All'attenzione di Michele NORGIA

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Da:
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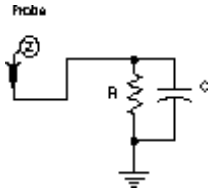
PROBLEM No.3 (Fall, 1999)

Your B=60 MHz oscilloscope has a 1 MΩ input resistance and is set at 1mV/div sensitivity. Because of Johnson noise $v_N = \sqrt{4\,kTRB}$, you should then expect to see a trace on the scope with $v_N = \sqrt{4 \cdot 40 \cdot 10^{-22} \cdot 60 \cdot 10^{-6} \cdot 1 \cdot 10^{6}} = 0.98\,mV\,rms$ noise, that should be clearly visible. How can you explain this? What is the correct expression of your noise voltage in this case?

Answer

We shall take account of the non-negligible effect of the input capacitance C across the 1 MΩ resistance, we have also a parasitic capacitance C, typically C=10 pF.



The parallel combination of R and C yields a high frequency cutoff much smaller than the oscilloscope measurement bandwith B. Because of this, the spectral density of noise is:

$$v_N^2(\omega) = (4\,kTR) \Big/ \left(1 + \frac{\omega^2}{\omega_{RC}^2}\right)$$

where $\frac{\square}{\omega_{RC}} = \frac{1}{RC}$ is the high frequency cutoff of the RC-group. By integrating $v_N^2(\omega)$ from f=0 to f=∞ we get for the total voltage noise seen at the input:

$$\square\ v_n = (4\,kTR)\int_0^\infty \left(1+\frac{\omega^2}{\omega_{RC}{}^2}\right)^{-1} df =$$

$$4\,kTR\omega_{RC}\int_0^\infty \left(1+\frac{\omega^2}{\omega_{RC}{}^2}\right)^{-1} d\left[\frac{\omega}{\omega_{RC}}\right] =$$

$$\frac{4\,kTR}{2\,\pi RC}\,\mathrm{ArcTan}\left[\frac{\omega}{\omega_{RC}}\right]_0^\infty = \frac{4\,kTR}{2\,\pi RC}\left(\frac{\pi}{2}\right) = \frac{kT}{C}$$

For example, using C=10 pF for the input capacitance we find:

$$v_n = \sqrt{\frac{k\,T}{C}} = \sqrt{\frac{40\cdot 10^{-22}}{10\cdot 10^{-12}}} = 0.02\ \mathrm{mV}$$

which is well below the scope sensitivity.

C−pF	v_n −mV
1	0.06
4.7	0.03
10	0.02
22	0.01

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La soluzione è disponibile in fomato notebook di *Mathematica* 4

Ho risolto il problema con mezzi esclusivamenet personali.

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