# Application Note No. 057

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

RF & Protection Devices

Never stop thinking

**Edition 2007-01-08**

**Published by**
**Infineon Technologies AG**
**81726 München, Germany**

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

**Revision History: 2007-01-08, Rev. 2.0**

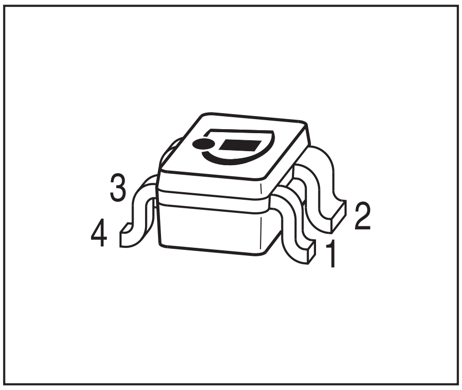
**Previous Version:**

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

# 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 | $IP_3$ 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) |

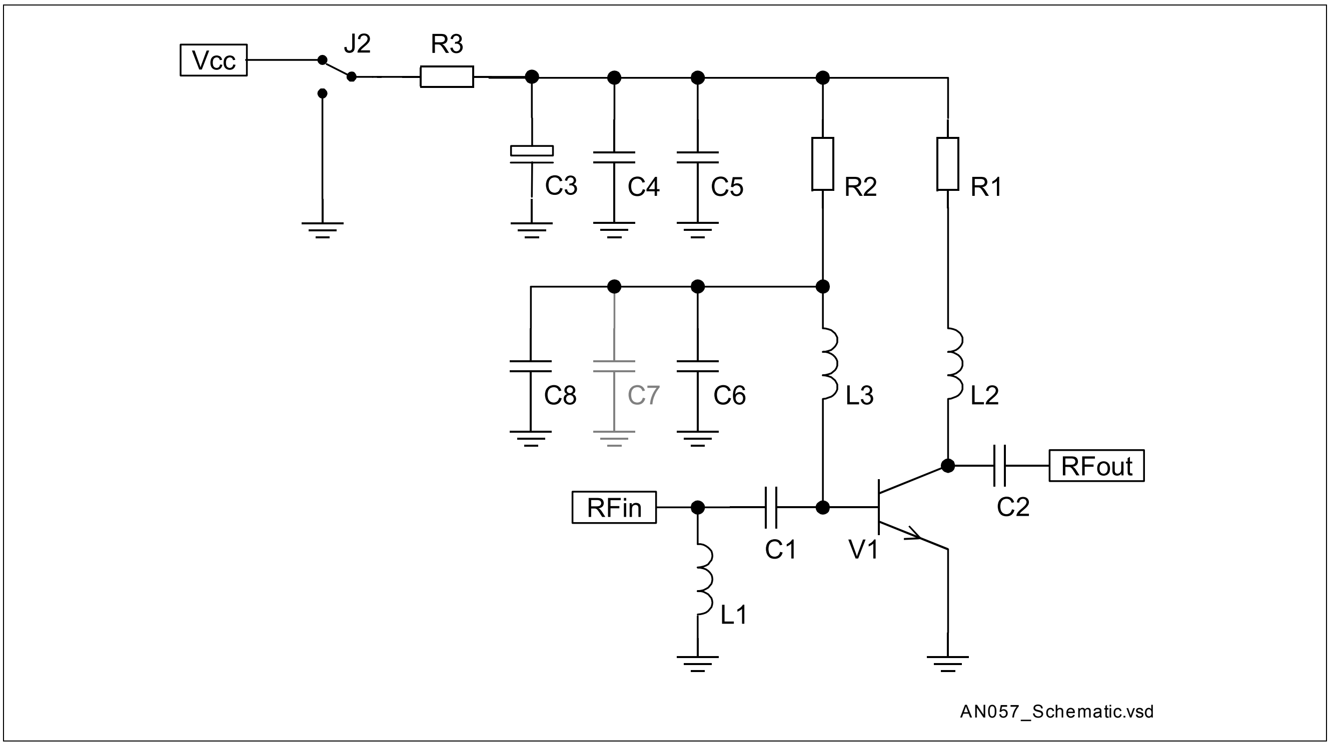



**Figure 1 Schematic of 1900 MHz Amplifier**

**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 µF | - | 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 IP3-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 kΩ | 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 |

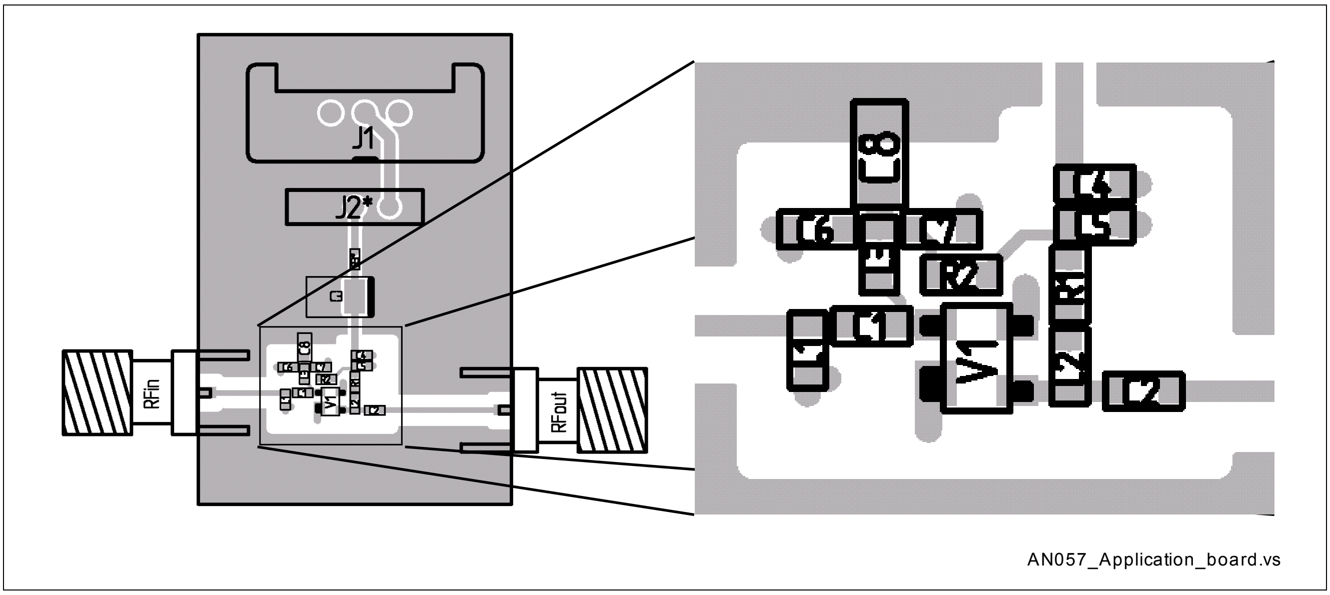



Figure 2 Application Board (scale 2:1, orginal size 23 x 35 mm)

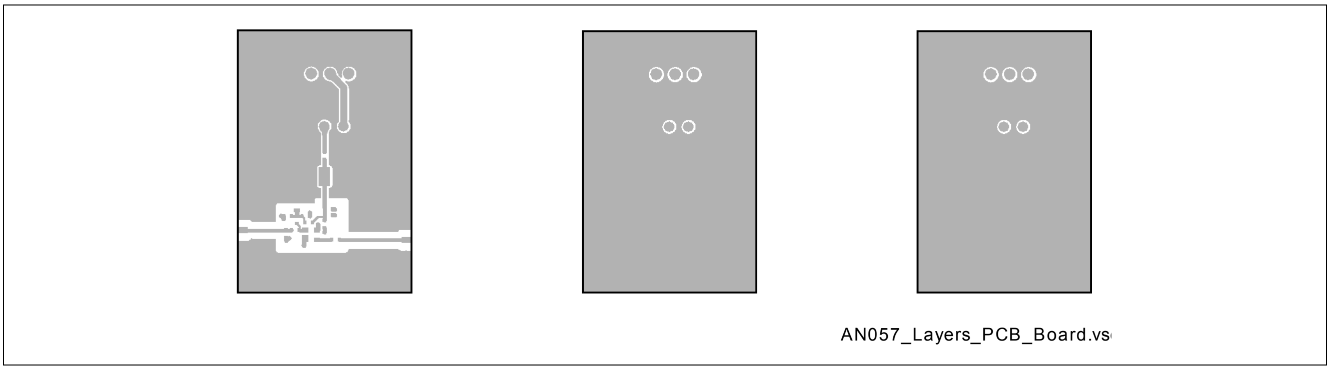



Figure 3 Top, Middle and Bottom layers of PCB-Board

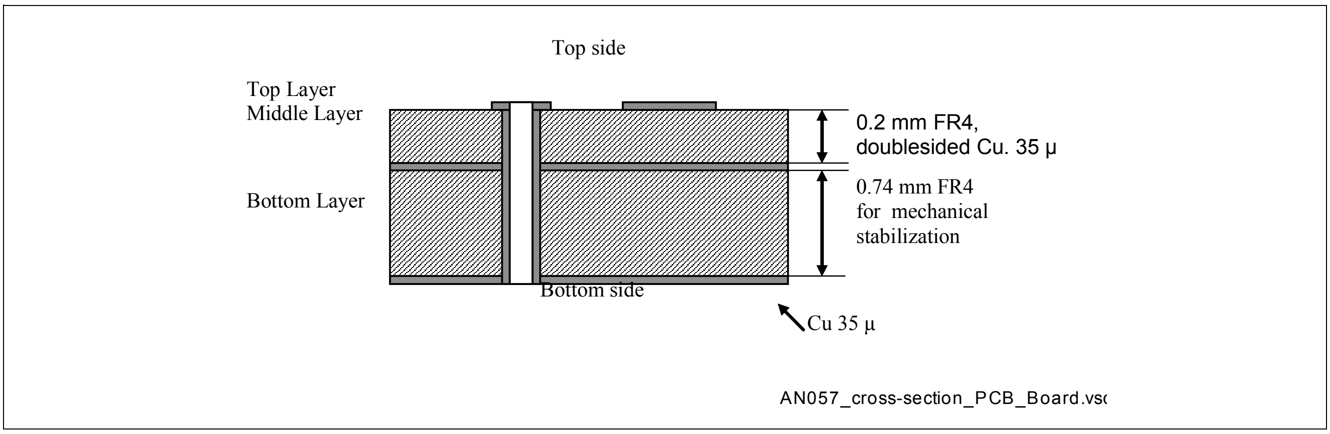



Figure 4 Cross-Section of PCB-Board

## 1.1 Measured parameter values

The curves shows the measured parameter values at 25 °C, $V_{CC}$ = 3.0 V and 1900 MHz unlesses 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 Pin = -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**)

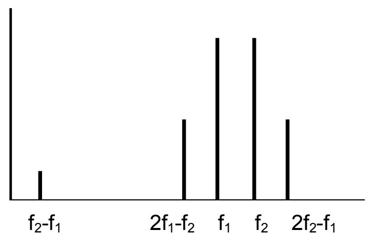


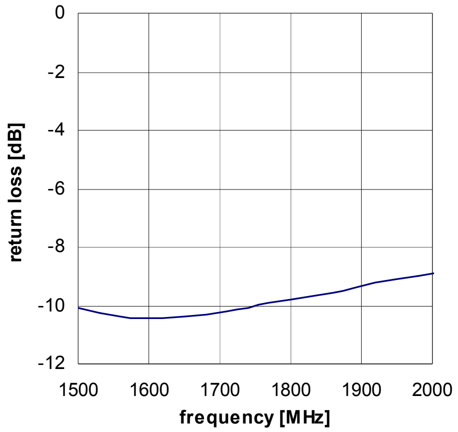

**Figure 5 Two tone test and generated intermodulation distortion**

This product (f2-f1) is a low frequency product that is generated, which can modulate the base-emitter and collector-emitter voltages of a transistor used in a amplifier, This results an fluctuating base voltage and collector voltage. For good linearity, a constant base and collector voltage are requiered. Lowering the collector voltage causes an amplifier to saturate earlier thus decreasing linearity for certain power level. The base voltage determines the quiescent current for the device, and thus the linearity.

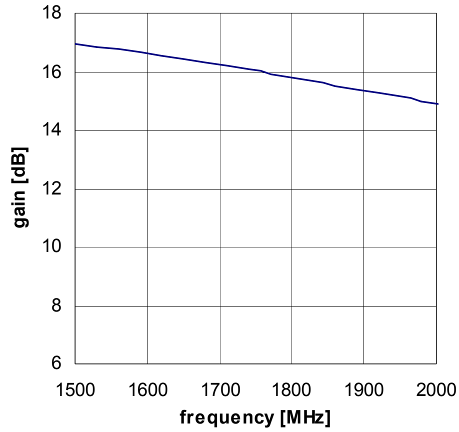
A fluctuating base voltage would change the linearity of the amplifier. Therefore it is important to apply proper bypassing at both collector and base. In **Figure 1** $C_3$ is a low frequency decoupling capacitor for the collector and $C_8$ for the base. In most cases, a 47 nF to 220 nF capacitor is 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

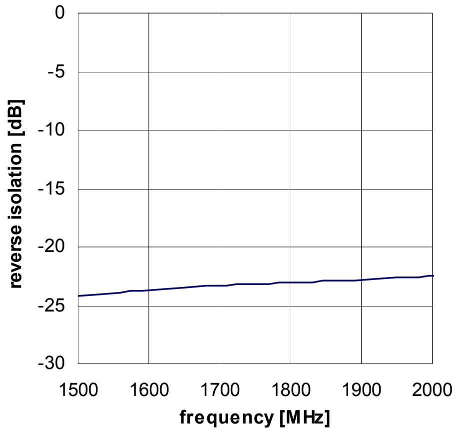
- The input return loss can be improved by reducing $L_1$ from 5.6 nH to 4.7 nH, however this will also increase the noise figure.
- The stability margin can be increased by increasing the value of $R_1$.
- For other supply voltages resistor $R_3$ can be used to help setting the collector voltage for 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 V - 2.2 V) / 6.5 mA = $R_3 \cong$ 120 Ω (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.



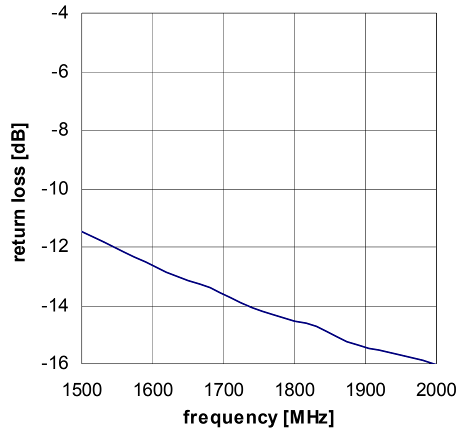

Input Return Loss vs Frequency



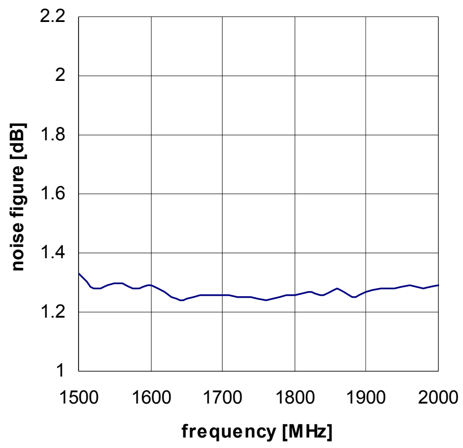

Gain vs Frequency at 1900 MHz



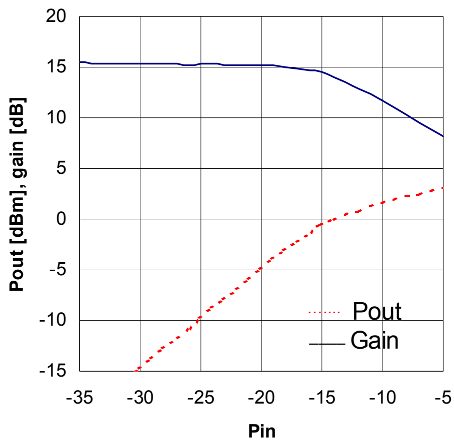

Reverse Isolation vs. Frequency



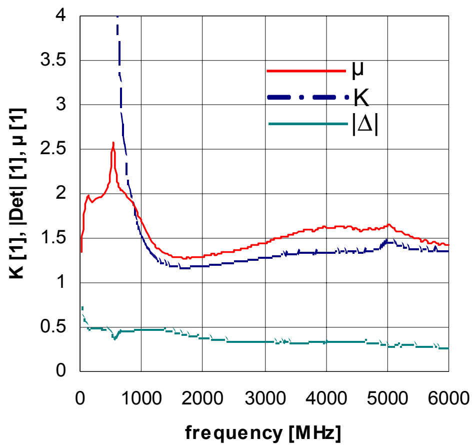

Output Return Loss vs. Frequency



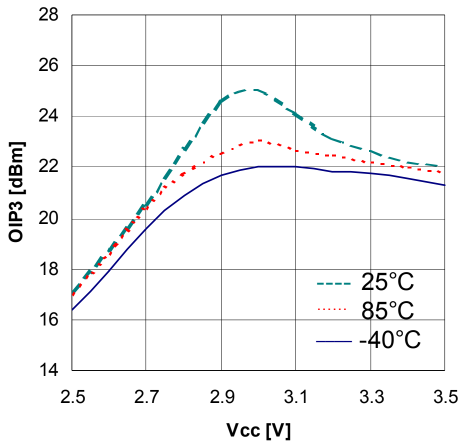

$NF$ vs Frequency (25 °C)




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

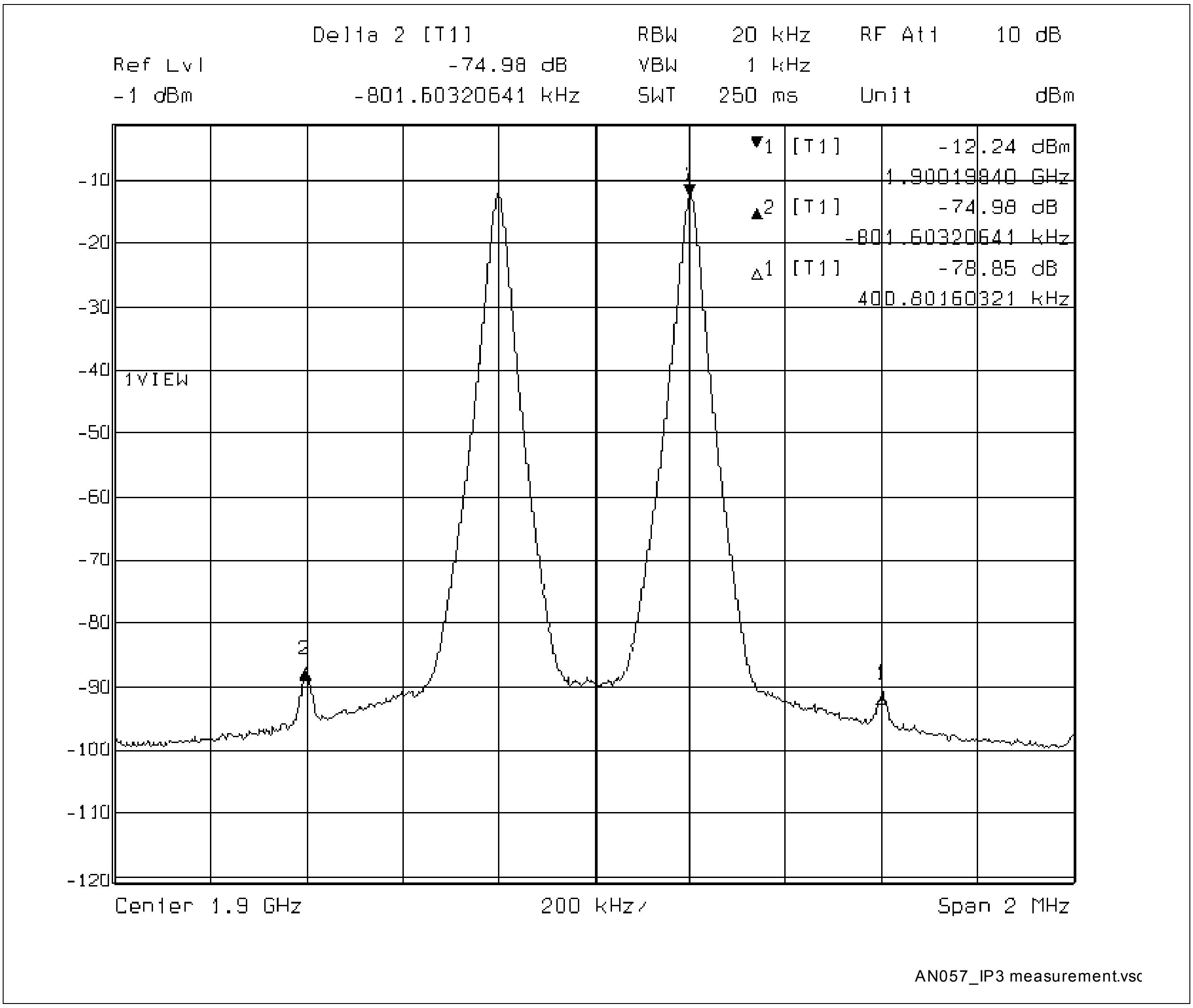



**Figure 6** $IP_3$ **measurement at** $V_{CC}$ **= 3 V,** $I_{CC}$ **= 6.5 mA,** $P_{in}$ **= -28 dBm per tone (**$OIP_3 \cong$ **24 dBm)**