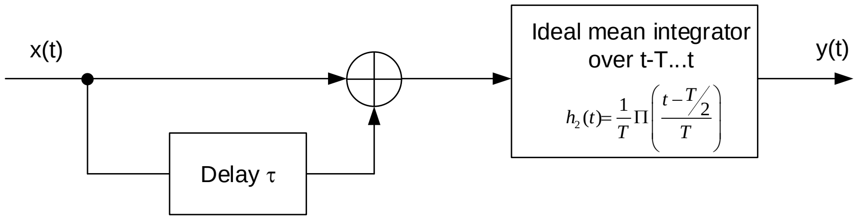
# COMMUNICATION THEORY, Class Exercise 2, Fall 2023

1. Derive the impulse response $h(t)$ and the frequency response or transfer function $H(f)$ of the following LTI system, and investigate how the results vary depending on the values of the delay $\tau$ and the integrating window $T$.




2. An LTI transmission channel has the following frequency response for $f_{MHz} \geq 0$, where $K = 3$ and $t_d = 0.04$ µs. Note that here the frequency domain is expressed in MHz.

$$H(f_{MHz}) = \begin{cases} Ke^{-j20\pi t_d} & f_{MHz} < 10\ MHz \\ K\left|\cos\left[\frac{6\pi}{70}(f_{MHz}-10)\right]\right| e^{-j2\pi f_{MHz} t_d} & 10\ MHz \leq f_{MHz} < 30\ MHz \\ K\left|\cos\left(\frac{6\pi}{7}\right)\right| e^{-j2\pi f_{MHz} t_d} & f_{MHz} \geq 30\ MHz \end{cases}$$

a) Assuming the channel impulse is real-valued, find the frequency response at $f_{MHz} < 0$

b) Determine at which frequencies the channel causes either amplitude or phase linear distortion, and whether it causes any non-linear distortion

3. A sinusoidal signal $a\cdot\cos(2\pi f_0 t)$ with frequency $f_0 = 1$ kHz and amplitude $a$ either 0.5 V or 1.0 V is used as the input $x(t)$ of a non-linear device, which is described by the following input-output response:

$$y(t) = 12x(t) - 3x^2(t) + x^3(t)$$

The output signal $y(t)$ is then filtered by an RC-lowpass filter described by it frequency response $H_{RC}(f) = \dfrac{1}{1 + j2\pi fRC}$ , with parameters $R = 1$ kΩ, $C = 0.500$ mF.

a) Find which harmonics of the original frequency $f_0$ appear in the output signal $y(t)$

b) Calculate the distortion coefficients associated to the harmonics and the total harmonic distortion factor (THD) of the filtered output signal, as per the following definitions:

- distortion coefficients $d_2 = \left|A_{2f_0}\right| / \left|A_{f_0}\right|,\ d_3 = \left|A_{3f_0}\right| / \left|A_{f_0}\right|, \ldots$
  with $A_f$ denoting the amplitude of a frequency component $f$
- total harmonic distortion factor $THD = \sqrt{d_2^2 + d_3^2 + \ldots}$