

Application Note: Using Multiple MMIC Power Amplifiers to Increase IP_3 and P_{1dB}

Scope

Critical specifications for the transmitter output stage in microwave and millimeter-wave radios are the P_{1dB} (or P_{SAT}) point for non-linear systems (e.g. FM, FSK), and the IP_3 for linear systems (e.g. QAM). For a specific application, commercially available GaAs MMIC power amplifiers can fall short in one or both of these performance factors. One approach to achieving the higher performance is to build a power amplifier using multiple MMICs in a balanced arrangement. The XP1000 is well suited for this type of implementation.

Block Diagram

A block diagram shown in Figure 1 outlines the arrangement of a balanced amplifier using two MMIC power amplifiers. This block diagram is extended in Figure 2 to show how more than two power amplifiers can be used to achieve even greater performance.

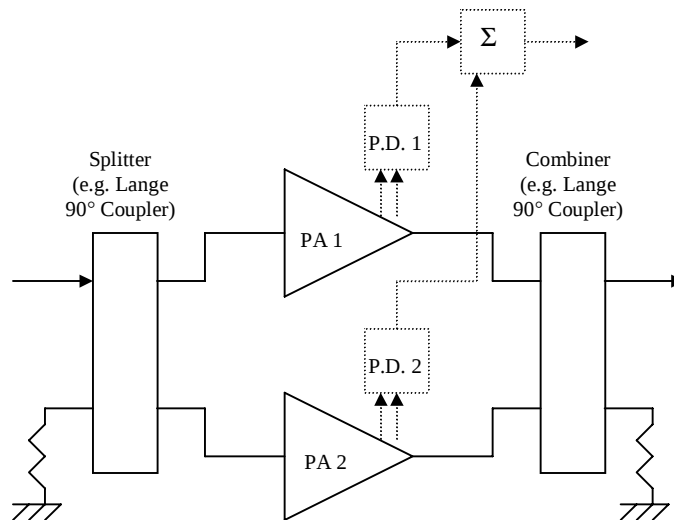


Figure 1: Two Power Amplifiers in Balanced Configuration

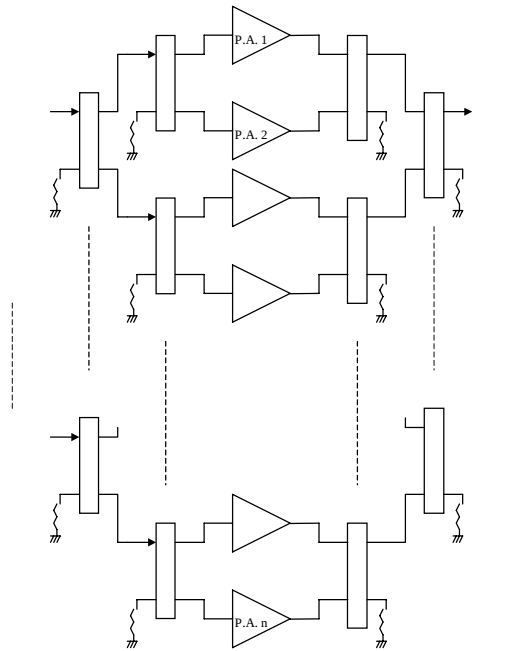


Figure 2: 'n' Power Amplifiers in Balanced Configuration

Circuit Description

For a single P.A., the following properties are usually known;

G	Gain
IIP_3	Third-Order Intercept point (referred to input)
OIP_3	Third-Order Intercept point (referred to output)
IP_{1dB}	1dB Compression point (referred to input)
OP_{1dB}	1dB Compression point (referred to output)

To find the $G[Bal]$, $OIP_3[Bal]$, $OP_{1dB}[Bal]$, of the 2 PA balanced configuration shown in Figure 1, assume the losses in the splitters and combiners to be zero, and that they have an equal 3dB split. Denote the input signal as $x(t)$. Assume both amplifiers have identical characteristics.

$$\begin{aligned}
 G[Bal] &= [x(t)-3dB]*G_{P.A.1} + [x(t)-3dB]*G_{P.A.2} \\
 &= 0.5*G_{P.A.1} + 0.5*G_{P.A.2} \\
 &= G \\
 OIP_3[Bal] &= OIP_{3(P.A.1)} + OIP_{3(P.A.2)} \\
 &= OIP_3 + 3dB \\
 OP_{1dB}[Bal] &= OP_{1dB(P.A.1)} + OP_{1dB(P.A.2)} \\
 &= OP_{1dB} + 3dB
 \end{aligned}$$

Similarly for the 'n'-stage configuration shown in Figure 2, with 2^n amplifiers in parallel and n couplers at input and output, and assuming no losses,

$$\begin{aligned}
 G[n] &= G \\
 OIP_3[n] &= OIP_3 + (n-1)*3dB \\
 OP_{1dB}[n] &= OP_{1dB} + (n-1)*3dB
 \end{aligned}$$

Coupler Losses

The coupler losses are a significant limiting factor, and restrict the number of parallel stages that can be used effectively, particularly if PAE is critical. If the insertion loss of each Lange coupler is L dB, then the loss at the input and output is L dB. The gain is then $G - 2L$ dB, and the output power is reduced by L dB, ie both the OP_{1dB} and the OIP_3 are reduced by L dB. As the loss of a Lange coupler is typically 0.5 to 1dB, there is a rapidly reached limit to the power available from this combining approach, and the PAE rapidly declines, by the power ratio of the output coupling loss.

Biasing

App Note[1] in the XP1000 Data Sheet on biasing, is relevant to each XP1000 used in the balanced configuration. App Note [1] recommends that for the XP1000, either all transistors are biased individually, or that just the upper path (Vd1,2) and the lower path (Vd3,4) are biased separately.

For power amplifiers in general, it is recommended that an active bias is used. This leads to constant drain current, as the RF power and temperature vary, leading to more reproducible results. Simple, low cost bias circuits can be made from a single PNP transistor, or an operational amplifier. See Figures 3 and 4 respectively.

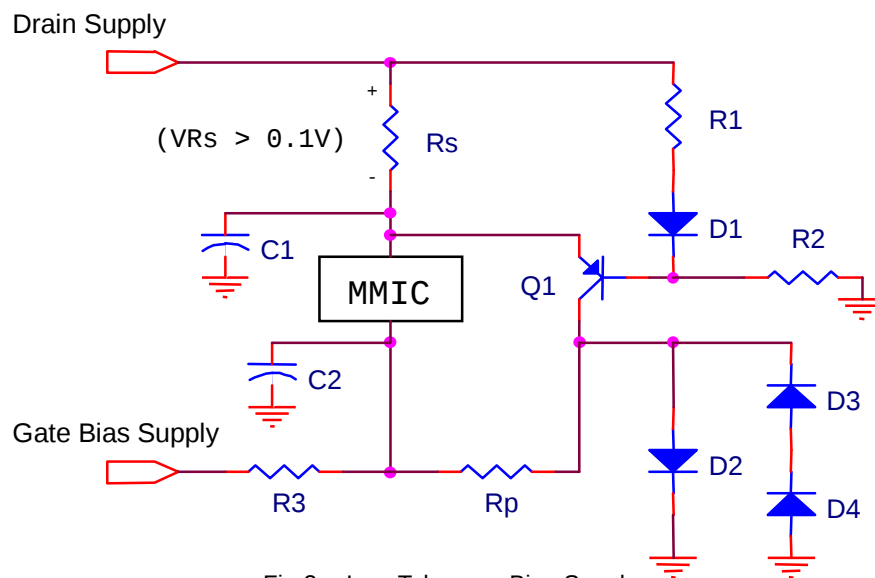


Fig 3 : Low Tolerance Bias Supply

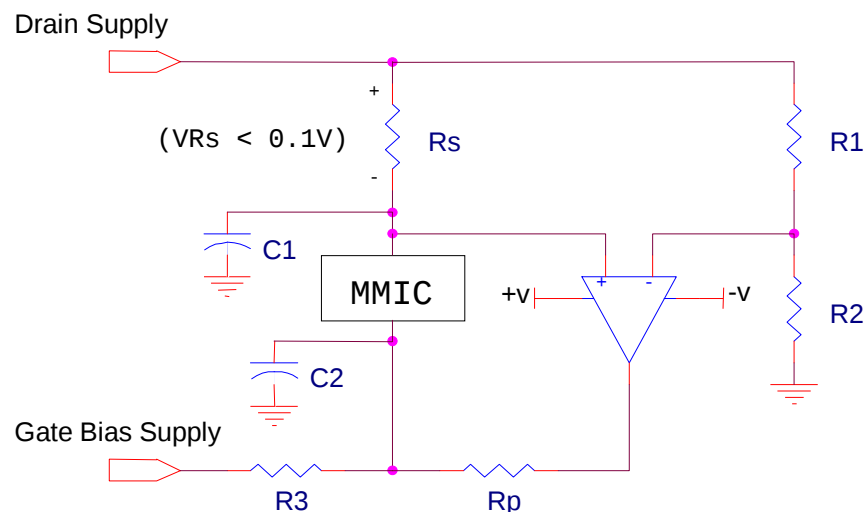


Fig 4 : Precision Bias Circuit

In the case of balanced configurations, it is important that each XP1000 is biased individually, again with one of the above two bias configurations. This leads to better performance, as die-to-die variations are handled within the active bias for the respective device, and not averaged through multiple devices.

Power Detection

Each XP1000 power amplifier has a built in power detector. A DC bias must be applied to the detector circuit. This can be applied either by feeding 1Volt directly to the Vd5 line, or by applying one of the drain voltages used elsewhere (~5.5V) through a resistor in the range 3kW to 6kW.

The 'V1 Out' and 'V2 Out' lines are a differential signal indicating the power level at the output of the XP1000. The signal should be passed through a differential amplifier, which rejects the common-mode temperature drift. The differential amplifier can be used in either voltage or current mode.

In applications described here, two or more amplifiers are used in a balanced configuration, the circuit designer has a choice of either relying on the power detected from one of the XP1000 onboard detectors, or through means of summing amplifiers, a better average of the power output can be obtained by monitoring the detector output on each of the XP1000's.

Refer to the Detector Curves given in the XP1000 for typical characteristics.

Lange Coupler

A method used in increasing the coupling between edge coupled lines is to use several lines parallel to each other, as is the idea with the Lange coupler shown in Figure 5. Here, four coupled lines are used with interconnections to provide tight coupling. This coupler can achieve 3dB coupling ratios, with more than an octave bandwidth, making it ideal for use in a wideband, balanced power amplifier application. Refer to Figure 6 for simulations of through and coupled responses of a Lange coupler designed to cover the full band of the XP1000 power amplifier.

The main disadvantage of the Lange coupler is practical, as the lines are very narrow and close together. A thin-film on ceramic implementation using air bridges to connect the lines is a common technology used for the implementation.

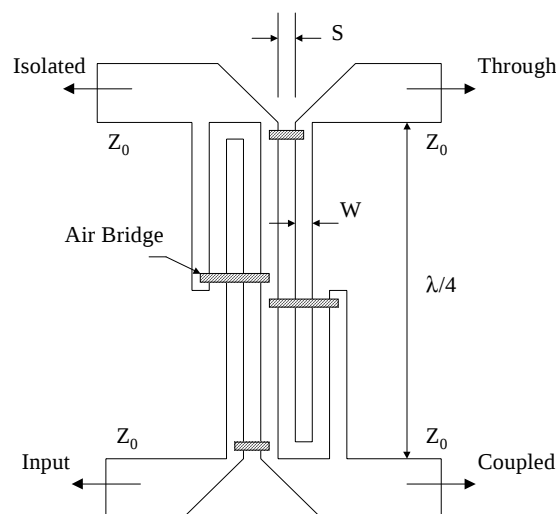


Figure 5: Lange Coupler

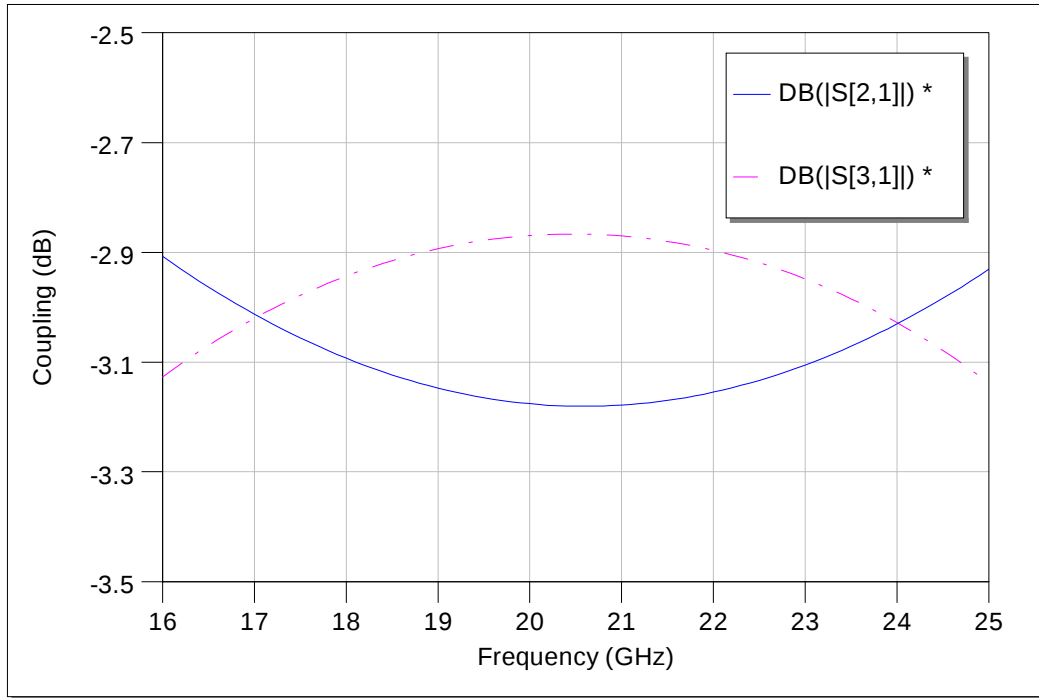


Figure 6: Lange Coupler Direct and Coupled Port Responses