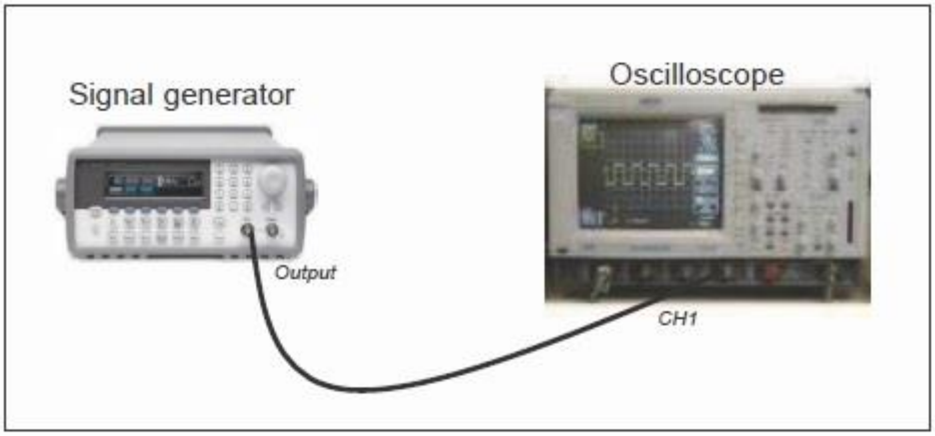
Characterization of periodic signals and linear systems (LTI)

Connect the output of signal generator with the input of the oscilloscope (CH1) through the BNC-BNC cable, according to the below figure.



Set the DC mode coupling on the oscilloscope.

FIRST PART: Time and frequency domain characterization of a sine signal.

I. Generation and observation of the sine signal in time domain.
   - Select the sine signal on the signal generator (push the sine button);
   - Set the following values: $f_0 = 1KHz, V_{pp} = 1V, V_{offset} = 0$;
   - Push the output button to enable the signal generation;
   - Observe the waveform on the oscilloscope.

Compare the nominal parameters with those measured on the oscilloscope (use the cursor button to carry out the measure).

II. Characterization of the sine signal in the frequency domain.
   - Set the FFT operation on the oscilloscope (math menu →operation:FFT) and observe the output referring to the frequency domain.

Questions: given $f_0 = 1KHz$, how many spectral lines do you observe? At which frequencies? What happens varying f_0?

III. Variation of the signal offset
   - Change the value of the offset and repeat the above described steps (I and II).

Question: are there any differences, with respect to the previous case, in time and frequency domains?

SECOND PART: Time and frequency domain characterization of a train of rectangular pulses.

I. Generation and observation of the signal
  - Select the train of rectangular pulses on the signal generator (push the square button);
  - Set the values: $f_0 = 1KHz, V_{pp} = 1V, V_{offset} = 0; duty\ cycle(d) = 50\%$
  - Push the output button to enable the signal generation;
  - Observe the waveform on the oscilloscope.

II. With reference to the generated signal, evaluate analytically the Fourier coefficients (c_n) and complete the table. Remember that:

$$x(t) = \sum_{n=-\infty}^{\infty} c_n e^{j2\pi n f_0 t}$$

Where

$$c_n = \begin{cases} V_{offset}, & n = 0 \\ Ad\ sinc(nd) = Ad\frac{\sin(\pi nd)}{\pi nd}, & n \geq 1 \end{cases}$$

Frequency [KHz]	Analytical Fourier coefficients	Measured coefficients
	$c_0 =$	$c_0 =$
	$c_1 =$	$c_1 =$
	$c_2/c_1 =$	$c_2/c_1 =$
	$c_3/c_1 =$	$c_3/c_1 =$
	$c_4/c_1 =$	$c_4/c_1 =$
	$c_5/c_1 =$	$c_5/c_1 =$

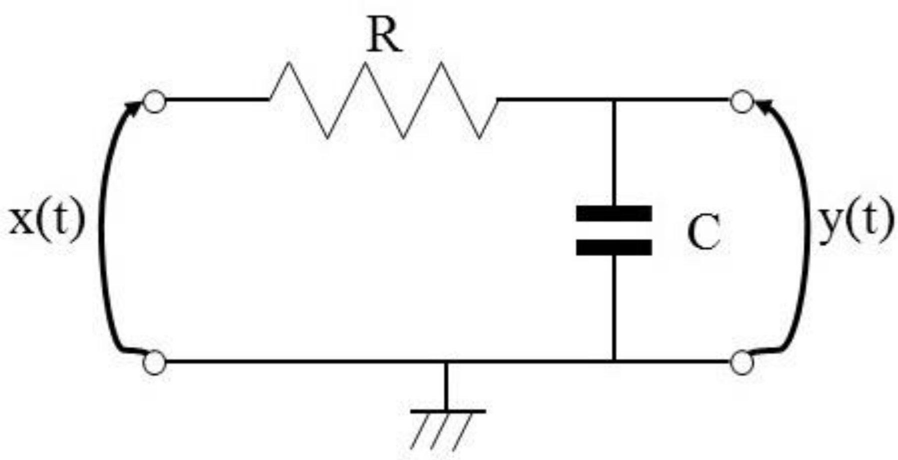
III. Complete the table with the characterization of the signal in frequency domain.
  - Set the FFT operation mode on the oscilloscope (math menu →operation:FFT) and compare the measured spectral lines with those analytically founded. The displayed values on the oscilloscope are normalized over the background noise (dB values), divide by the first coefficient to provide a direct comparison between the analytical coefficients and the ones measured on the oscilloscope.

IV. Variation of the signal parameters.
  - Change the offset of the signal ($V_{offset} = 0{,}5V$) and the frequency ($f_0 = 10KHz$).

Question: are there any differences, with respect to the previous case, in time and frequency domains?

THIRD PART: Using a breadboard to reproduce an RC low-pass filter as shown in the following figure. Select the cutoff frequency desired (in between 3-6 KHz) and calculate the relative resistance value if the capacitor has a capacity of $C = 10\,nF$.

$f_c = \quad KHz; \qquad R = \quad K\Omega$



Measure the amplitude and phase characteristics of the signals and the complete the following table, remember that:

- $H(f) = {}^{1}/_{1 + j2\pi fRC}$
- $f_c = {}^{1}/_{2\pi RC}$
- $x(t) = V_x \cos(2\pi ft + \varphi_x)$
- $y(t) = V_y \cos(2\pi ft + \varphi_y) = V_x|H(f)| \cos(2\pi ft + \varphi_x + \arg\{H(f)\}) = V_x|H(f)|\cos(2\pi f(t - \tau) + \varphi_x)$
- $|H(f)| = {}^{V_y}/_{V_x}$
- $\arg\{H(f)\} = \varphi_y - \varphi_x = -2\pi f\tau$

f [KHz]	V_x [V]	V_y [V]	$\lvert H(f)\rvert$	$\tau[us]$	arg{H(f)} [rad]
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Then use the Matlab script (rc.m) stored in the shared folder, insert the measured values and compare the ideal transfer function characteristics with previously measured values.

- Copy and paste the rc.m Matlab file to the desktop, use the copy of the file to perform the laboratory experience in order to do not modify the original file.
- To save the Matlab plot is possible to use “save as” in the file menu.
- Insert the range of frequency to be simulated in the code (line 25).
- Launch the code by pressing the run button.
- Delete the copy on the desktop at the end of the experience.