Phase Noise

There are also **short-term** instabilities (e.g., msec to μ**sec**) in oscillator **frequency**!

We can model these as:

$$v_c(t) = A_c \cos\left[\omega_0 t + \varphi_n(t)\right]$$

where the **relative** phase $\varphi_n(t)$ is a random process called **phase noise**.

Generally, this **random** process $\varphi_n(t)$ has a **very small** magnitude, *i.e.*:

$$\left|\varphi_n(t)\right| \ll 1$$

Q: *Gee, this looks a lot like **phase modulation**!*

A: Essentially, it **is**.

Phase noise causes the frequency to change

Note since the **phase changes** as a function of time, the **frequency** will as well! Specifically:

$$\omega(t) = \frac{d\left[\omega_0 t + \varphi_n(t)\right]}{dt} = \omega_0 + \frac{d\,\varphi_n(t)}{dt} = \omega_0 + \omega_n(t)$$

where:

$$\omega_n(t) = \frac{d\,\varphi_n(t)}{dt}$$

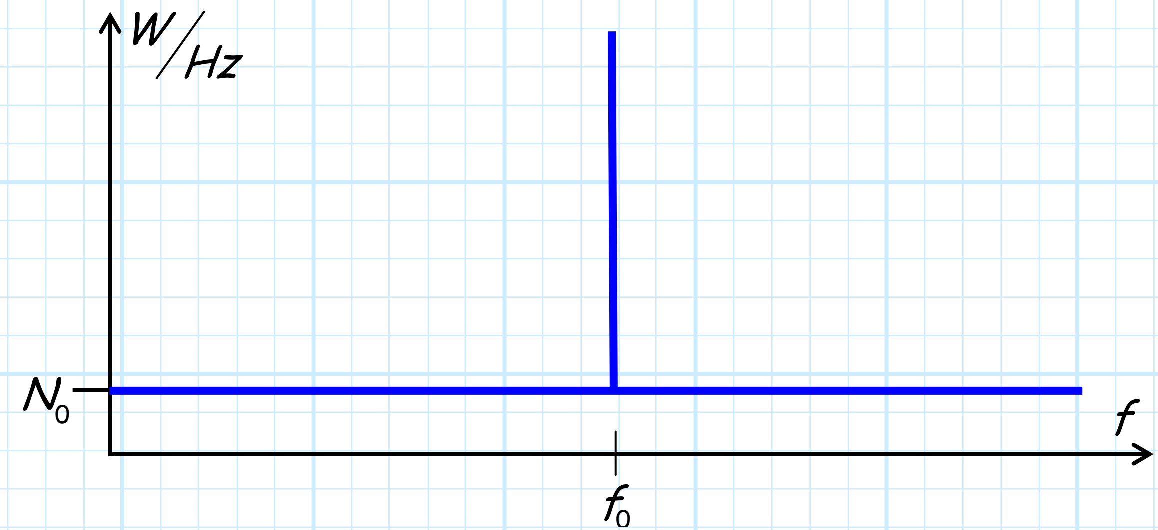
As a result, the **frequency** of the oscillator is also a **random** process.

$$\left\{ \text{In other words, the oscillator frequency changes } \textbf{randomly} \text{ as a function of time!} \right\}$$

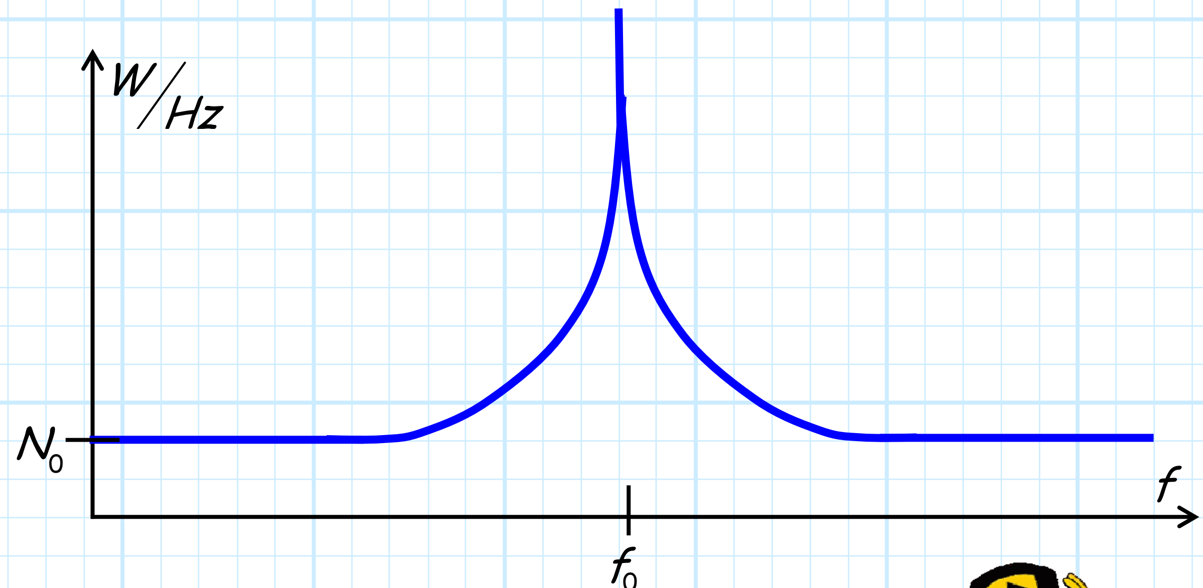
→ This random fluctuation **spreads** the oscillator signal **spectrum**.

Our spectrum is impure!

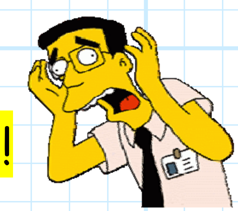
In other words, **instead** of the spectrum of a **perfect**, "pure" tone (plus the noise floor)…



…we find that **phase noise** causes a wider, **imperfect** spectrum:



→In this case, we say our oscillator is **spectrally impure**!

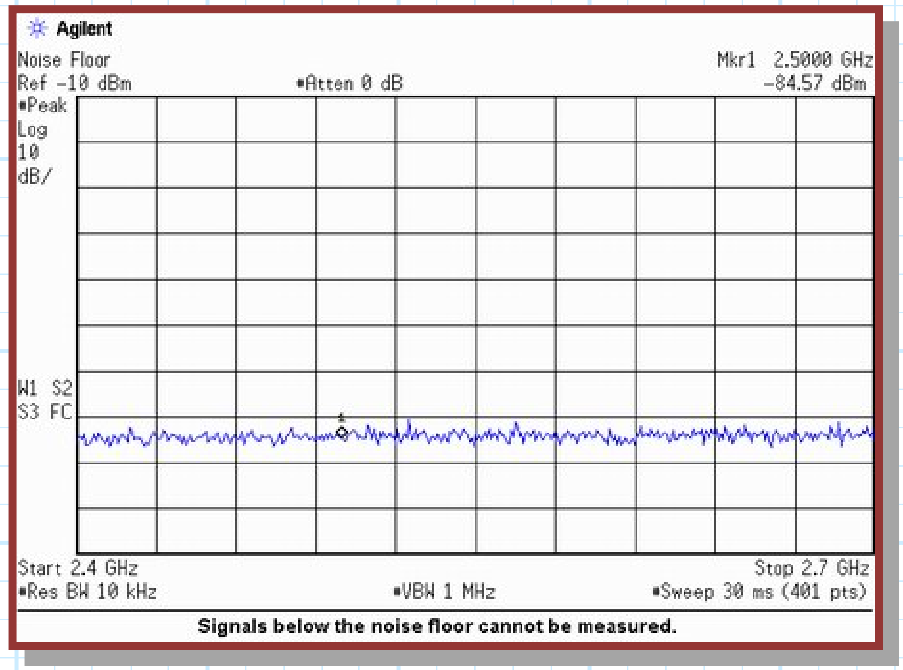


Phase noise is not white noise

Since the phenomenon of phase noise is a **random** process, we must describe the signal spectrum in terms of its **average** spectral power density N.

* Average **Spectral** Power Density expressed in units of ***mW/Hz***, or ***dBm/Hz***, or ***dBc/Hz***.

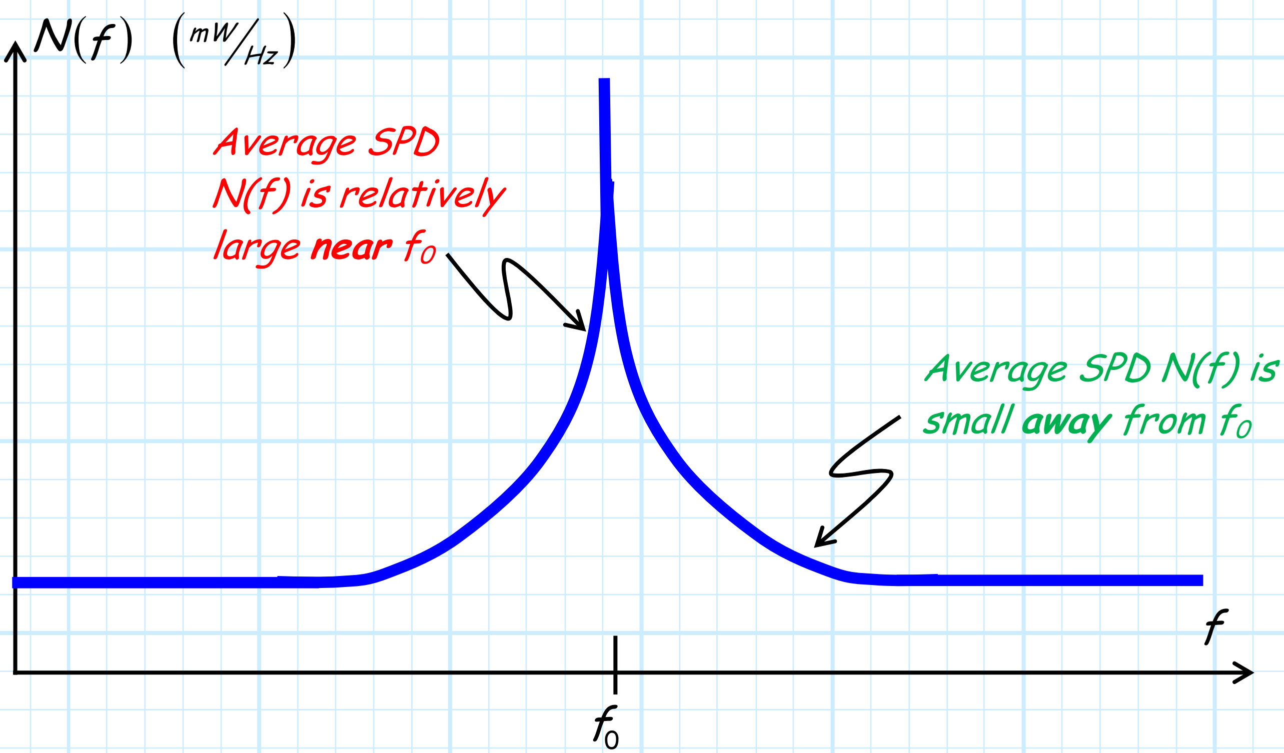
Recall for **white** noise, the spectral power density N is a **constant** with respect to frequency.



→However, for **phase** noise, the resulting spectral power density N **changes** as a **function** of frequency!

Noise increases as we approach f_0

Specifically, the average spectral power density of an oscillator **increases** as frequency f **nears** the nominal signal (i.e., **carrier**) frequency f_0.

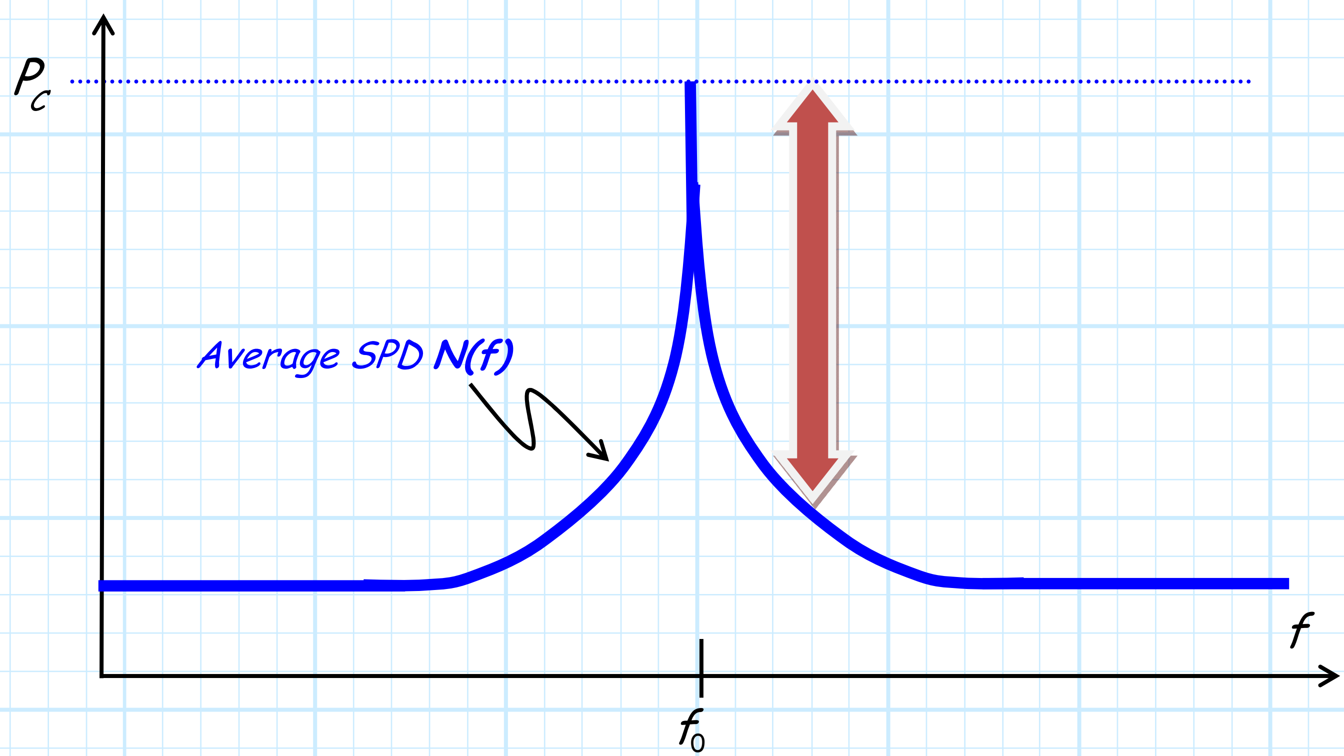


Recall we typically express average spectral power density in *mW/Hz* or ***dBm/Hz***…

Reference the noise to the carrier power

...but, we generally express the average spectral **power density** $N(f)$ of an oscillator output in ***dBc/Hz*** !

In other words, we are only concerned about the magnitude of the phase noise, **in comparison to the available oscillator signal power** P_c!

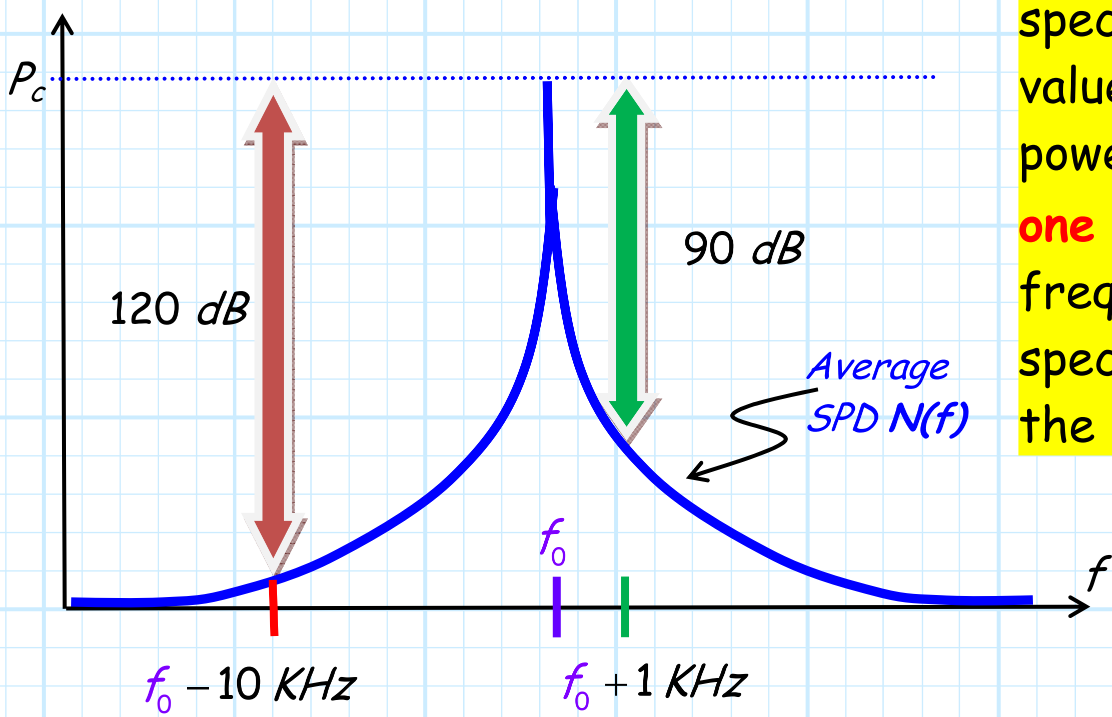


Specify at a few points

Q: *But phase noise results in an average spectral power density $N(f)$ that is a **function** of frequency f (i.e., $N(f) \neq N_0$!).*

*Must we then **explicitly** determine this function $N(f)$?*

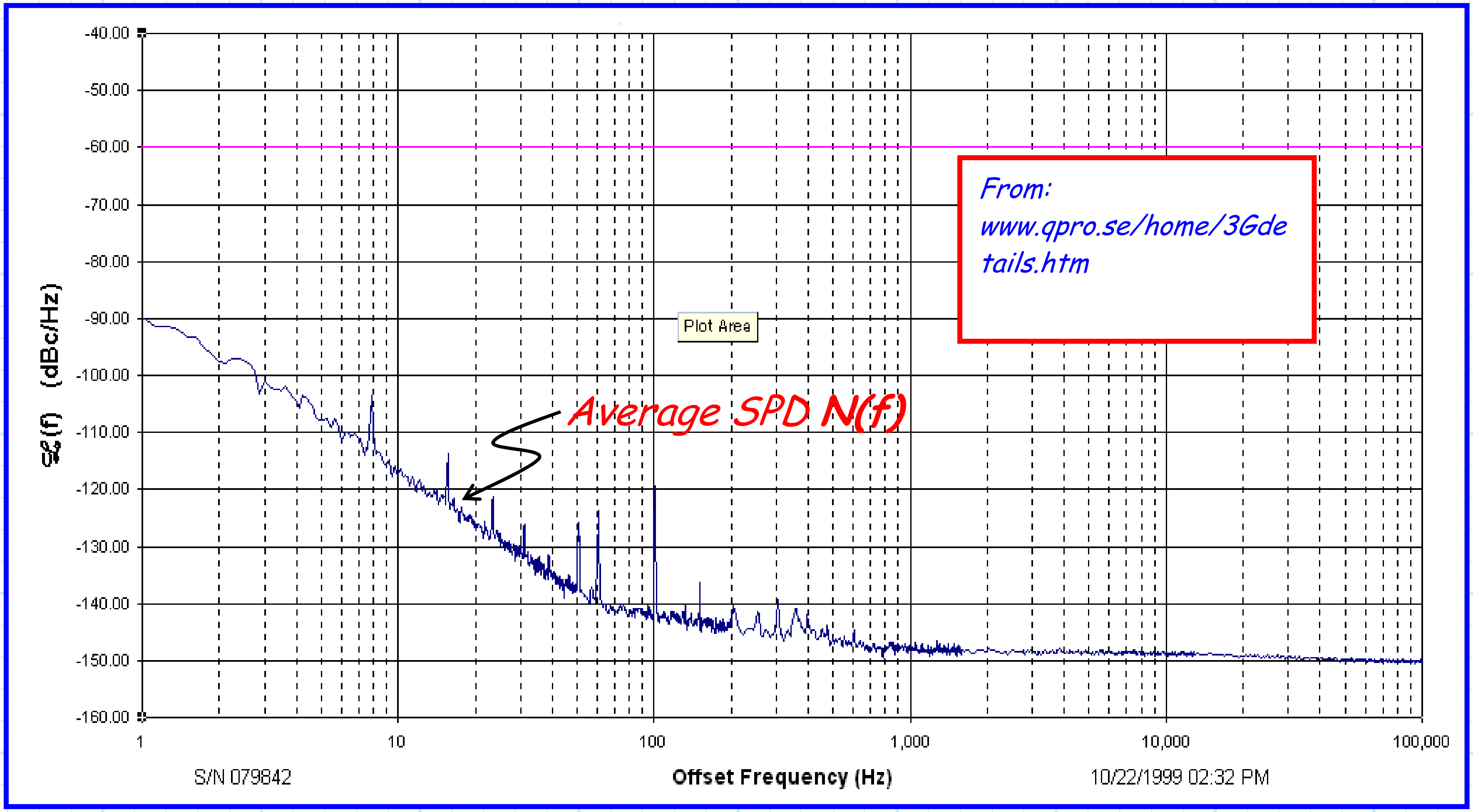
A: Generally speaking **no**.



Phase noise is generally specified by stating the value of the average noise power spectrum $N(f)$ at one or two specific frequencies—frequencies specified with **respect** to the carrier frequency f_0.

An example of phase noise

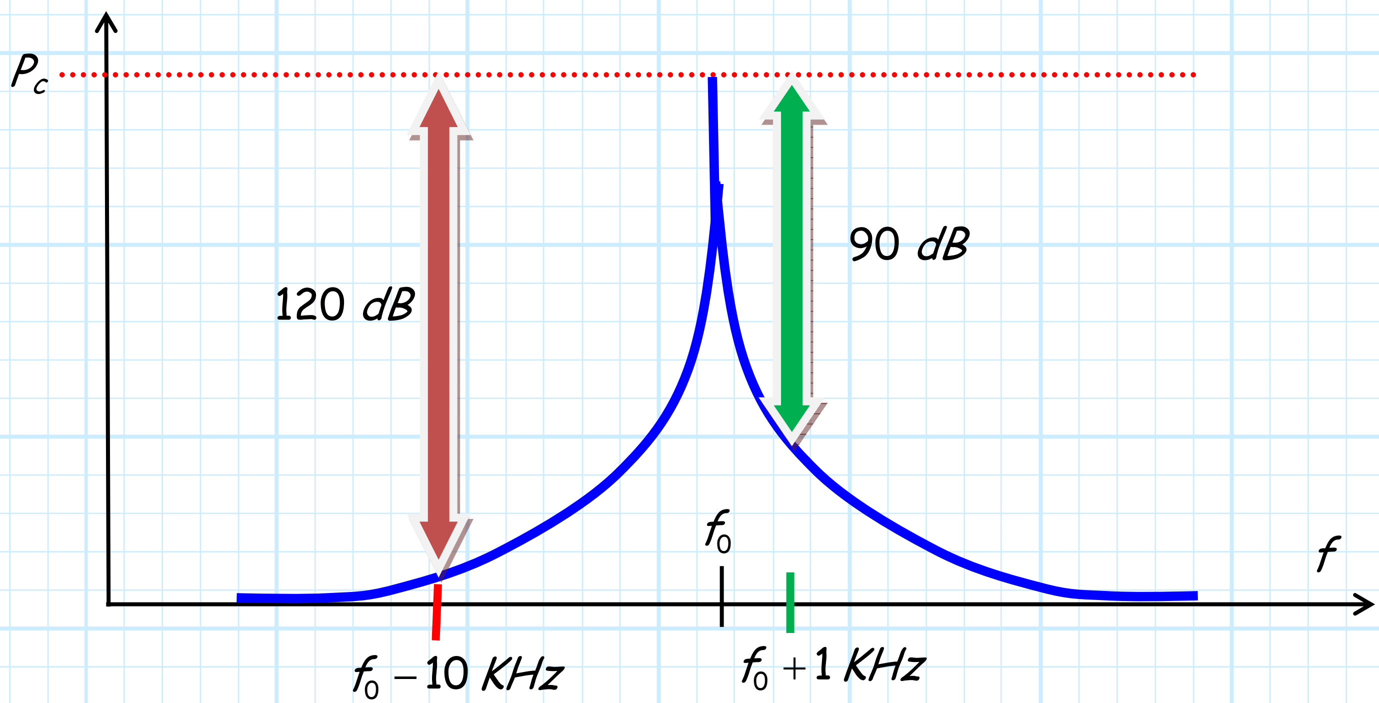
Typically, the frequencies where the phase noise is **specified** ranges from 1 *KHz* to 100 *KHz* **from the carrier** frequency f_0.



Make sure you do this correctly!

For example, a **typical** oscillator spec might say:

***"-90 dBc**, in a **1 Hz bandwidth**, at **1 KHz** from **the carrier**, and **-120 dBc**, in a **1 Hz bandwidth**, at **10 KHz** from the carrier."*



Make sure that **you** know how to proper specify the phase noise of an oscillator. It is **often** incorrectly done, and the source of many **lost points** on an exam or project!