

Application Note No. 057

A 1.9 GHz Low Noise Amplifier optimized for high IP3 using BFP540

RF & Protection Devices



Never stop thinking

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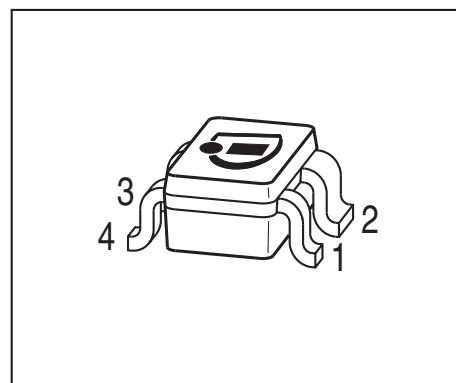
Page	Subjects (major changes since last revision)
All	Document layout change

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1 A 1.9 GHz Low Noise Amplifier optimized for high IP3 using BFP540

Features

- $NF = 1.3$ dB
- Gain = 15.5 dB
- $OIP_3 = 24$ dBm
- Small SOT343 package



Description

Infineon's BFP540 is a high performance, low cost silicon bipolar transistor housed in a 4-lead ultra-miniature SOT343 surface mount package. This device is designed for applications requiring high performance such LNAs, VCOs, portable telephones, spread spectrum transceivers and other low noise applications. Applying Infineon's BFP540, low noise, high gain, high linearity at low power consumption are possible.

This application note describes a low noise, high gain, low component count LNA for 1900 MHz, and it also provides general guidelines for improving 3rd order intercept performance for Infineon grounded emitter transistors.

Figure 1 shows a low noise amplifier stage for 1900 MHz using BFP540. The circuit described is useful for low cost, battery-powered applications such as the LNA stage for a CDMA handset. The design goals were gain > 15 dB, $NF < 1.4$ dB, input and output return losses better than 10 dB, $OIP_3 > 20$ dBm, unconditional stability and low PC board area.

Table 1 shows the measured parameter values. These values includes the losses of the SMA connectors and microstrip lines of the FR4 epoxy board. If the connector and PCB loss were extracted, the noise figure result would improve by 0.1-0.2 dB. **Figure 1** to **Figure 4** shows the schematic and the layout of the amplifier.

Table 1 Measured parameter values at 1900 MHz, 25 °C, I_{CC}

Parameter	Symbol	Unit	Value	Reference (Figures)
Power Gain ($ S_{21} ^2$)	G_p	dB	15.5	Gain vs Frequency at 1900 MHz
Noise Figure	NF	dB	1.3	NF vs Frequency (25 °C)
Input Return Loss	R_{Lin}	dB	9	Input Return Loss vs Frequency
Output Return Loss	R_{Lout}	dB	15	Output Return Loss vs. Frequency
Third-Order Intercept Point	OIP_3	dBm	24	IP₃ measurement at $V_{CC} = 3$ V, $I_{CC} = 6.5$ mA, $P_{in} = -28$ dBm per tone ($OIP_3 \cong 24$ dBm)
Output Power at 1 dB Compression	P_{1dB}	dBm	-1	Gain, P_{out} vs. P_{in} at 1900 MHz ($P_{1dB} = -1$ dBm)

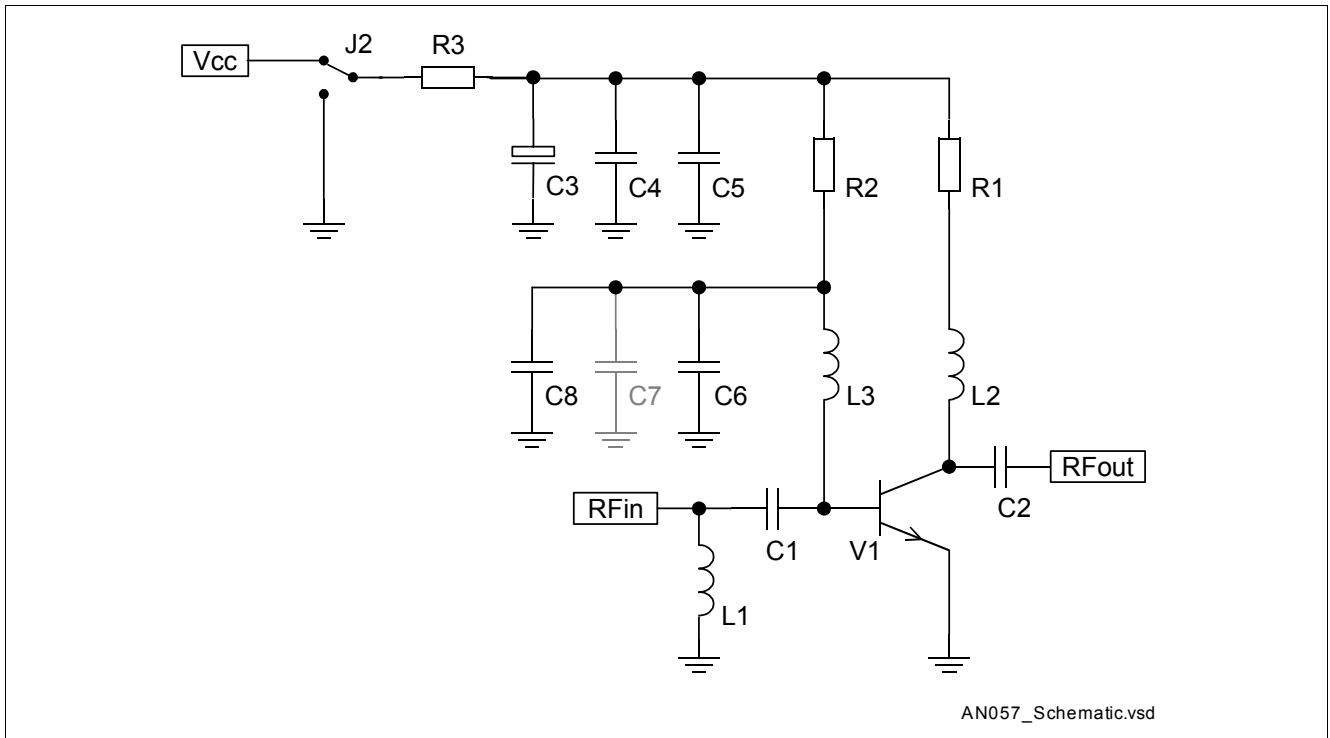
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Figure 1 Schematic of 1900 MHz Amplifier

Table 2 Component Part list

Name	Value	Package	Manufacturer	Function
C1	6.8 pF	0402	Murata (COG)	Input matching
C2	100 pF	0402	Murata (COG)	DC block
C3	6.8 μ F	-	S+M (10 V)	Block capacitor and improve IP ₃
C4	10 nF	0402	Murata (X7R)	Block capacitor
C5	100 nF	0402	Murata (COG)	RF decoupling
C6	15 pF	0402	Murata (COG)	RF decoupling
C7	-	-	-	Not applied
C8	47 nF	0603	S+M (X7R)	To improve IP ₃ -performance
L1	5.6 nH	0402	S+M	Input matching
L2	4.7 nH	0402	S+M	Output matching
L3	100 nH	0402	S+M	Biasing
R1	15 Ω	0402	S+M	Improves stability
R2	22 k Ω	0402	S+M	Biasing
R3	120 Ω	0402	S+M	Set for desired supply voltage
V1	BFP540	SOT343	Infineon	
X1	SMA-connector	SMA	Johnson	
X2	SMA-connector	SMA	Johnson	
J1	5 Pin		STOCKO / MKS1650	PIN connector
J2	3 Pin		APEM / NK 236	Switches LNA ON/OFF

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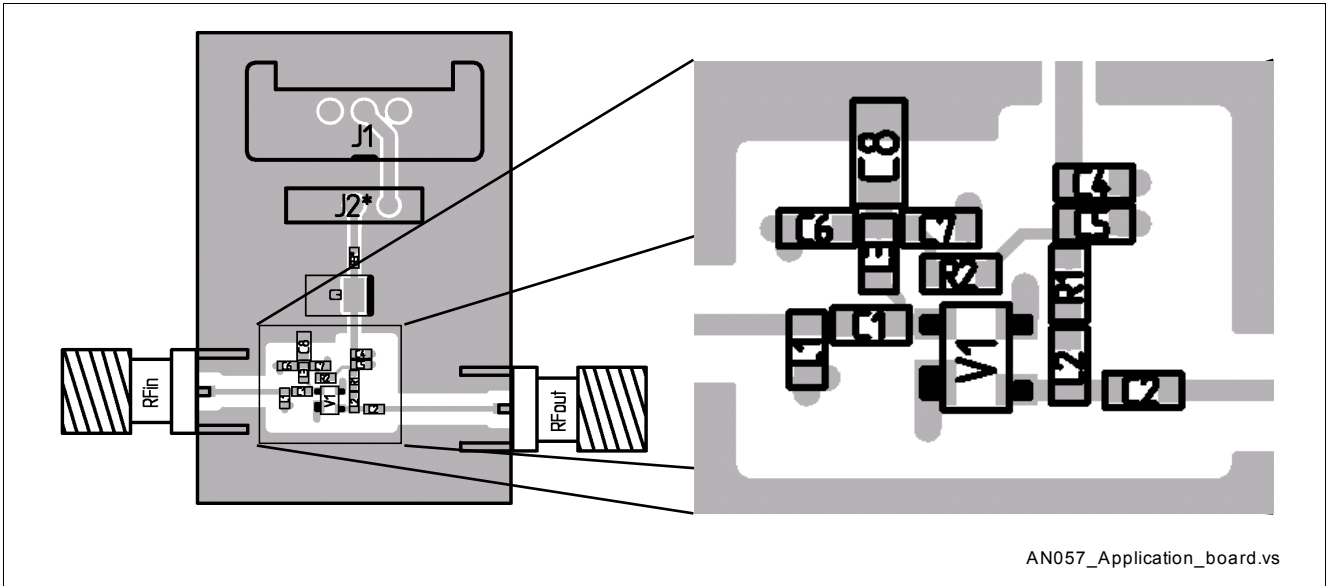


Figure 2 Application Board (scale 2:1, original size 23 x 35 mm)

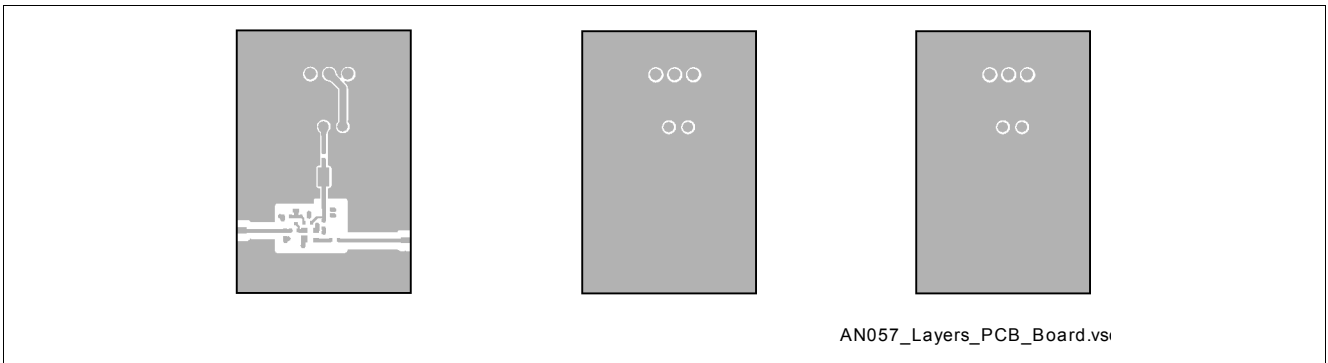


Figure 3 Top, Middle and Bottom layers of PCB-Board

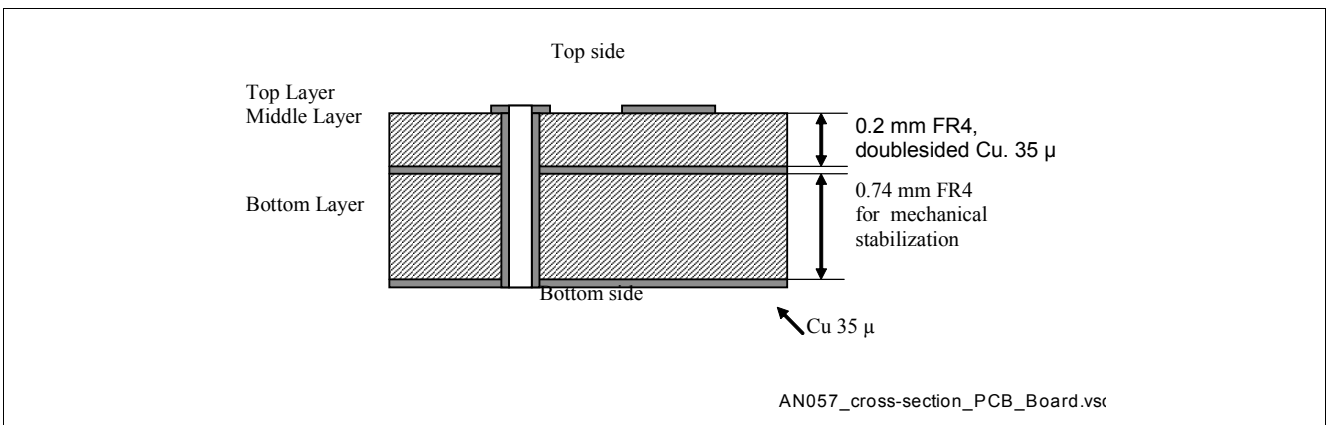


Figure 4 Cross-Section of PCB-Board

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1.1 Measured parameter values

The curves shows the measured parameter values at 25 °C, $V_{CC} = 3.0$ V and 1900 MHz unless otherwise noted. These values include the losses of the SMA connectors and microstrip lines of the 0.2 mm FR4 epoxy board. The first four curves show the S-parameter. The noise figure, output power and gain are presented in the following two and stability factors, calculated from the S-parameters measured at the SMA-connectors is shown subsequently. Finally the IP_3 measurement with $P_{in} = -28$ dBm are presented in the last two curves.

1.2 Improving the IP_3

The IP_3 is usually determined by using a two tone test, i.e. two equal carriers generate distortion products, both in-band and out of band (Figure 5)

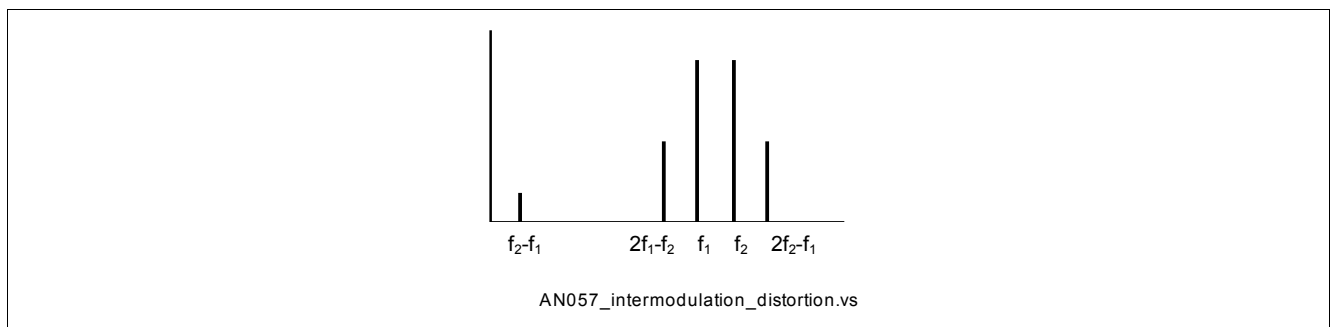


Figure 5 Two tone test and generated intermodulation distortion

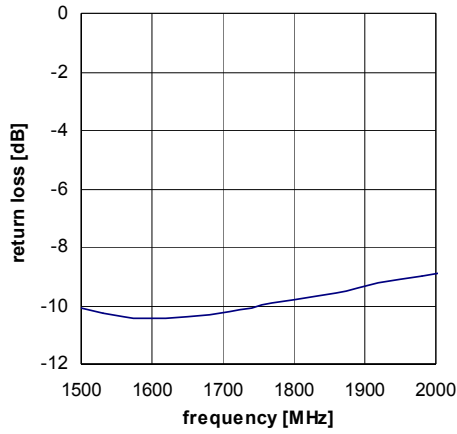
This product (f_2-f_1) is a low frequency product that is generated, which can modulate the base-emitter and collector-emitter voltages of a transistor used in an amplifier, This results in a fluctuating base voltage and collector voltage. For good linearity, a constant base and collector voltage are required. Lowering the collector voltage causes an amplifier to saturate earlier thus decreasing linearity for a certain power level. The base voltage determines the quiescent current for the device, and thus the linearity.

A fluctuating base voltage would change the linearity of the amplifier. Therefore it is important to apply proper bypassing at both collector and base. In Figure 1 C_3 is a low frequency decoupling capacitor for the collector and C_8 for the base. In most cases, a 47 nF to 220 nF capacitor is sufficient at the base. C_8 improves the IP_3 considerably. An improvement of 5 to 12 dBm can be expected. Similar effects can be expected when C_3 is also applied, however the effects are less dramatic.

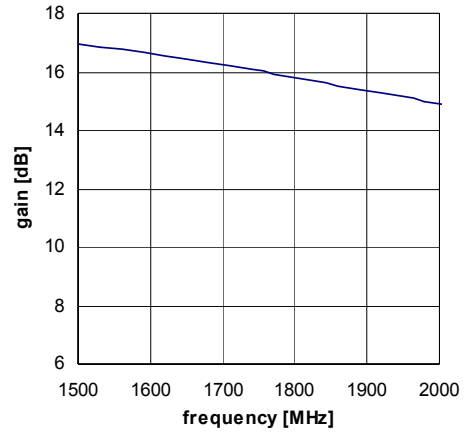
1.3 In order to optimise the design for a particular application, observe the following points

- The input return loss can be improved by reducing L_1 from 5.6 nH to 4.7 nH, however this will also increase the noise figure.
- The stability margin can be increased by increasing the value of R_1 .
- For other supply voltages resistor R_3 can be used to help setting the collector voltage for a given collector current. For a supply voltage of $V_{CC} = 3$ V and $I_{CC} = 6.5$ mA the following resistor R_3 is recommended: $(3 \text{ V} - 2.2 \text{ V}) / 6.5 \text{ mA} = R_3 \cong 120 \Omega$ (see Figure 1). R_3 also helps to cancel the H_{FE} -spread and helps to stabilise device current over supply voltage and temperature variation.
- Consider the LNA on/off switching time which is primarily determined by the time constant set by the $R_2 C_8$ combination.

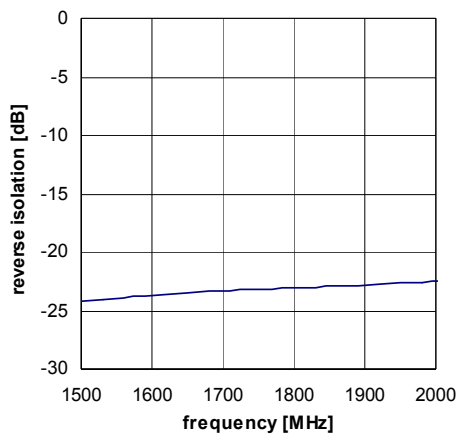
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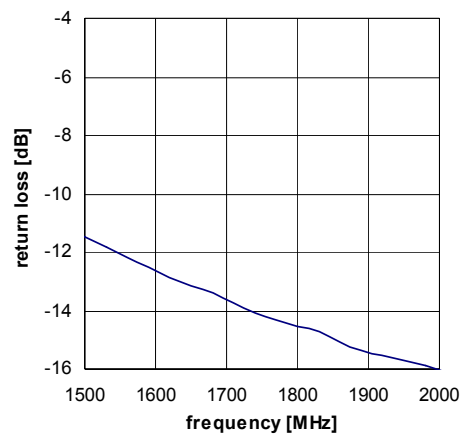
Input Return Loss vs Frequency



Gain vs Frequency at 1900 MHz

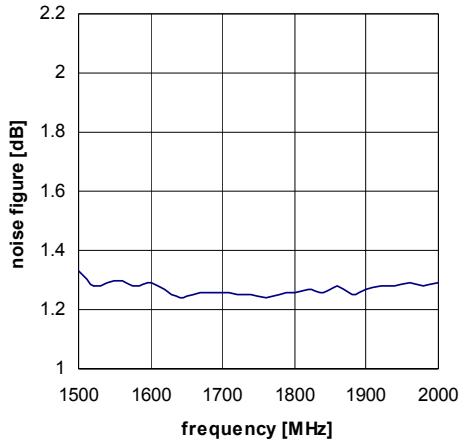


Reverse Isolation vs. Frequency

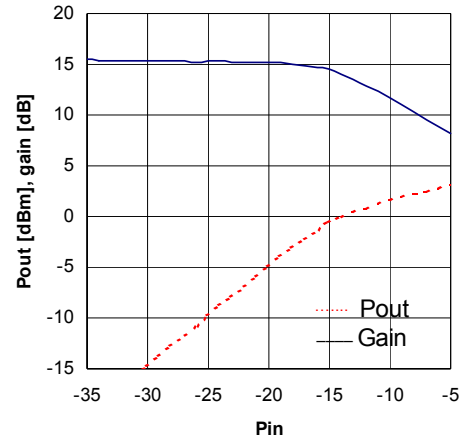


Output Return Loss vs. Frequency

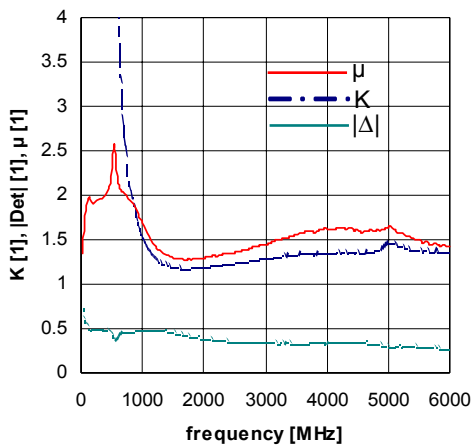
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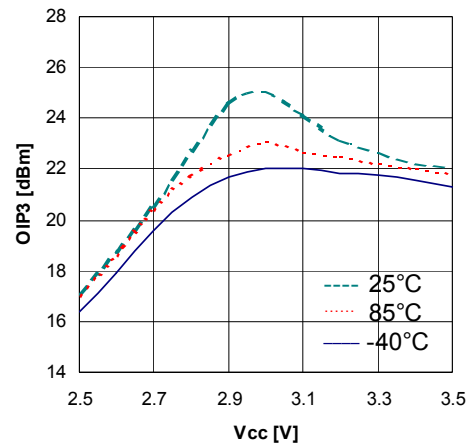
NF vs Frequency (25 °C)



Gain, P_{out} vs. P_{in} at 1900 MHz ($P_{1dB} = -1$ dBm)



Stability Factor μ , K, the magnitude of the S-matrix determinant vs. Frequency



OIP_3 vs. V_{CC} and Temperature

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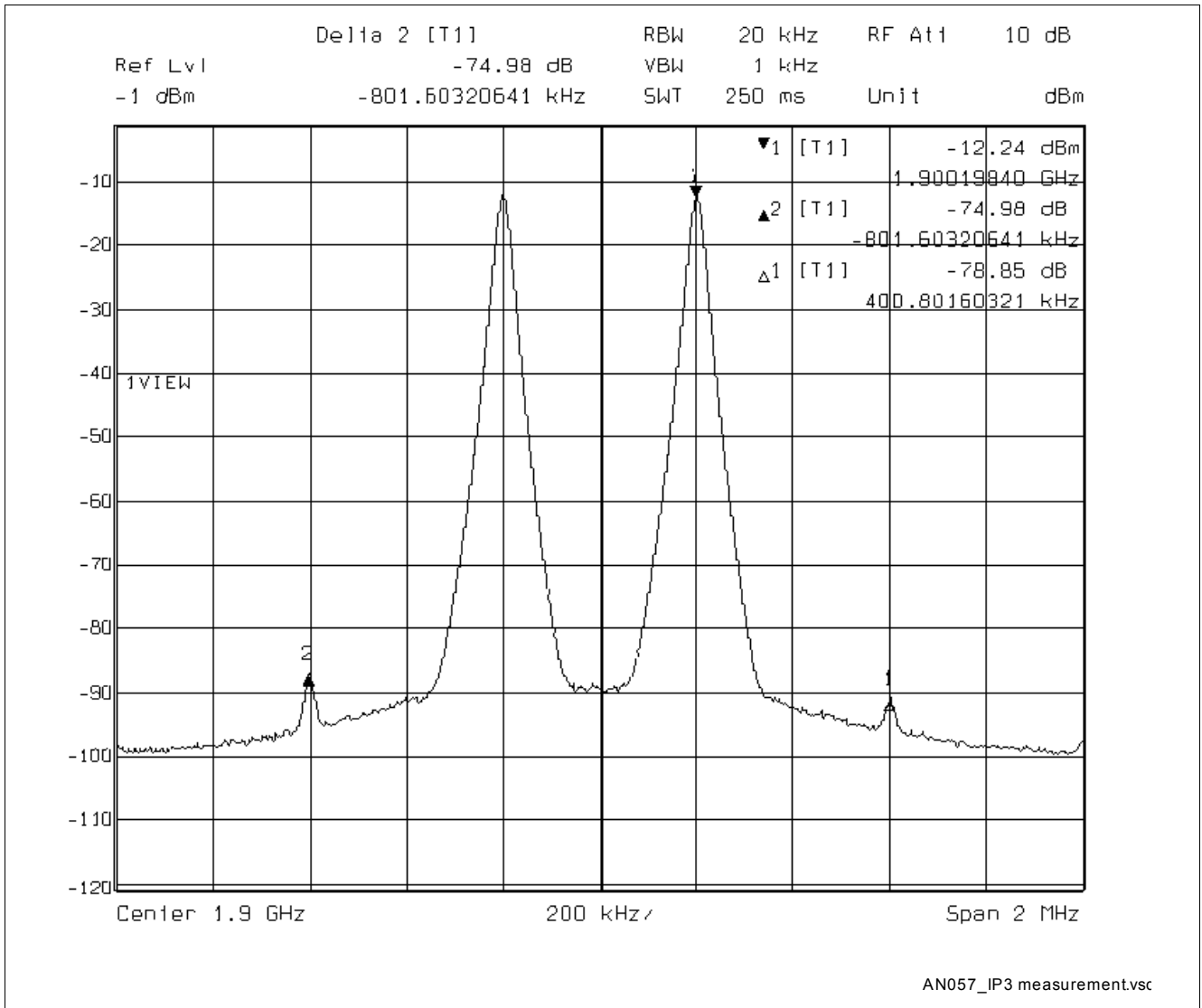


Figure 6 IP_3 measurement at $V_{CC} = 3\text{ V}$, $I_{CC} = 6.5\text{ mA}$, $P_{in} = -28\text{ dBm}$ per tone ($OIP_3 \cong 24\text{ dBm}$)