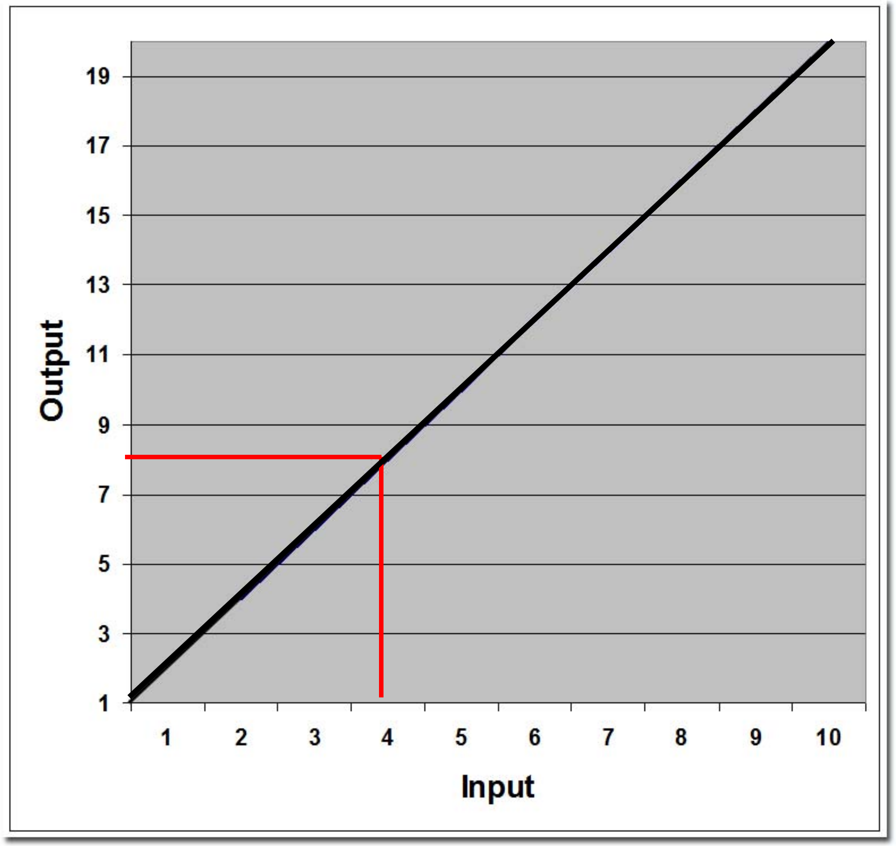
Ricevitore e componenti non lineari

Pierfrancesco Lombardo

Linear Gain

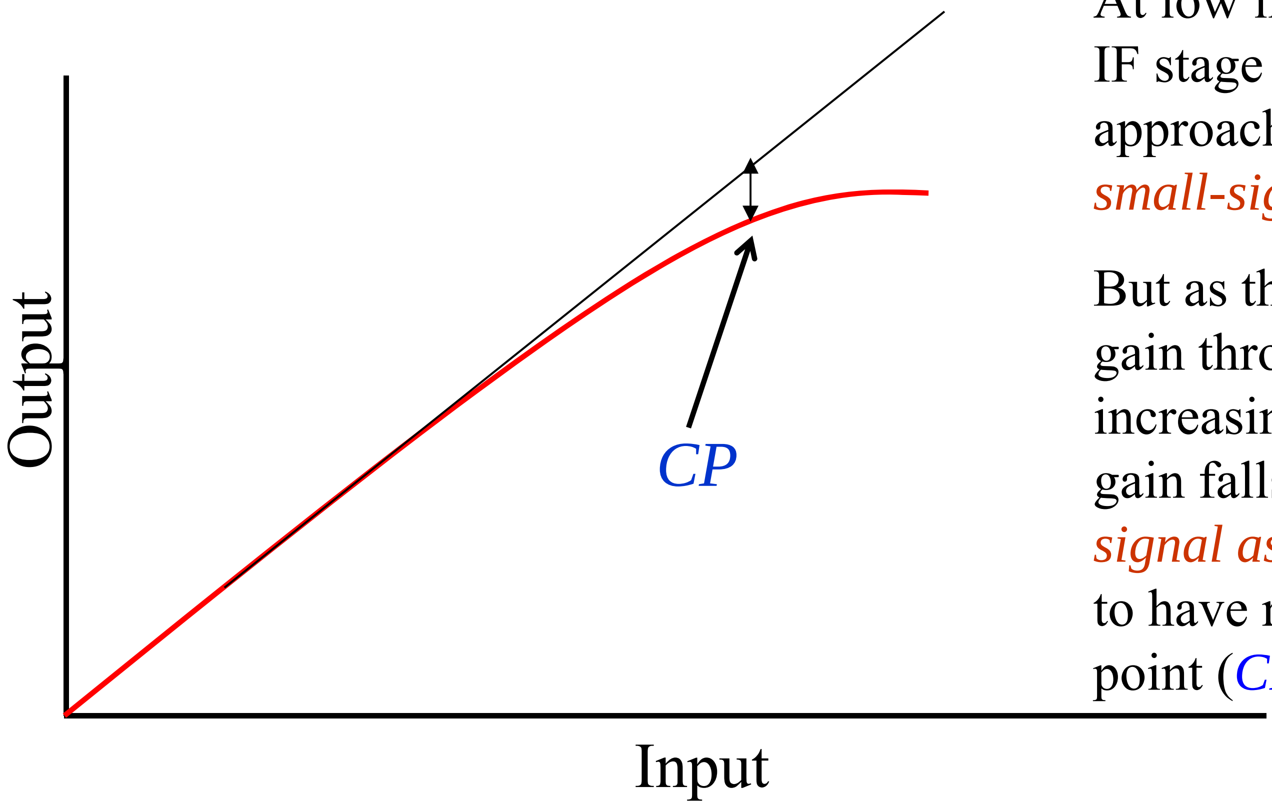


Linear gain in a circuit is normally represented by a straight line.

The scale on the Input and Output axis reflect the gain through the circuit. In this example, a gain of 2:1.

However, all RF & IF circuits are inherently nonlinear.

Gain and the Compression Point



At low input levels, receiver RF and IF stage gain are generally linear—approaching a level called the *small-signal asymptotic value.*

But as the input level increases, gain through the stage becomes increasingly nonlinear. When the gain falls *n* dB below the *small-signal asymptotic value*, it has said to have reached its compression point (*CP*).

The compression point, stated in dB, is frequently given as either 1 dB or 3 dB below the small-signal asymptotic value.

Why it is called 3rd order

The performance of an ideal amplifier can be represented by the transfer function:

$$V_{out} = A_0 + A_1 V_{in}$$

An amplifier with some distortion due to **nonlinearities** can be expressed by a transfer function in the form of a power series expansion:

$$V_{out} = A_0 + A_1 V_{in} + A_2 V_{in}^2 + A_3 V_{in}^3 + A_4 V_{in}^4 \ldots$$

An input signal with two frequencies ω_1 and ω_2 may be shown as:

$$V_{in} = V_1 \cos(\omega_1 t) + V_2 \cos(\omega_2 t)$$

The **first** order term $A_0 + A_1 V_{in}$ gives the fundamental products

$$V_{out} = A_0 + A_1 V_1 \cos(\omega_1 t) + A_1 V_2 \cos(\omega_2 t)$$

The **second** order term $A_2 V_{in}^2$ determines the second order products:

$$A_2 V_{in}^2 = \frac{A_2 V_1^2}{2} + \frac{A_2 V_2^2}{2} + \frac{A_2 V_1^2}{2}\cos(2\omega_1 t) + \frac{A_2 V_2^2}{2}\cos(2\omega_2 t) + \frac{A_2 V_1 V_2}{2}[\cos(\omega_1 t + \omega_2 t) + \cos(\omega_1 t - \omega_2 t)]$$

DC terms ***2nd harmonic terms*** ***2nd order IMD terms***

Why it is called 3rd order (cont'd)

The **third** order term $A_3 V_{in}^3$ determines the third order products:

$$A_3 V_{in}^3 = \frac{3A_3}{2}\left[V_1 V_2^2 + \frac{V_1^3}{2}\right]\cos(\omega_1 t) + \frac{3A_3}{2}\cos\left[V_1^2 V_2 + \frac{V_2^3}{2}\right]\cos(\omega_2 t) +$$

Fundamental frequency terms

$$\frac{A_3 V_1^3}{4}\cos(3\omega_1 t) + \frac{A_3 V_2^3}{4}\cos(3\omega_2 t) +$$

3rd harmonic terms

$$\frac{3A_3 V_1^2 V_2}{4}[\cos(2\omega_1 t + \omega_2 t) + \cos(2\omega_1 t - \omega_2 t)] + \frac{3A_3 V_1 V_2^2}{4}[\cos(2\omega_2 t + \omega_1 t) + \cos(2\omega_2 t - \omega_1 t)]$$

3rd order IMD terms – The troublemakers

Nonlinearity and Intermodulation Distortion

- Nonlinearity in RF and IF circuits leads to two undesirable outcomes: harmonics and intermodulation distortion.
- Harmonics in and of themselves are not particularly troublesome.
- For example, if we are listening to a QSO on 7.230 MHz, the second harmonic, 14.460 MHz is well outside the RF passband.
- However, when the harmonics mix with each other and other signals in the circuit, undesirable and troublesome intermodulation products can occur.

Intermodulation Distortion Products: Example (I)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**	**f1**	**7.224**
(4)	**Signal Two**	**f2**	**7.227**
(5)	Third-Order	2f2-f1	7.230
(6)	Fifth-Order	3f2-2f1	7.233

Intermodulation Distortion Products: Example (II)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**		
(4)	**Signal Two**		
(5)	Third-Order		
(6)	Fifth-Order		

2f1 = 2 x 7.221 = 14.442

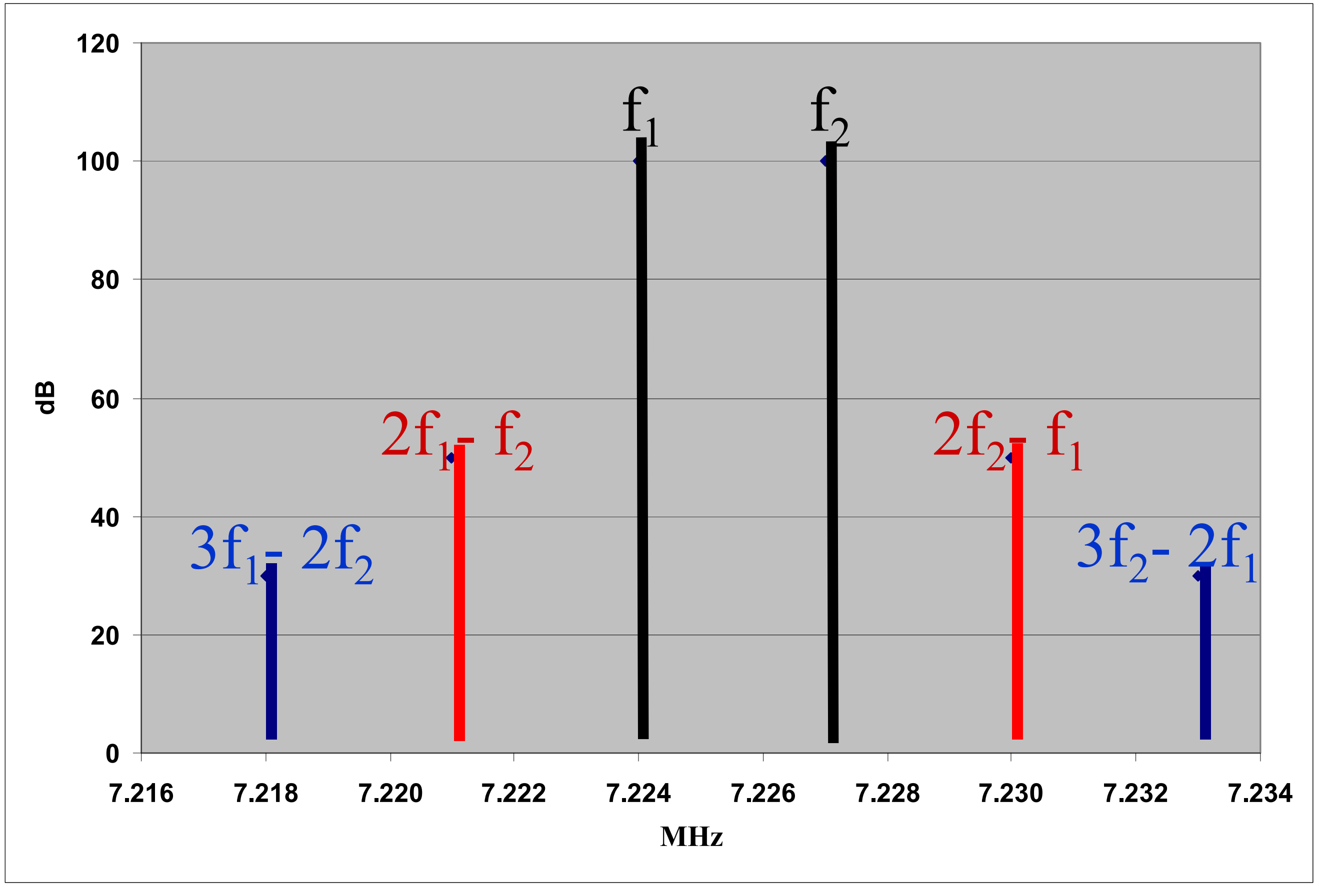
f2 = 7.227

14.442 - 7.227 = 7.221

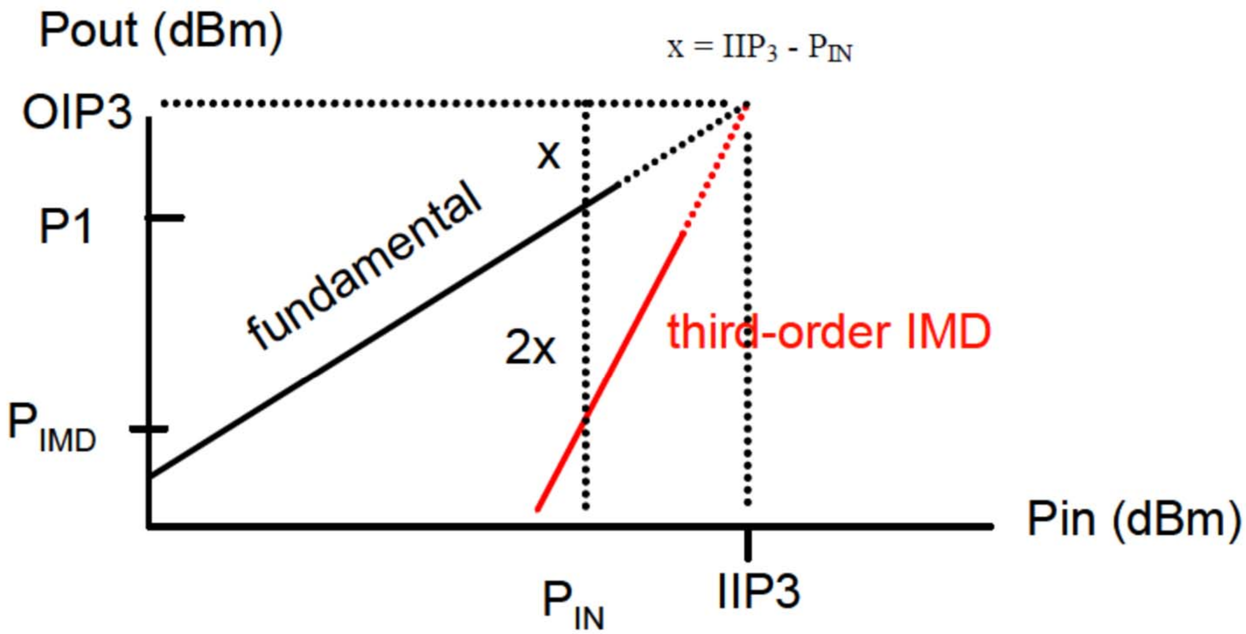
Intermodulation Distortion Products: Example (III)

(1)	Fifth-Order	3f1-2f2	7.218
(2)	Third-Order	2f1-f2	7.221
(3)	**Signal One**	**f1**	**7.224**
(4)	**Signal Two**	**f2**	**7.227**
(5)	Third-Order	2f2-f1	7.230
(6)	Fifth-Order	3f2-2f1	7.233

Intermodulation Distortion Products: Example (IV)

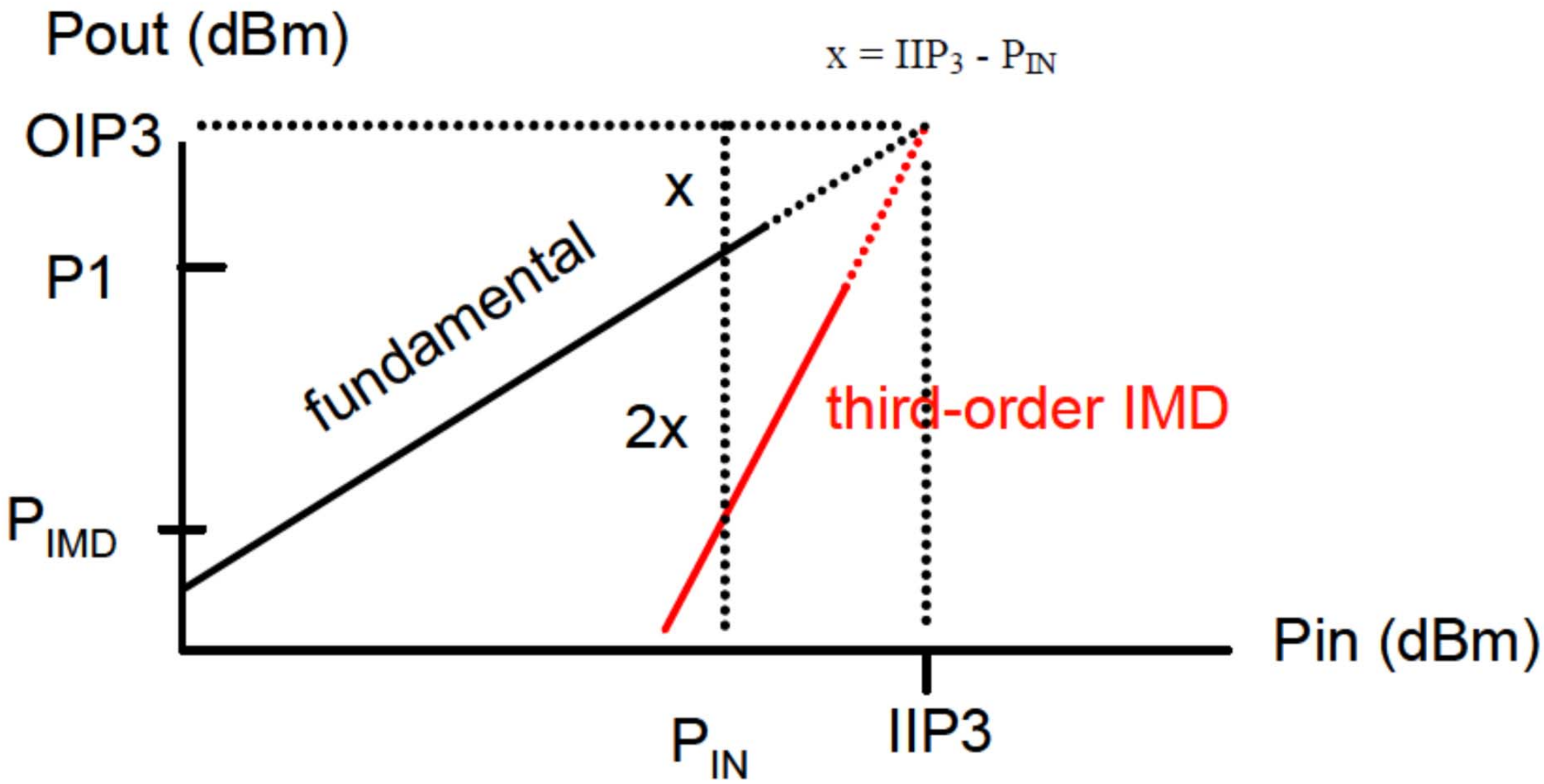


Spurious-Free Dynamic Range



$$IIP_3 = P_{IN} + \frac{1}{2}\left(P_1 - P_{IMD}\right)$$

Spurious-Free Dynamic Range



IP3 for cascaded system

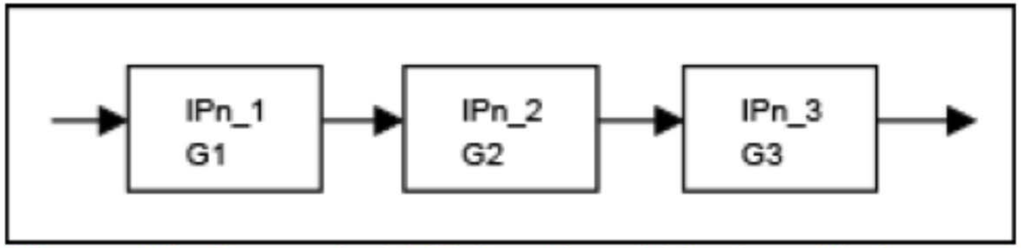


Figure 12. Cascaded RF functional blocks with known IPn.

The total gain of a cascaded structure is:

$$G = G1 \times G2 \times G3 \text{ (in linear)}$$

or

$$g = g1 + g2 + g3 \text{ (in dB or dBm)}$$

One can just use the equation, applied for three stages:

$$\left(\frac{1}{OIP_n}\right)TOT = \left(\frac{1}{OIP_{n\_1}} + \frac{G_2}{OIP_{n\_2}} + \frac{G_2 \times G_3}{OIP_{n\_3}}\right)$$