^2 - 2)v + 1] = 2v + 4c^2 - 2 = 0$$

$$u = \frac{\omega^2}{\omega_n^2} = 1 - 2\zeta^2, \text{ i.e., } \omega = \omega_n \sqrt{1 - 2\zeta^2} < \omega_n$$



$$|H(j\omega_p)| = \frac{1}{2\zeta\sqrt{1-\zeta^2}} > \frac{1}{2\zeta} = |H(j\omega_n)|$$







$$H_C(j\omega) = \frac{V_C}{V_{in}} = \frac{Z_C}{Z_R + Z_C} = \frac{1/j\omega C}{R + 1/j\omega C} = \frac{1}{j\omega RC + 1} = \frac{1}{j\omega\tau + 1}$$



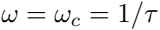
$$H_R(j\omega) = \frac{V_R}{V_{in}} = \frac{Z_R}{Z_R + Z_C} = \frac{R}{R + 1/j\omega C} = \frac{j\omega RC}{j\omega RC + 1} = \frac{j\omega\tau}{j\omega\tau + 1}$$

1990

$$H_R(j\omega) = \frac{1}{j\omega\tau + 1} j\omega\tau$$

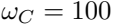
150000

$$\ln H_R(j\omega) = 20 \log_{10} \left| \frac{1}{j\omega\tau + 1} \right| + 20 \log_{10} |j\omega\tau| = \ln H_C(j\omega) + 20 \log_{10}(\omega\tau)$$



$$\angle H_R(j\omega) = \angle \left(\frac{1}{j\omega\tau + 1} \right) + \angle j\omega\tau = \angle H_c(j\omega) + \frac{\pi}{2}$$







1990-1991



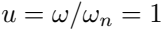
$$\frac{V_c}{V_{in}} = \frac{Z_c}{Z_L + Z_R + Z_c} = \frac{1/j\omega C}{j\omega L + R + 1/j\omega C} = \frac{1}{(j\omega)^2 LC + j\omega RC + 1}$$

$$\frac{1/LC}{(j\omega)^2 + j\omega R/L + 1/LC} = \frac{\omega_n^2}{(j\omega)^2 + 2\zeta\omega_n j\omega + \omega_n^2} = \frac{1}{\left(1 - \frac{\omega^2}{\omega_n^2}\right) + j2\zeta \frac{\omega}{\omega_n}}$$

$$\omega_n = \frac{1}{\sqrt{LC}},$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}$$

$$|H_c(j\omega)| = \frac{1}{\sqrt{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + 4\zeta^2 \frac{\omega^2}{\omega_n^2}}} = \frac{1}{\sqrt{(1-u)^2 + 4\zeta^2 u}}$$



1990

$$\frac{V_R}{V_{in}} = \frac{Z_R}{Z_L + Z_R + Z_C} = \frac{R}{j\omega L + R + 1/j\omega C} = \frac{j\omega RC}{(j\omega)^2 LC + j\omega RC + 1}$$

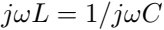
$$\frac{j\omega R/L}{(j\omega)^2 + j\omega R/L + 1/LC} = \frac{2\zeta\omega_n j\omega}{(j\omega)^2 + 2\zeta\omega_n j\omega + \omega_n^2} = H_0(j\omega) 2\zeta\omega_n j\omega$$

$$\ln H_R(j\omega) = \ln H_c(j\omega) + \ln(2\omega j\omega) \quad \ln H_R(j\omega) = \ln H_c(j\omega) + \ln(2\omega j\omega)$$

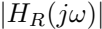
2010 2010



2 + 2 = 4



A pixelated, black and white representation of the mathematical expression $1/x = 1/x$. The image is composed of several distinct parts: a '1' on the left, followed by a horizontal line representing a fraction bar, then an 'x' in the denominator. This is followed by an equals sign, another horizontal fraction bar, another '1', and a final 'x' in the denominator. The entire image is rendered in a low-resolution, pixelated style using shades of gray and black on a white background.





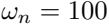


$$\frac{V_L}{V_{in}} = \frac{Z_L}{Z_L + Z_R + Z_C} = \frac{j\omega L}{j\omega L + R + 1/j\omega C} = \frac{(j\omega)^2 LC}{(j\omega)^2 LC + j\omega RC + 1}$$

$$\frac{(j\omega)^2}{(j\omega)^2 + j\omega R/L + 1/LC} = \frac{(j\omega)^2}{(j\omega)^2 + 2\zeta\omega_n j\omega + \omega_n^2} = H_0(j\omega) \frac{(j\omega_n)^2}{(j\omega_n)^2 + 2\zeta\omega_n j\omega + \omega_n^2}$$

$$\ln H(j\omega) = \ln H_c(j\omega) + \ln(j\omega)^2 = \angle H_c(j\omega) + \angle(j\omega)^2$$

2010s 2010s





2019-2020 = 2019-2020

20log10(20log10,000=80

$$H(j\omega) = \frac{Z_2(j\omega)}{Z_1(j\omega)} = \frac{R_2 || 1/j\omega C_2}{R_1 + 1/j\omega C_1} = \frac{R_2/(1 + j\omega R_2 C_2)}{(1 + j\omega R_1 C_1)/j\omega C_1} = \frac{j\omega \tau_3}{(1 + j\omega \tau_1)(1 + j\omega \tau_2)}$$

