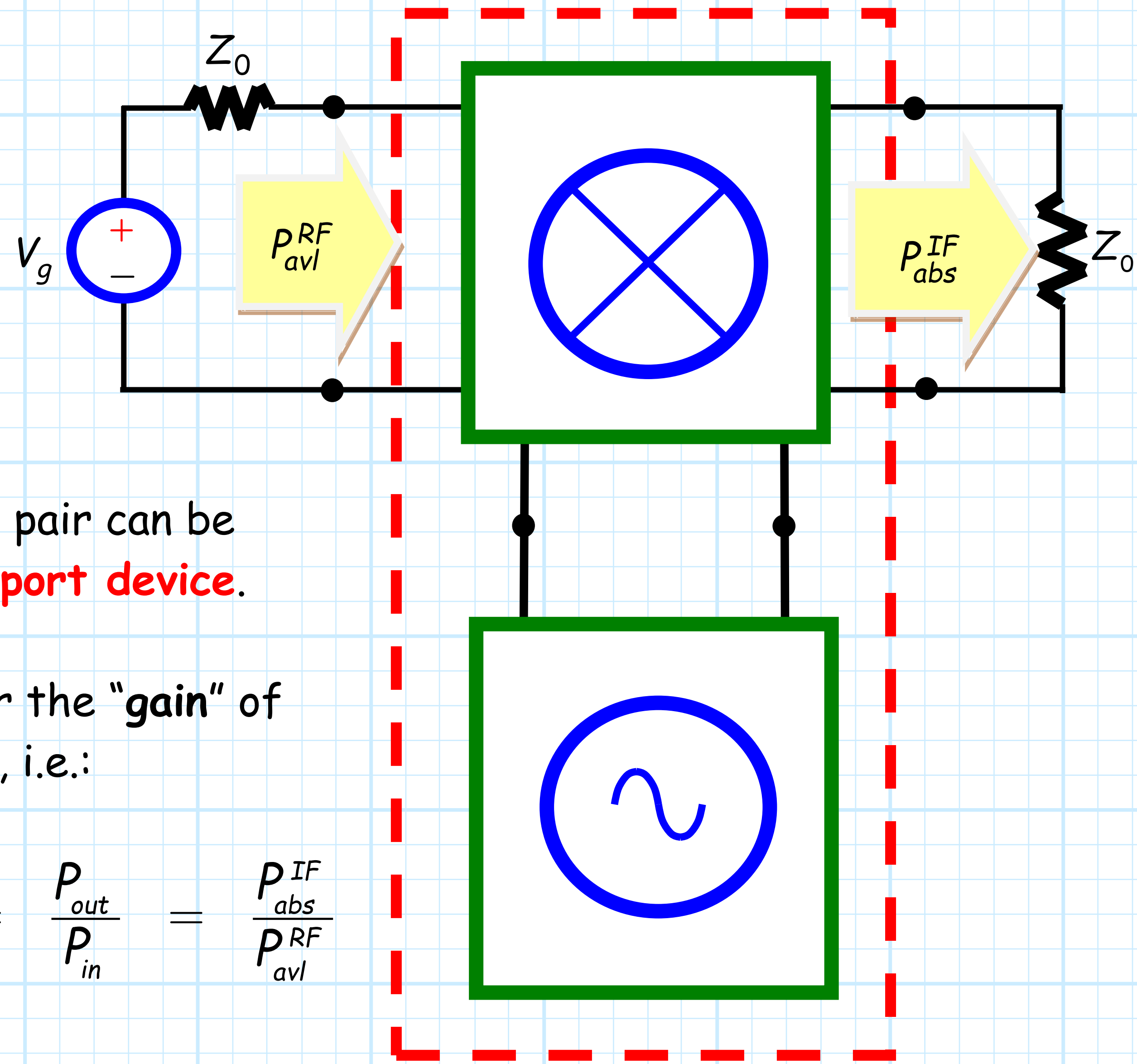
Mixer Conversion Loss



Again, a mixer/LO pair can be considered a **two-port device**.

Now, let's consider the "**gain**" of this 2-port device, i.e.:

$$\text{Mixer "Gain"} = \frac{P_{out}}{P_{in}} = \frac{P_{abs}^{IF}}{P_{avl}^{RF}}$$

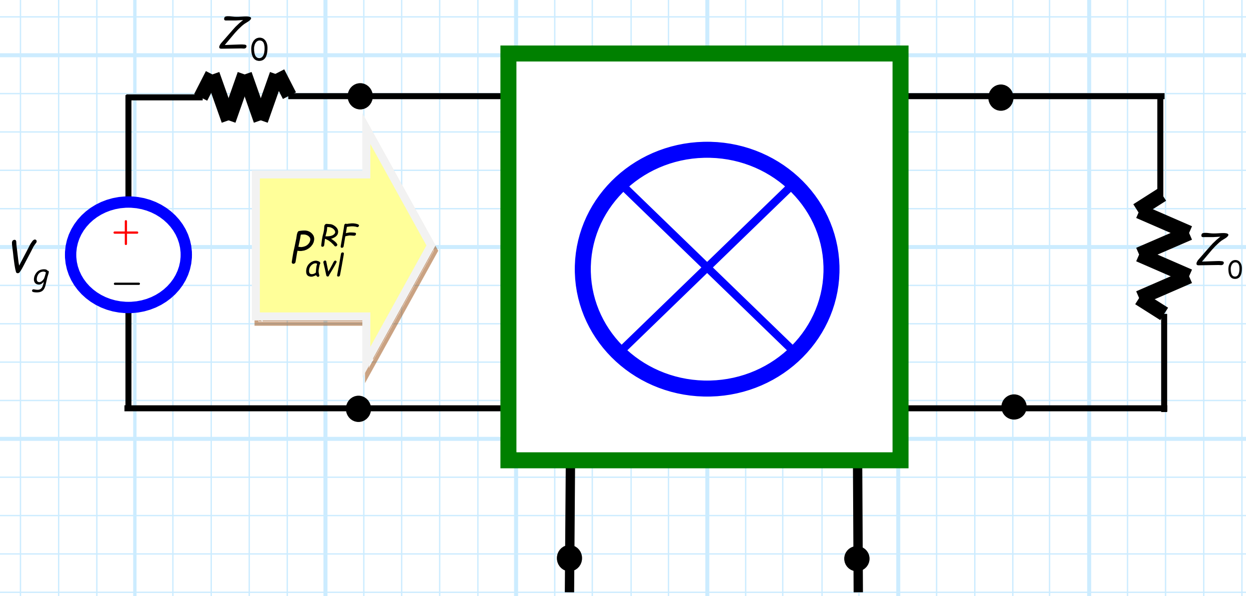
Available power

If the RF port of the mixer is **reasonably matched**, then total voltage is approximately equal the **incident voltage** on the RF port:

$$v_{RF}(t) \;=\; v_{RF}^{+}(t) \;=\; A_{RF}\cos\left[\omega_{RF}\,t + \varphi_{RF}\right]$$

And so the **available power** of the "matched" source is:

$$P_{avl}^{RF} = \frac{\left|V_{RF}^{+}\right|}{2\,Z_0} = \frac{A_{RF}^2}{2\,Z_0}$$



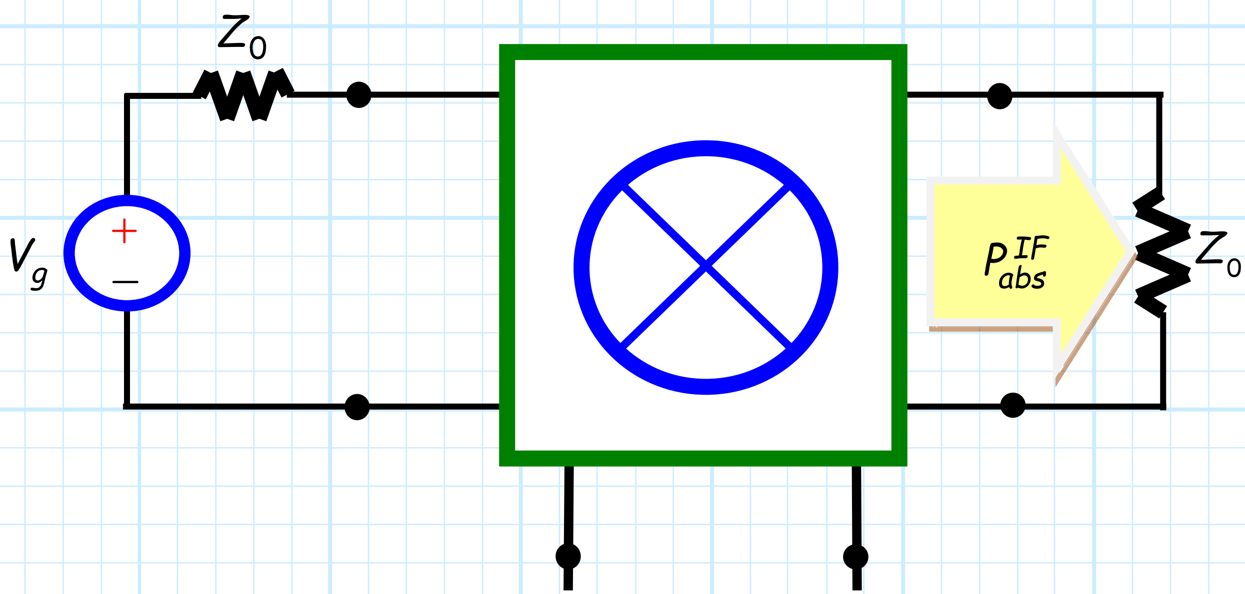
Absorbed power

Likewise, the **total** down-converted signal voltage at the IF port is equal to the **incident voltage** on the "**matched" load**:

$$v_{IF}(t) = v_{IF}^{+}(t) = A_{RF}\,\frac{2}{\pi}\cos\left[\left(\omega_{RF}-\omega_{LO}\right)t+\varphi_{RF}\right]$$

And so the **power absorbed** by the "matched" load is:

$$P_{abs}^{IF} = \frac{A_{RF}^{2}}{2\,Z_0}\left(\frac{2}{\pi}\right)^{2} = P_{avl}^{RF}\left(\frac{2}{\pi}\right)^{2}$$



Mixer "gain"

From this we conclude that the **"gain"** of an ideal **balanced switching mixer is**:

$$\text{Mixer "Gain"} = \frac{P_{abs}^{IF}}{P_{avl}^{RF}} = \left(\frac{2}{\pi}\right)^2 = \frac{4}{\pi^2} \cong 0.405$$

In other words, the **down-converted** signal power is just **40.5%** of the **RF signal power**!

Or, when expressed with the **decibel operator**:

$$dB\left[\frac{P_{abs}^{IF}}{P_{avl}^{RF}}\right] = 10\,log_{10}\left[\frac{4}{\pi^2}\right] \cong -3.9$$

And so, an ideal **balanced mixer** gain is about **-4.0 dB**.

Conversion Loss

Note that this mixer "gain" is less than one (i.e., less than 0 *dB*) so it actually represents a **loss**.

Thus, mixers are not specified in terms of their gain, but instead in terms of their **conversion loss**:

$$dB[\text{Conversion Loss}] \doteq -10\log_{10}\left(\frac{P_{abs}^{IF}}{P_{avl}^{RF}}\right) = 10\log_{10}\left(\frac{P_{avl}^{RF}}{P_{abs}^{IF}}\right)$$

Note that conversion loss is simply the **inverse** of mixer gain, and thus we find that the **ideal balanced mixer** has a conversion loss of approximately **4.0 *dB*.**

Remember all those sinusoids!

Q: *I don't understand.*

An ideal ***switch is lossless****, so wouldn't an ideal* ***switching mixer*** *exhibit* ***no loss*** *as well?*

A: Remember, there are **more** signals created at the IF port than **just** the down-converted term! I.E.,:

$$v_{IF}(t) = A_{RF} \sum_{n \in odd} \frac{2}{\pi |n|} \cos\left[\left(\omega_{RF} + n\omega_{LO} \right) t - \varphi_{RF} \right]$$

Another 40.5% is found!

Recall that the **two largest** terms are for $n = \{-1,1\}$:

$$v_{IF}(t) \cong V_{RF} \frac{2}{\pi} cos\left[\left(\omega_{RF} - \omega_{LO}\right)t - \varphi\right] + V_{RF} \frac{2}{\pi} cos\left[\left(\omega_{RF} + \omega_{LO}\right)t - \varphi\right]$$

which are the **down-converted** ($n = -1$) and "**up-converted**" ($n = +1$) terms.

This up-converted term (with frequency $\omega_{RF} + \omega_{LO}$) has the **same conversion gain** as the down-converted term:

$$\frac{P_{abs}^{IFup}}{P_{avl}^{RF}} = \left(\frac{2}{\pi}\right)^2 = \frac{4}{\pi^2} \cong 0.405$$

In other words, the **up-converted** signal power is also just **40.5%** of the **RF signal power**!

19% for the remaining sinusoids

Together, these two signals (down-converted and up-converted) represent **81%** of the **RF signal power**.

The **remaining 19%** of the RF signal power is (at least **ideally**) distributed across the remaining IF signals (i.e., where ***n* is odd and** $|n| \geq 3$):

$$v_n^{IF}(t) = A_{RF} \frac{2}{\pi |n|} \cos\left[\left(\omega_{RF} + n\omega_{LO}\right)t - \varphi_{RF}\right]$$

Conversion loss is bad

Q: *You keep using **weasel words** like "at least **ideally**".*

*Should I then **infer** that the conversion loss of a **real** balanced mixer is actually **not** 4.0 dB?*

A: That is correct!

Due to a **number** of issues (e.g. **poor** port-matching, **lossy** devices, and **spurious** signal creation), the conversion loss of a "**real**" mixer will be **greater** than the **ideal**.

The conversion loss of **actual** balanced mixers will **typically** range from **4.0 *dB* to 10.0 *dB***.

→ You should select a mixer with as **low** a conversion loss as **possible**!