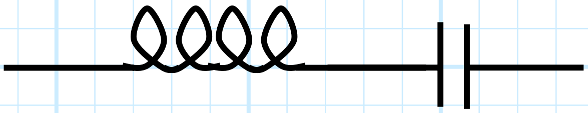
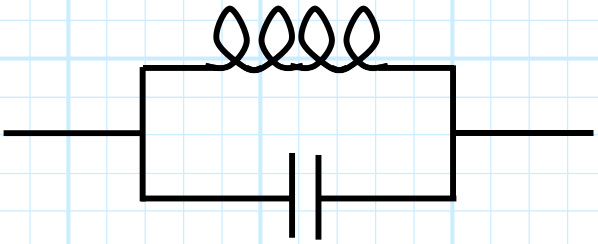
Oscillators

Generally speaking, we construct an oscillator using a **gain device** (e.g., a transistor) and a **resonator**.

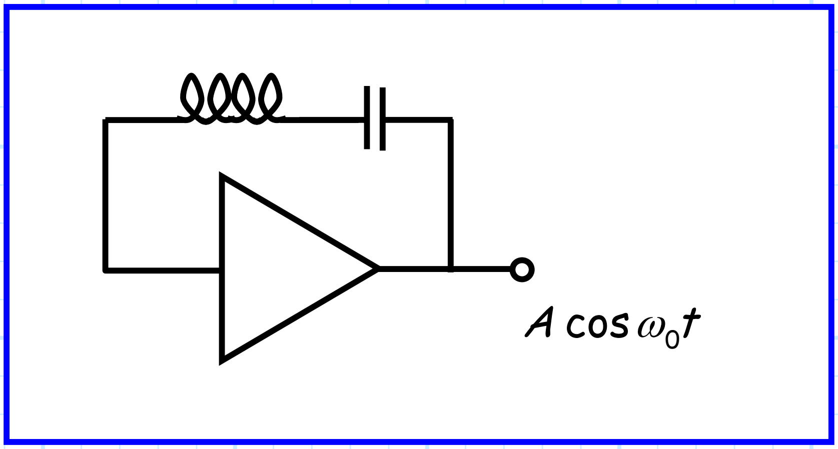
Examples of resonators include **LC networks**:



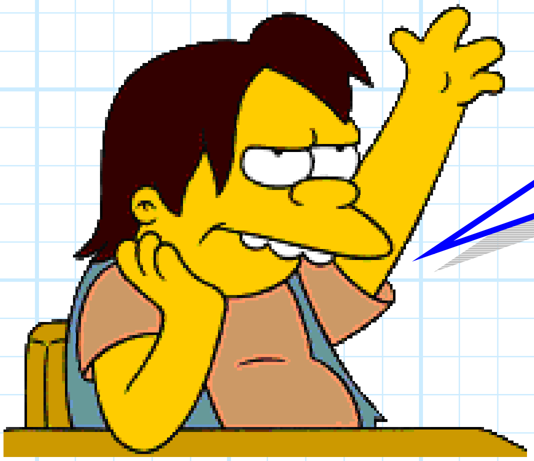
$$\omega_0 = \frac{1}{\sqrt{LC}}$$



To make an oscillator, we basically take the **output** of an amplifier and "feed it back" (i.e., feedback), **through** the resonator, to the **input** of the gain device.



Under the proper conditions, this device will be **unstable**—it will **oscillate**!



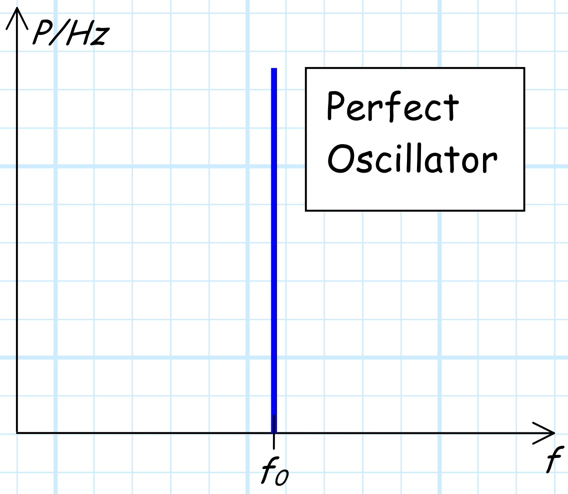
Q: *But at what signal* ***frequency*** *ω_0 will an oscillator oscillate?*

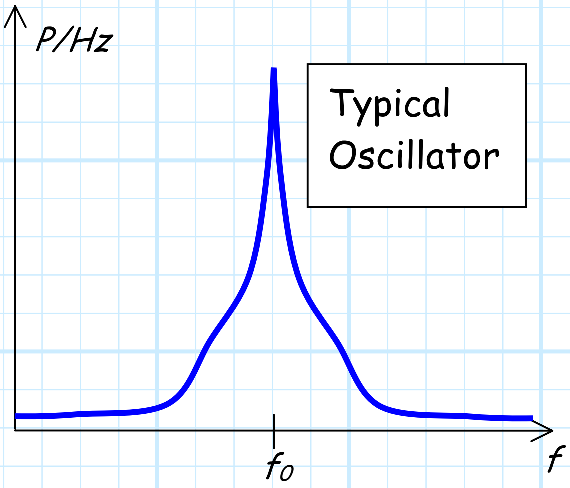
A: Every resonator has a **resonant frequency**. The oscillator will oscillate at **this** frequency!

The **good news:** a **perfect** resonator will resonate precisely at frequency ω_0.

The **bad news:** there are **no** perfect resonators! Therefore, the oscillating frequency of an oscillator is a bit **ambiguous**.

A **spectral analysis** (e.g., power vs. frequency) of an oscillator output reveals that energy is **spread** over a range of frequencies centered around ω_0, rather than **precisely** at frequency ω_0.





* The “bandwidth” of this output spectrum is related to the **quality** of the resonator.

* A **high-Q** resonator provides a spectrum with a **narrow** width (i.e., spectrally pure).

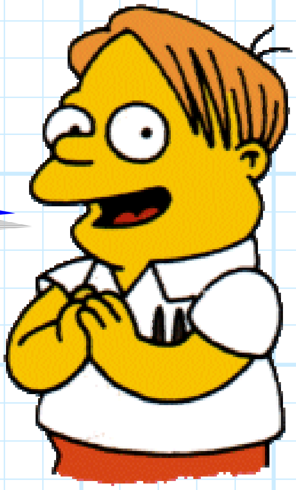
* A **low–Q** resonator provides an output with a **wider** spectral width.

* Generally, low-Q resonators are **lossy**, where as high-Q resonators ehibit **low loss**!

LC networks are generally quite lossy, and thus low-Q!

Q: *Yikes! Are there any high-Q resonators available for constructing microwave oscillators?*

A: *Of course! Among my favorite resonators are* ***crystals*** *and* ***dielectric cavities.***



Crystal Resonators: Like the name suggests, these devices are in fact **crystals** (e.g. Quartz). The resonant frequency of a crystal resonator is dependent on its **geometry** and its atomic **lattice** structure. These resonators are typically used for **RF** oscillators, where signal frequency is less than 2 GHz.

Dielectric Cavity Resonator – Cavity resonators have a resonant frequency that is dependent on the **cavity geometry**. **Dielectric** cavities are popular since they have low loss and can be made very **small**. Oscillators made with these devices are called **Dielectric Resonance Oscillators**, or **DROs**. Typically, these resonators will be used for **microwave** oscillators, at frequencies greater than 2 GHz

Transmission Line Resonator - We can also make a resonator out of **transmission line** sections. Typically, these are used in stripline or **microstrip** designs (as opposed to coaxial). Technically, these are **LC resonators**, as we utilize the inductance and capacitance of a transmission line. As a result, transmission line resonators typically have a **lower Q** than crystals or cavities, although they exhibit lower loss than "**lumped**" element LC resonators.

Q: *So, would we* ***ever*** *use a lumped LC network in a RF/microwave oscillator design?*

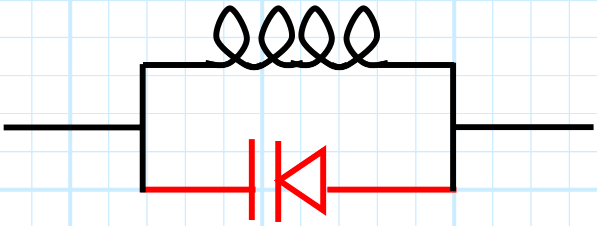
A: Actually, there is **one** application where we almost certainly **would**! The main drawback of the resonators described above is that they are **fixed**.

In other words they cannot be *tuned*!

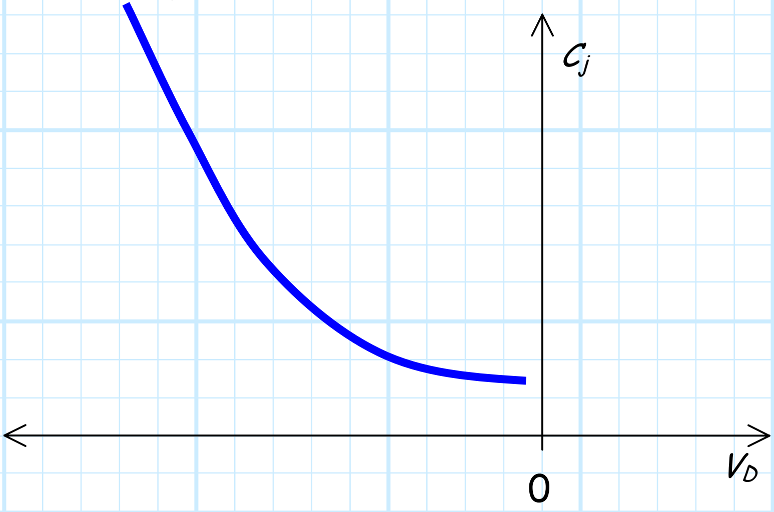
If we wish to **change** the oscillating frequency ω_0, we must change (i.e., **tune**) the resonator.

This is **tough** to do if the resonant frequency depends on the **size** or **shape** of the resonator (e.g., crystals and cavities)!

Instead, we might use a **lumped LC** network, where the capacitor element is actually a **varactor diode**:



A varactor diode is a *p-n* junction diode whose **junction capacitance** (C_j) varies as a function of **diode voltage** (v_D), when **reversed** biased. E.G.,:

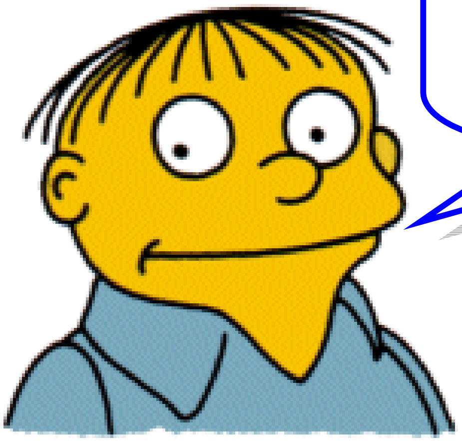


Thus, by **changing** the diode (reverse) bias voltage, we **change** the capacitance value, and thus **change** the resonate (i.e., oscillator) frequency:

$$\omega_0(v_D) = \frac{1}{\sqrt{L\,C(v_D)}}$$

We call these oscillators **Voltage Controlled Oscillators** (**VCOs**).

Q: *Just exactly why would we ever* ***want*** *to change an oscillator's frequency ?*



A: We'll soon discover that a **tunable** oscillator is a critical component in a **super-heterodyne** receiver design!