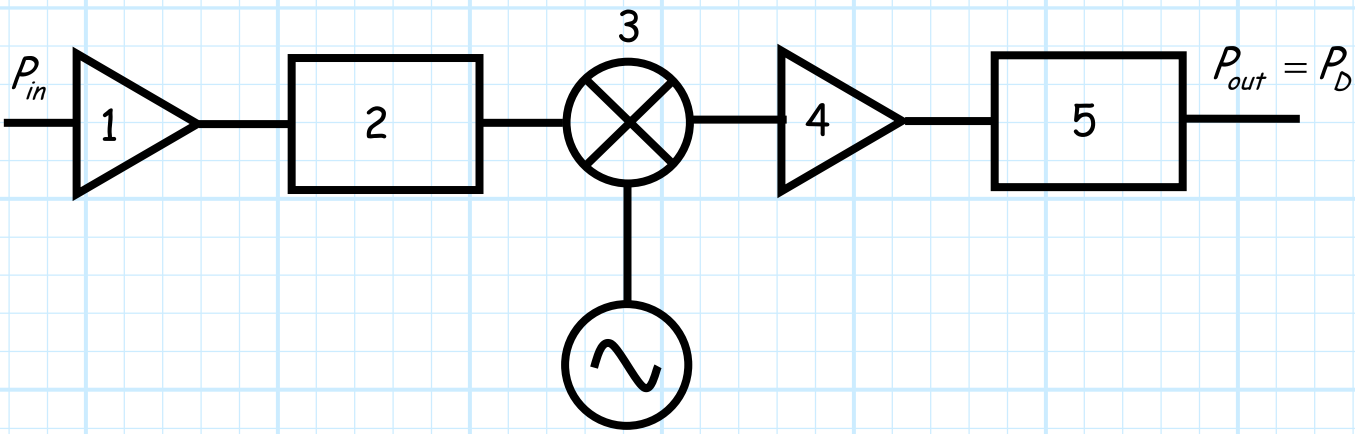
Receiver Gain

Let's consider **each element** of a basic super-het receiver:



1. LNA - Required to make the receiver **noise figure** F as small as possible, thus making the receiver very **sensitive.**

2. Preselector – Required to **reject** all spurious-signal creating frequencies, while simultaneously letting the desired RF bandwidth pass to the mixer.

3. Mixer - Required for down-conversion; often sets the receiver **compression point**.

4. IF Filter - Required to **suppress** all mixer IF output signals, with the **exception** of the one desired signal that we wish to demodulate. Also determines the **noise bandwidth** B of the receiver.

5. IF Amp - **Q:** ***Why*** *is this device required?* ***What*** *receiver parameter does it determine?*

A: It **is** true that the IF amplifier does **not** generally affect receiver bandwidth, or sensitivity, or saturation point, or image rejection.

→ However, the IF amp **is** the component(s) that we use to properly set the overall **receiver gain**.

Say that we have designed a receiver with some specific *TDR* (i.e., *MDS* and P_{in}^{sat}). This receiver will be connected to a demodulator with a specific *IDR* (i.e., P_D^{min} and P_D^{max}). All we have left to do is determine the proper gain of the **IF amplifier** to give us the **required gain** of the overall receiver.

We know that the overall receiver gain *G* must be **sufficiently large** such that the **smallest** possible receiver input signal (MDS) is boosted **at least** to the level of the smallest required demodulator signal (P_D^{min}). Thus, the absolute **smallest** value that the receiver gain should be is G_{min}:

$$G_{min} \doteq \frac{P_D^{min}}{MDS} \quad or \quad G_{min}(dB) \doteq P_D^{min}(dBm) - MDS(dBm)$$

Likewise, the overall receiver gain *G* must be **sufficiently small** to insure that the **largest** possible receiver input signal (P_{in}^{sat}) arrives at the demodulator with a power **less** than to the maximum level P_D^{min}. Thus, the absolute **largest** value that the receiver gain should be is G_{max}:

$$G_{max} \doteq \frac{P_D^{max}}{P_{in}^{sat}} \quad or \quad G_{max}(dB) \doteq P_D^{max}(dBm) - P_{in}^{sat}(dBm)$$

Q: *Seems **simple** enough! Just select an **IF amplifier** so that the overall receiver gain lies **between** these two limits:*

$$G_{min} < G < G_{max}$$

Right?

A: Not exactly. We are typically faced with a **big problem** at this point in our receiver design. To illustrate this problem, let's do an **example**.

Say our receiver has these **typical** values:

$$P_{in}^{sat} = -10dBm$$

$$MDS = -90dBm$$

$$P_D^{max} = -20dBm$$

$$P_D^{min} = -60dBm$$

Note then that $TDR = 80dB$ and $IDR = 40dB$.

Thus, this receiver must have a gain of **at least**:

$$
\begin{aligned}
G_{min}(dB) &= P_D^{min}(dBm) - MDS(dBm) \\
&= -60 - (-90) \\
&= 30\,dB
\end{aligned}
$$

But likewise have a gain of **no more** than:

$$
\begin{aligned}
G_{max}(dB) &= P_D^{max}(dBm) - P_{in}^{sat}(dBm) \\
&= -20 - (-10) \\
&= -10\ dB
\end{aligned}
$$

So **here's** our solution! The receiver gain must be any value **greater than 30 dB**, as long as it is simultaneously **less than -10dB**:

$$30dB < G(dB) < -10dB$$

Hopefully, it is evident that there are **no solutions** to the equation above!!

Q: *Yikes! Is this receiver **impossible** to build?*

A: Note that the values used in this example is are very **typical**, and thus the problem that we have encountered is likewise **very typical**.

We almost **always** find that $G_{min} > G_{max}$, making the solution G to the equation $G_{min} < G < G_{max}$ **non-existent**!

To see why, consider the **ratio** G_{max}/G_{min}:

$$\frac{G_{max}}{G_{min}} = \frac{P_D^{max}/P_{in}^{sat}}{P_D^{min}/MDS} = \frac{P_D^{max}/P_D^{min}}{P_{in}^{sat}/MDS} = \frac{IDR}{TDR}$$

In other words, for G_{max} to be **larger** than G_{min} (i.e., for $G_{max}/G_{min} > 1$), then the IDR must be **larger** than the TDR (i.e., $IDR/TDR > 1$).

But, we find that almost always the demodulator dynamic range (IDR) is **much less** than the receiver dynamic range (TDR), thus G_{max} is **almost never** larger than G_{min}.

Big Solution → However, there is **one** fact that leads to a solution to this **seemingly** intractable problem. The desired input signal power can be as small as MDS or as large as P_{in}^{sat}, but it **cannot be both values at the same time**!

Thus, the receiver gain G may need to be **larger** than G_{min} (i.e., when $P_s^{in} = MDS$) or **smaller** as G_{max} (i.e., when $P_s^{in} = P_{in}^{sat}$), but it does **not** need to be to be **both at the same time**!

In other words, we can make the gain of a receiver **adjustable**, such that it becomes **large** enough ($G > G_{min}$) when the input signal is **small**, but becomes **small** enough ($G < G_{max}$) when the input signal is **large**.

Q: ***Change*** *the gain of the receiver, how can we possibly do* ***that****?*

A: We can make the gain of the **IF** amplifier **adjustable**, thus making the overall receiver gain adjustable. This gain is automatically adjusted in response to the signal power, and we call this process **Automatic Gain Control** (AGC).