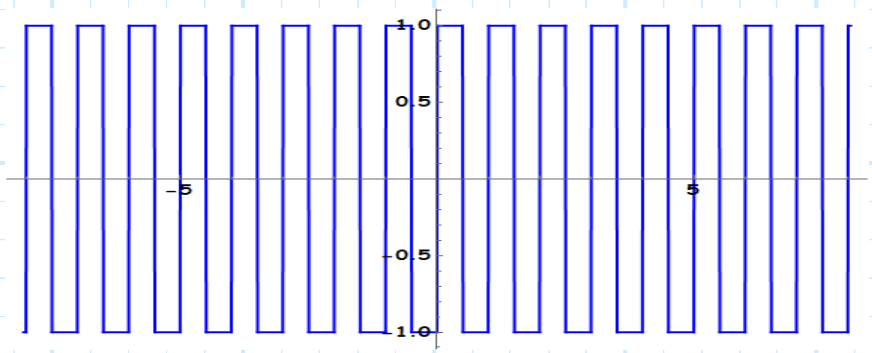
LO Drive Power

Q: *I don't understand.*

The "control voltage" for the switching mixer is the LO signal.

$$v_{ctrl}(t) = v_{LO}(t)$$

But, the "control voltage" for the switching mixer analysis was a ***square wave.***

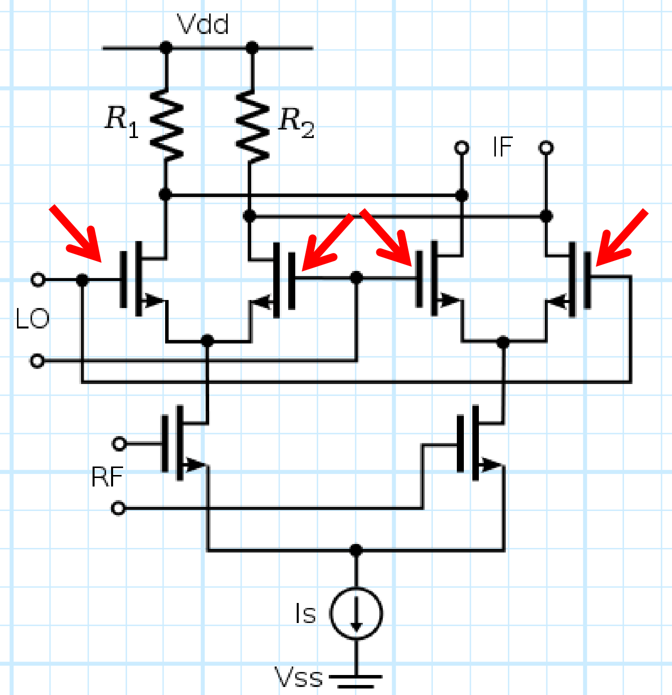


And yet, the LO oscillator produces a ***sinewave.***

A: This is **all true**.

MOSFET as a switch

https://commons.wikimedia.org/wiki/File:Double_Balanced_Mixer_in_Integrated_Circuit.svg

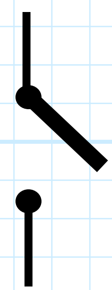


Consider this **active** mixer design:

Note the **LO port** is attached to the **gate terminals** of the NMOS devices.

These (non-linear) NMOS devices are acting as **switches**—they ideally toggle between **cutoff** mode (i.e., switch is **open**), and **triode** mode (i.e., switch is **closed**).

cutoff mode



triode mode

The mode of these NMOS devices are of course determined by the **gate voltage**—which is clearly the **LO voltage**!

Cutoff and Triode

Thus, **if** the LO sinusoidal voltage is **large enough**, it will **toggle** the MOSFET switch between **open** and **closed** (just like a square-wave would).

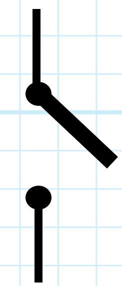
When the LO voltage is **sufficiently positive**:

$$v_{LO}(t) > V_G^{closed}$$

the "switch" will **close** (triode!).

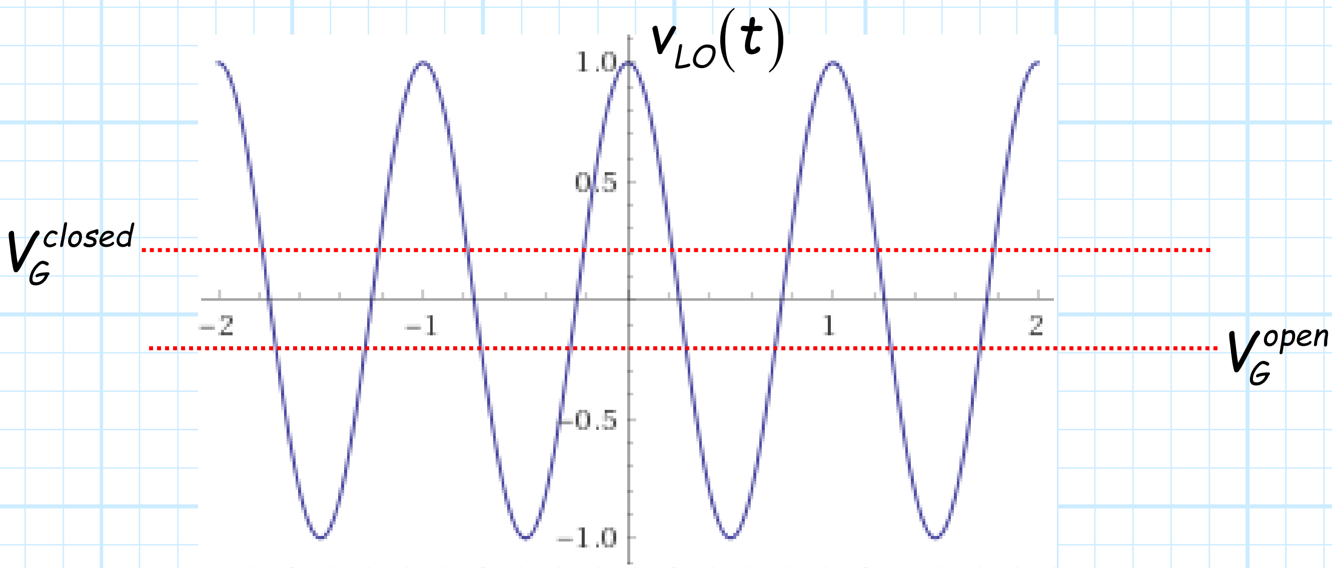
And when the LO voltage is **sufficiently negative**:

$$v_{LO}(t) < V_G^{open}$$



the "switch" will **open** (cutoff).

Just be large enough to switch



Thus—for this switch control—it **doesn't much matter** whether the LO signal is a **square**-wave or a **sine**-wave, just a long as it:

a) is oscillating at the **proper frequency** ω_{LO}, and

b) is **sufficiently large**!

A balanced diode mixer

Passive mixers generally implement **diodes**; for example:

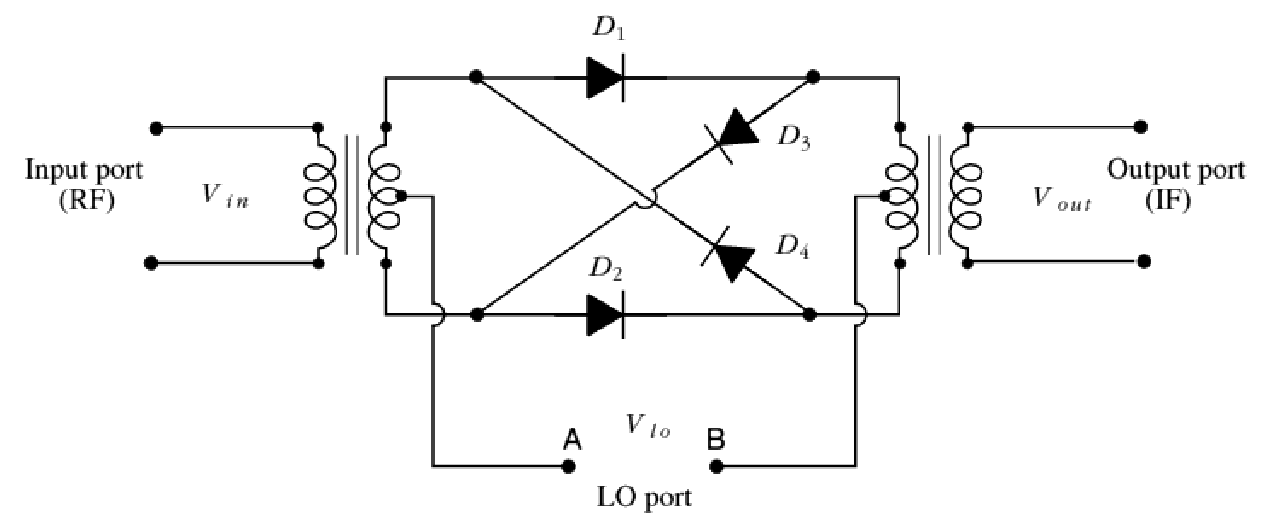


Figure 13.1a Double Balanced Mixer.

https://www.st-andrews.ac.uk/~www_pa/Scots_Guide/RadCom/part13/page1.html

The job of the LO signal is to "switch" the non-linear diodes between emphatically **reverse-biased** (switch is **open**) and emphatically **forward-biased** (switch is **closed**).

Make sure you do this…

Again, the LO signal needs to **be sufficiently large** to (emphatically) change these diode **bias states**.

Q: *So **how** large is "sufficiently large"?*

A: For passive (i.e., **diode**) balanced mixers, we find that this drive power is **typically** in a range from **+8.0 to +16.0 *dBm*.**

This value is a very important device parameter, called the mixer **LO drive power** P_{drive}^{LO}.

To achieve the specified mixer conversion loss (e.g., 4.0 *dB*), the LO signal power **MUST exceed** this LO drive power:

$$P_{avl}^{LO} > P_{drive}^{LO}$$

It is up to **you** (i.e., the engineer) to **ensure** this is achieved!

...because bad things happen if you don't!

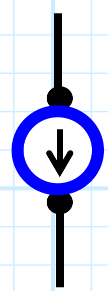
Q: *So, what happens if my LO* ***signal power*** P_{avl}^{LO} *is* ***less*** *than my mixer LO* ***drive power*** P_{drive}^{LO}*?*

A: Besides getting fired, you will find that the **apparent conversion loss** of the mixer will **increase** (which is **why** you got fired)!

When the LO signal is **too small**, it **cannot** adequately "switch" the semiconductor devices in the mixer.

For example, the switching NMOS devices may be **neither** in cutoff or triode—it instead might be in **saturation mode**!

Saturation mode



$$i = K\left(v_{GS} - V_t\right)^2$$

We call it multiplier mode

As a result, the (too small) LO voltage becomes like a "**small-signal**", and we say the mixer is **no longer in "switch" mode**!

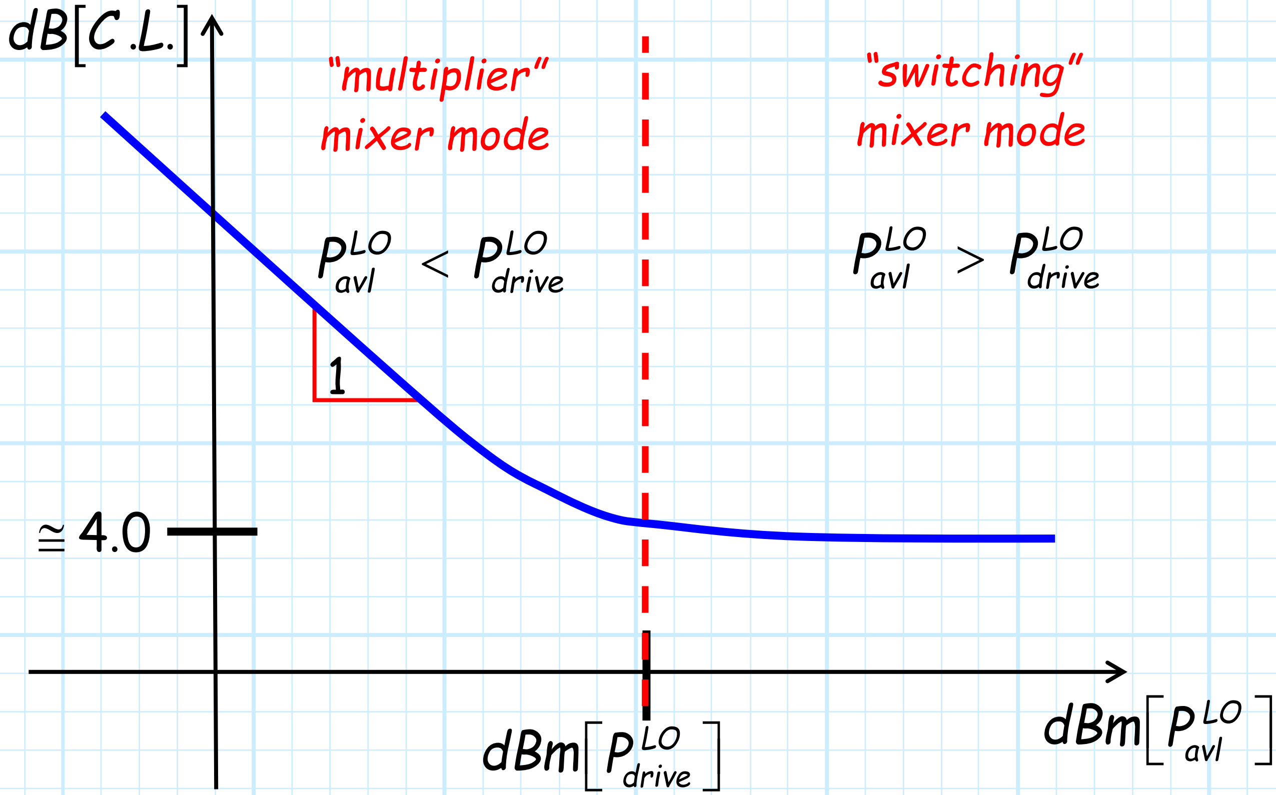
Instead, we say the mixer is in "**multiplier mode**", where the IF signal power (and thus conversion loss) is **proportional** to the LO power.

$$P_{IF} \propto A_{RF}^2 A_{LO}^2$$

This is **bad news**, since your LO power is now **not** particularly large!

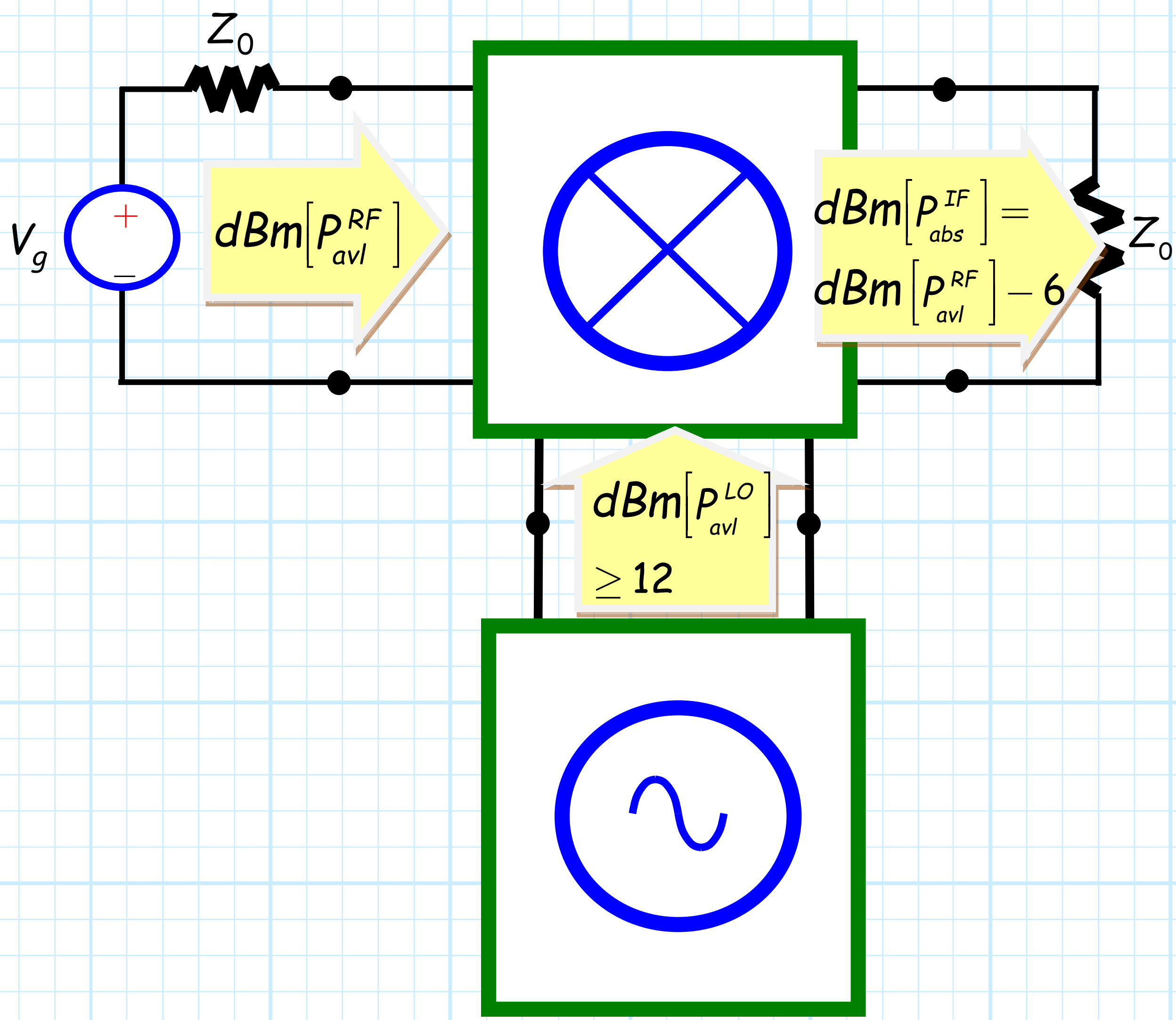
Conversion Loss increases proportionally

Thus, if the LO power drops **below** the required mixer drive power, the conversion loss will increase **proportionately—1 *dB* per *dB***!



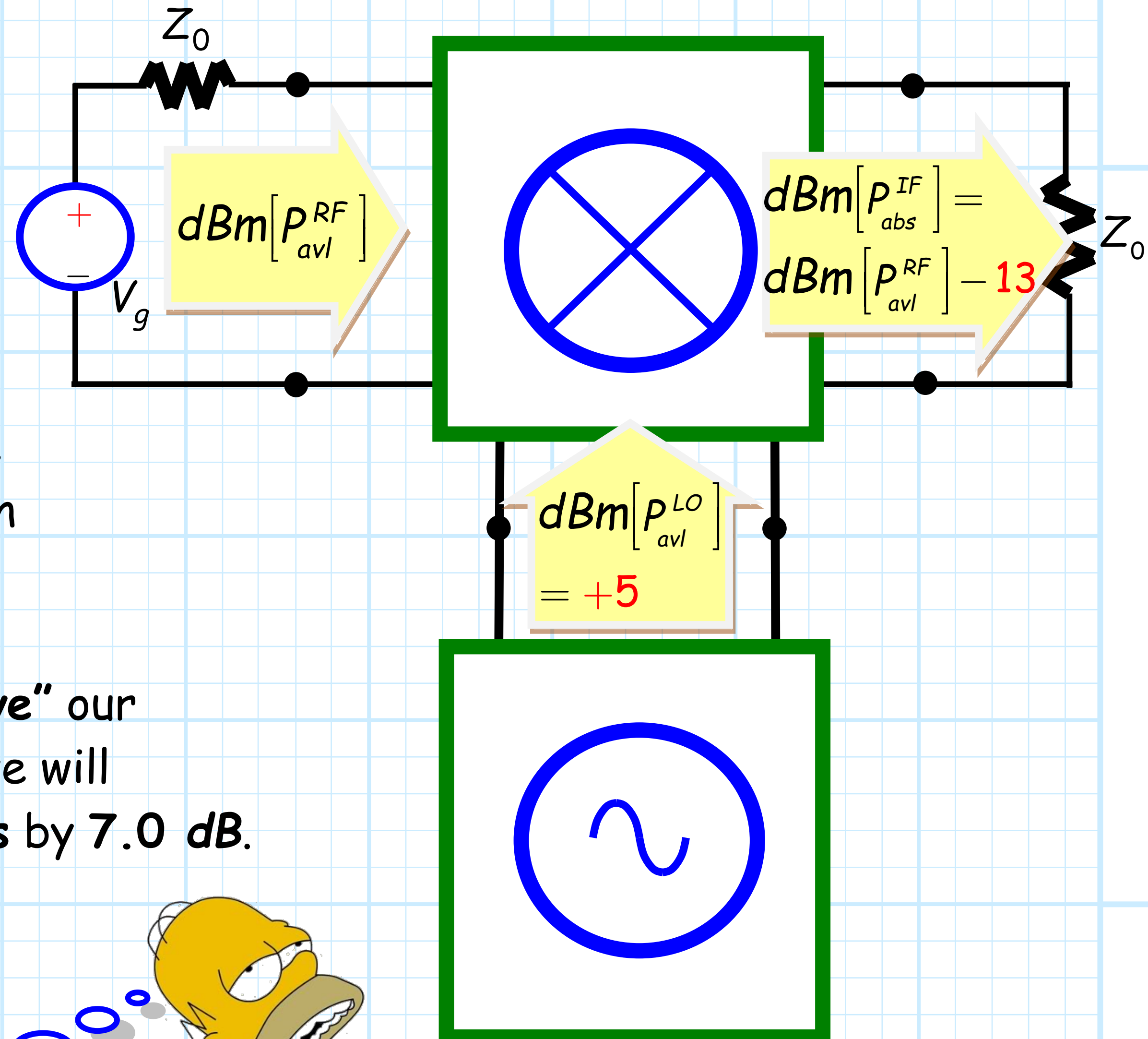
For example

For **example**, say a mixer requires an LO drive power of 12.0 *dBm*, and exhibits a conversion loss of 6.0 *dB*…



Don't starve your mixer!!!

…now say we **mistakenly** drive the mixer with an LO signal of **only** +5 *dBm* (**7dB** less than the drive power!).



We find that the mixer conversion loss will **increase** to 13.0 *dB* (***7 dB***) more than before!

In other words, if we "**starve**" our mixer LO by ***7.0 dB***, then we will increase the **conversion loss** by ***7.0 dB***.

Lesson learned→

Don't starve your mixer!