Russell J. Hoppenstein

## *TI High Speed Designs: Verified Design*

# *Low Frequency RF Amplifier Solution*

## TI High Speed Designs

TI High Speed Designs are analog solutions created by TI's analog experts. Verified Designs offer the theory, component selection, simulation, complete PCB schematic & layout, bill of materials, and measured performance of useful circuits. Circuit modifications that help to meet alternate design goals are also discussed.

## Design Resources

| | |
|---|---|
| TRF37A73 | Product Folder |
| TRF37B73 | Product Folder |
| TRF37C73 | Product Folder |
| TRF37D73 | Product Folder |
| TRF37A73EVM | Evaluation Board |
| TRF37B73EVM | Evaluation Board |
| TRF37C73EVM | Evaluation Board |
| TRF37D73EVM | Evaluation Board |

## Circuit Description

The TRF37x73 gain block family can operate down to 1 MHz. When operating in the lower frequencies bands the coupling caps and RF choke must be modified for best operation. This design provides the low frequency component recommendations and provides performance plots over temperature and voltage for operation within the lower part of the amplifier's useable range.

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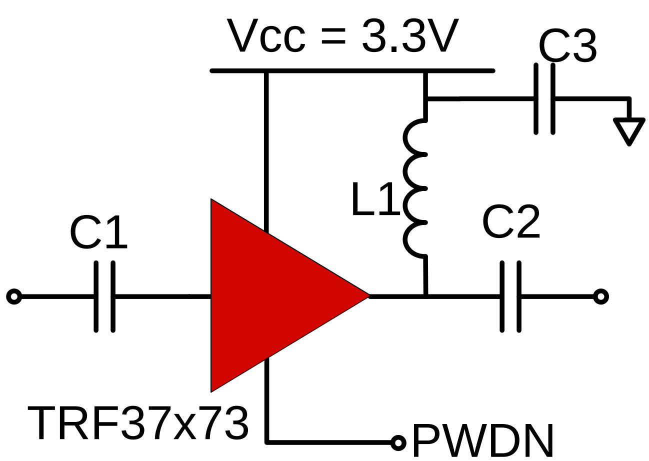


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## Introduction

The TRF37x73 gain block family is internally matched and can operate down to 1 MHz. The gain flavors are shown in Table 1.

**Table 1: TRF37x73 Gain Flavors**

| Device | Nominal Gain |
|---|---|
| TRF37A73 | 12 dB |
| TRF37B73 | 15 dB |
| TRF37C73 | 18 dB |
| TRF37D73 | 21 dB |

## 1 Application Schematic

The application schematic is shown in Figure 1. The TRF37x73 inherently will support operation to very low frequencies; however, the external coupling capacitors (C1, C2) and RF choke (L1) must be modified to provide best performance at the lower frequencies. At lower frequencies the coupling capacitors are increased in value and are chosen to provide low impedance coupling at the frequency of interest. The RF choke must be modified to a larger value as well that will provide a higher AC impedance at the frequency of interest (i.e. work better as a choke). The bypass cap (C3) is not critical and used to provide a good wideband bypass to ground.

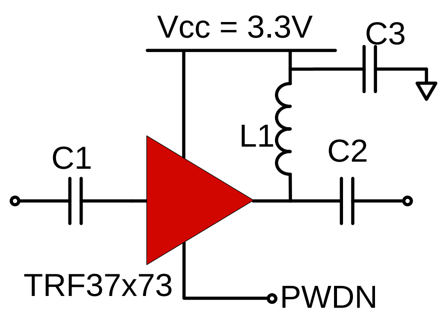



**Figure 1: Application Schematic**

## 2 Measurement Results

### *2.1 Baseline Performance*

The baseline performance data is taken with the nominal component values provided on the device EVM measured to the lower frequency band. The RF component values are shown in Table 2. The performance plots across all gain flavors is shown in Figure 2.

**Table 2. Nominal RF Component Values**

| Ref Designator | Value |
|---|---|
| **C1, C2** | 1000 pF |
| **L1** | 100 nH |

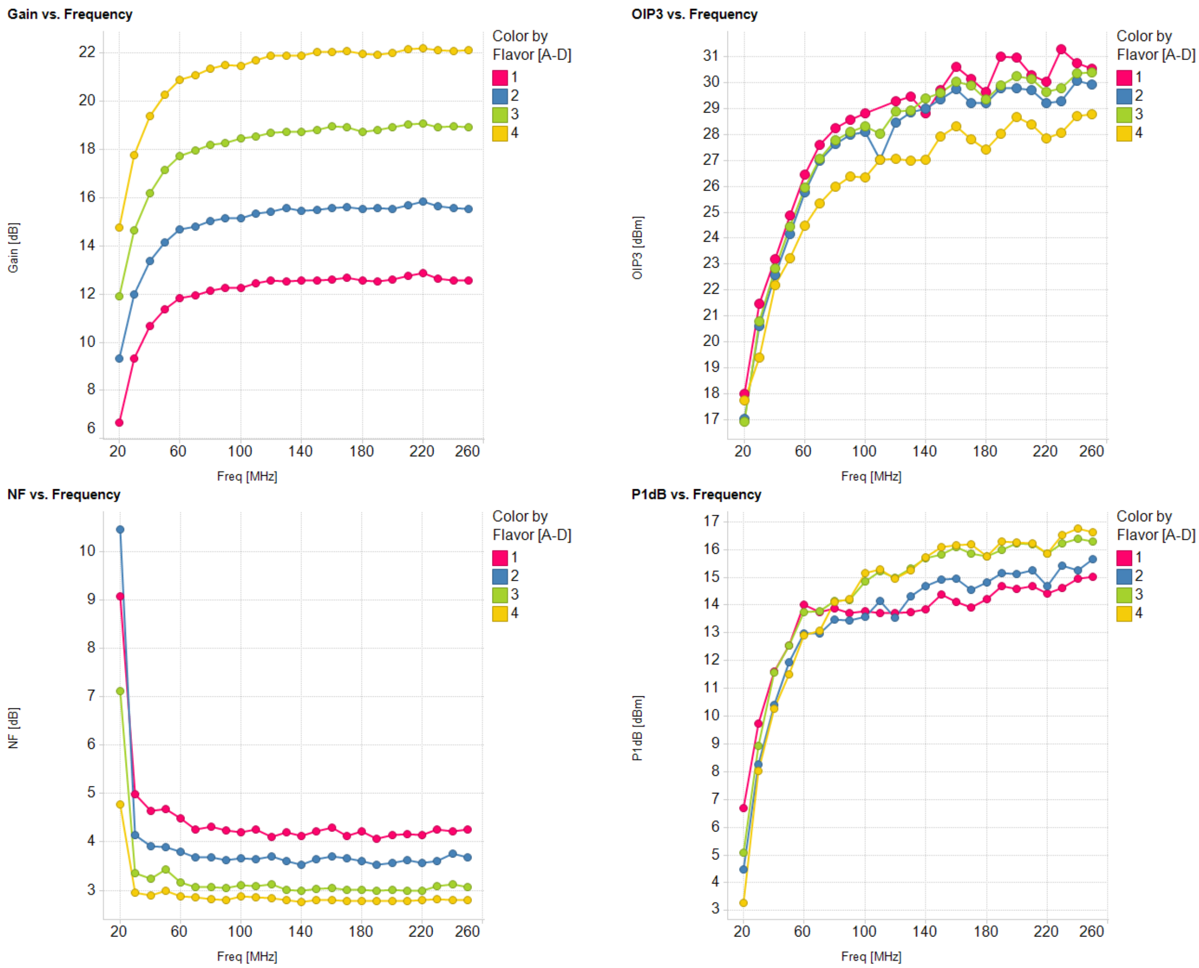



**Figure 2: Low Frequency Performance with Nominal RF Component Values**

As the frequency drops the RF performance parameters degrade quickly. This performance degradation is not due to the parts, but is primarily due to the limitations in the RF choke at these frequencies. Modification of the RF components is needed to maintain reasonable performance.

## *2.2 Low Frequency (LF) Circuit Modifications*

For operation at the lower frequencies the RF component values are modified to maintain reasonable performance. The choice for the RF choke can be tricky. It is important to balance the inductance value for best RF choke with low DC resistance with high enough SRF (Self Resonance Frequency). For operation at frequencies down to 1 MHz the RF component values were modified as shown in Table 3.

**Table 3. Low Frequency RF Component Values**

| Ref Designator | Value |
|---|---|
| **C1, C2** | 0.1 uF |
| **L1** | 4.7 uH |

The inductor used in the analysis is the Colicraft 0805 sized 0805LS-472XJL. This inductor choice is suitable for low frequency operation below 50 MHz and may not be quite optimal as the frequency increases due to SRF limitations.

The performance results of all the gain flavors with this modification are shown in Figure 3.

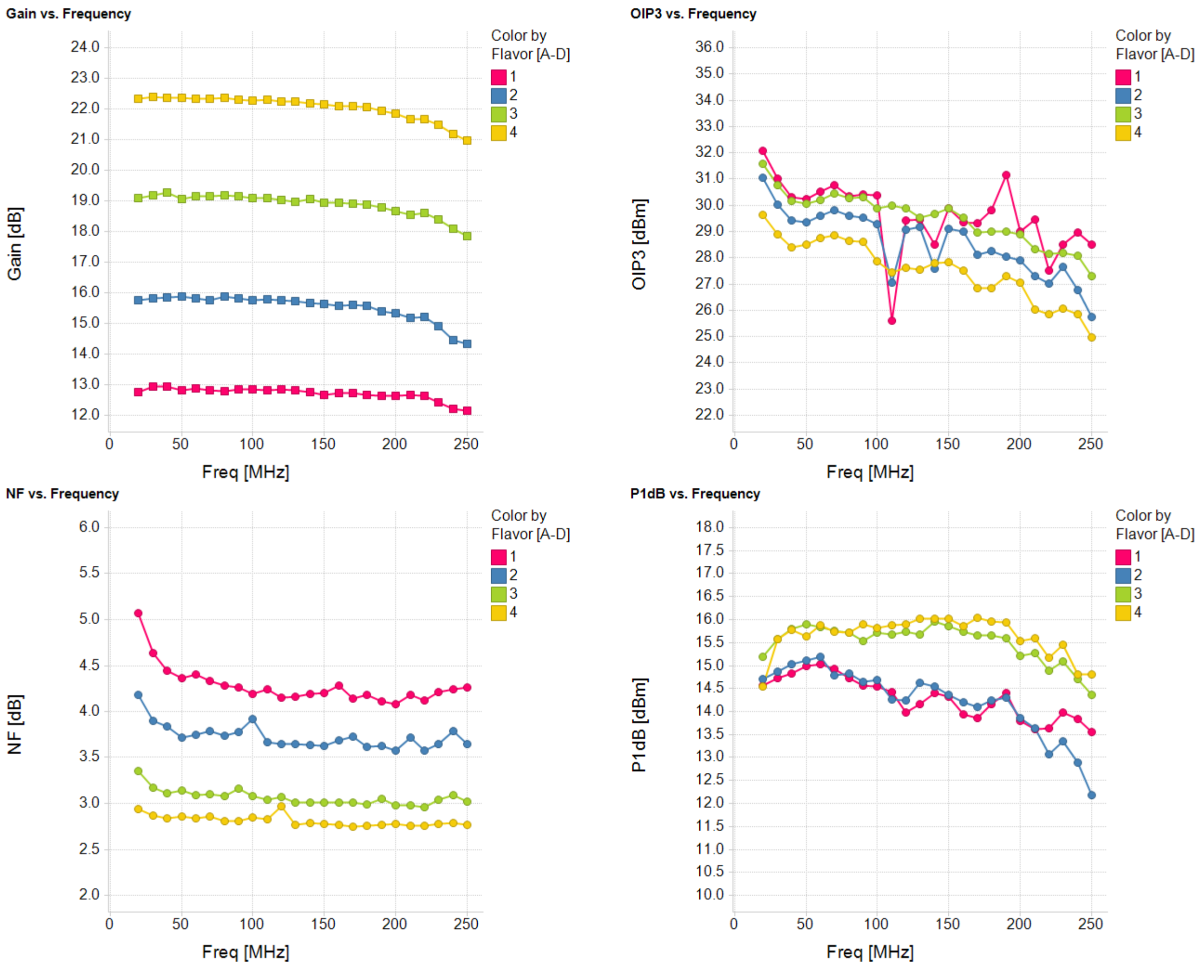



**Figure 3: Low Frequency Performance with LF Optimized RF Components**

Note that with the optimized LF RF components the gain response does not drop sharply; it remains fairly steady down to 20 MHz. With this configuration, the higher frequencies are becoming compromised. Good performance is maintained to around 200 MHz before there is a noticeable degradation in the RF performance parameters.

Operation of gain and OIP3 response down to 1 MHz are shown in Figure 4 with the same circuit configuration.

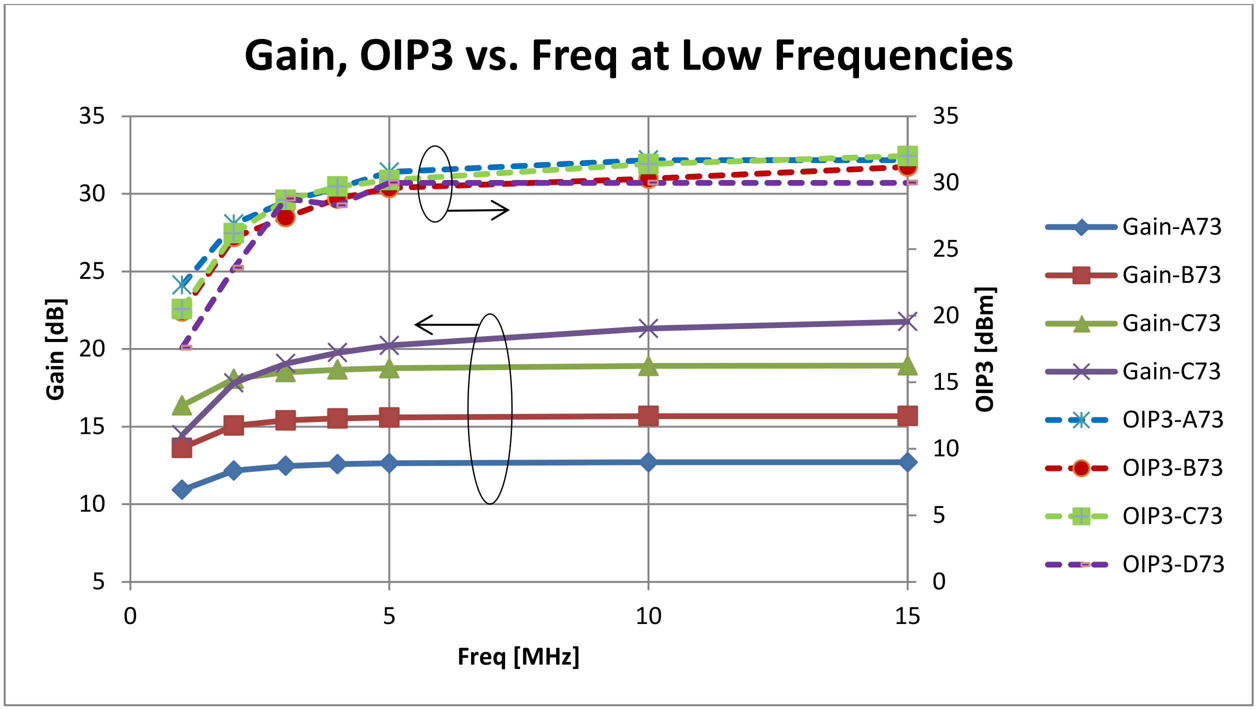



**Figure 4: Gain and OIP3 Response down to 1 MHz**

### *2.3 Intermediate Frequency (IF) Circuit Modifications*

For cases where operation is not needed all the way down to 1 MHz, an intermediate frequency circuit modification is employed to achieve good performance over a wide frequency range. Here again the primary change is in the RF choke. The RF component values are shown in Table 4.

**Table 4. Intermediate Frequency RF Component Values**

| Ref Designator | Value |
|---|---|
| **C1, C2** | 0.1 uF |
| **L1** | 680 nH |

The inductor used is the Colicraft 0603LS-681XJL. This inductor choice is suitable for low frequency operation in the 50 MHz to 400 MHz band. The performance results of all the gain flavors with this modification are shown in Figure 5.

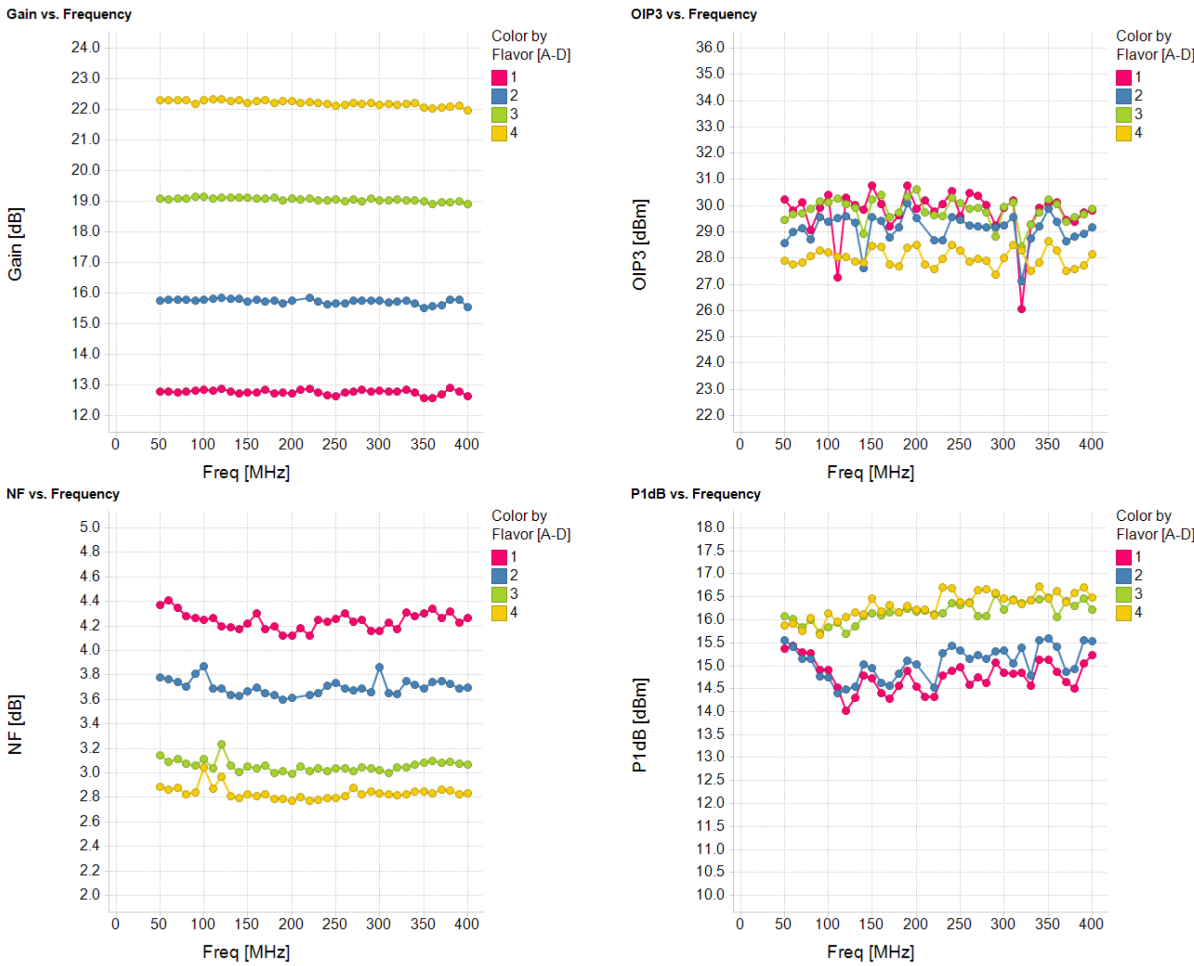



**Figure 5: Low Frequency Performance with IF Optimized RF Components**

This configuration provides good RF performance from 50 MHz to 400 MHz.

## 3 Conclusion

Circuit modifications to the RF coupling capacitors and RF choke are needed to maintain good amplifier performance in the low frequency range. The key point is to select the proper RF choke that will provide a high AC impedance at the frequency band of interest but will have low DC resistance so that there is negligible bias voltage loss. In addition, keep cognizant of the SRF performance of the choke. At frequencies above the SRF the properties of the inductor are increasing not well defined.

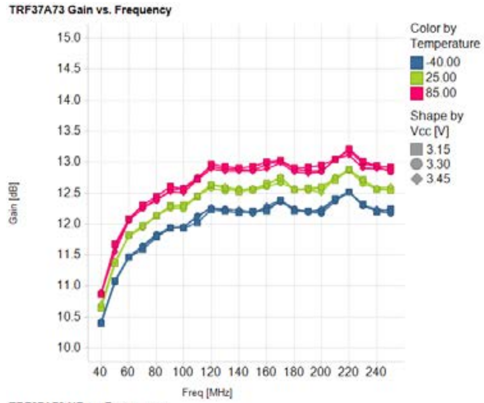
Recommended values for the coupling caps and RF choke within different bands are summarized in Table 5.

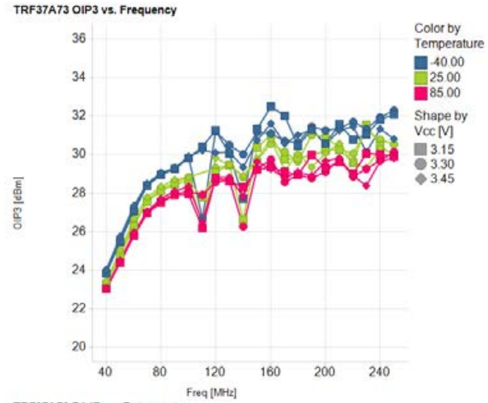
**Table 5: RF Component Value Recommendations per Band**

| Frequency Band | C1, C2 | L1 |
|---|---|---|
| **1 MHz – 50 MHz** | 0.1 uF | 4.7 uH |
| **50 MHz – 400 MHz** | 0.1 uF | 680 nH |
| **> 400 MHz** | 1000 pF | 100 nH |

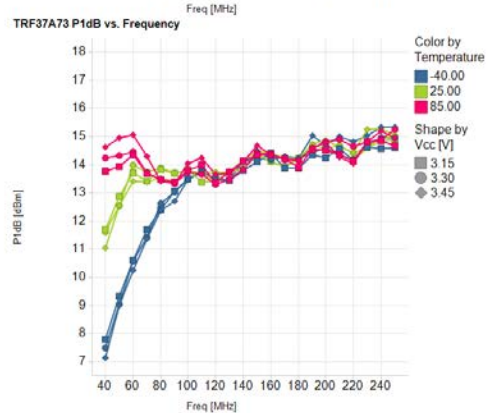
The comprehensive performance data for each configuration over all the gain flavors over temperature and voltage is shown in the Appendices for reference.

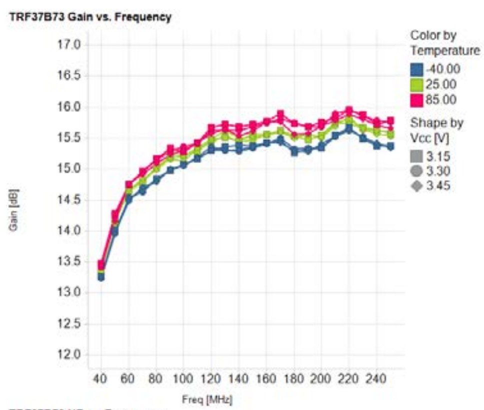
## Appendix A: Low Frequency Performance with Nominal Circuit Values over Temp, Vcc

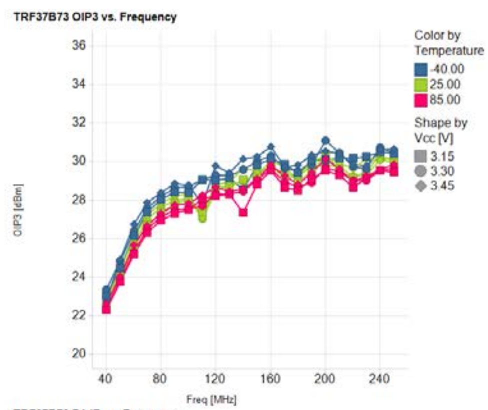


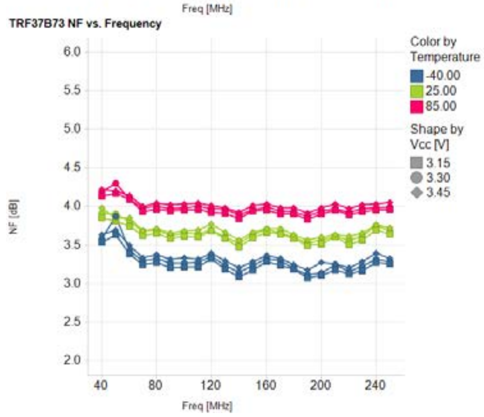



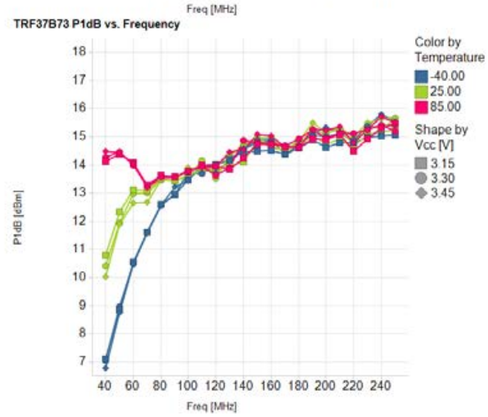




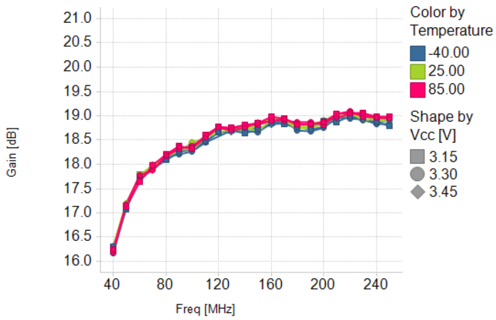



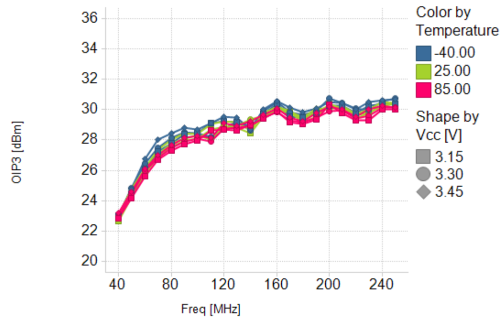



TRF37C73 Gain vs. Frequency




TRF37C73 OIP3 vs. Frequency

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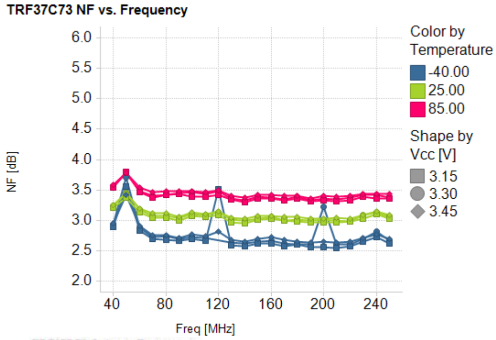


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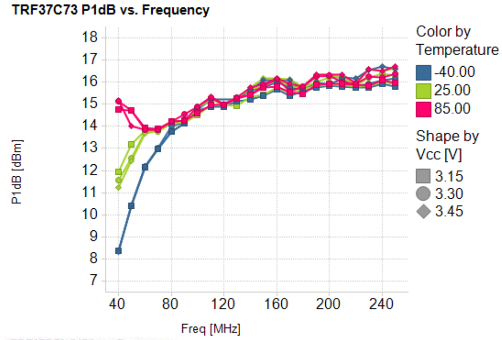


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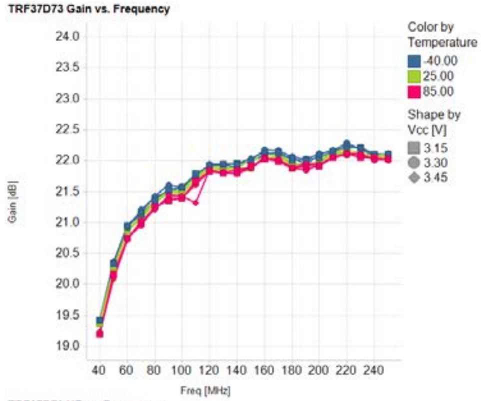


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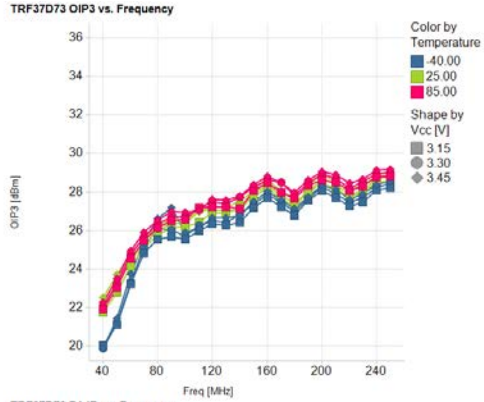


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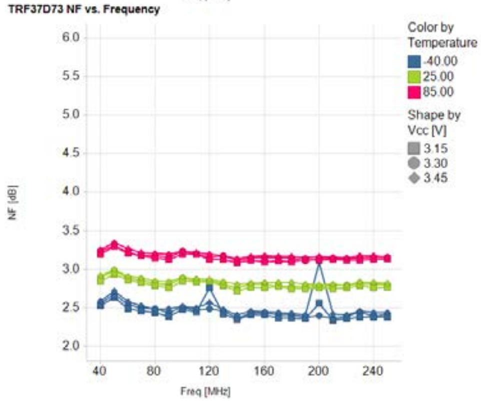
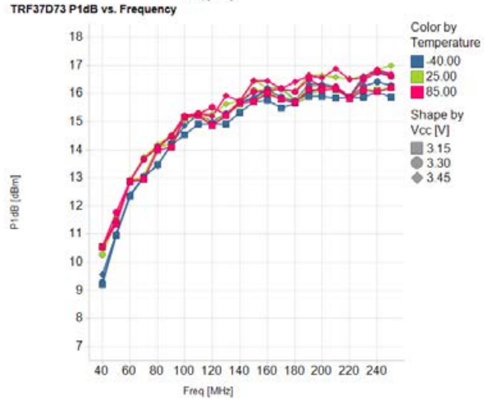
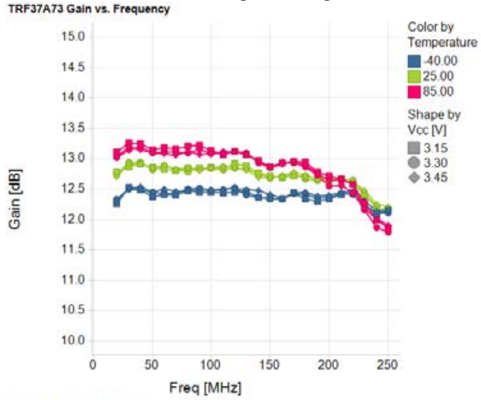
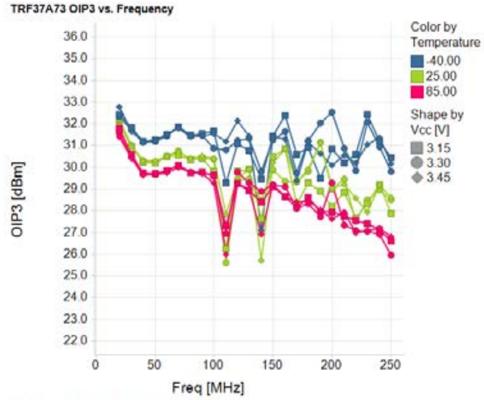


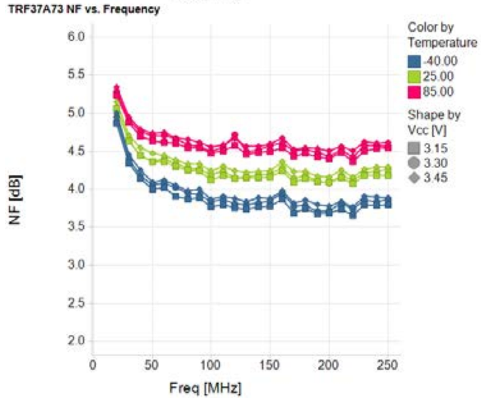

TRF37D73 P1dB vs. Frequency

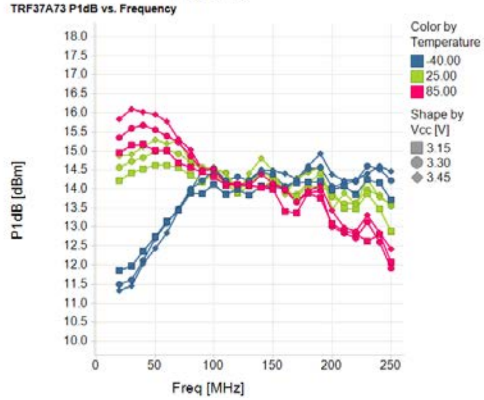


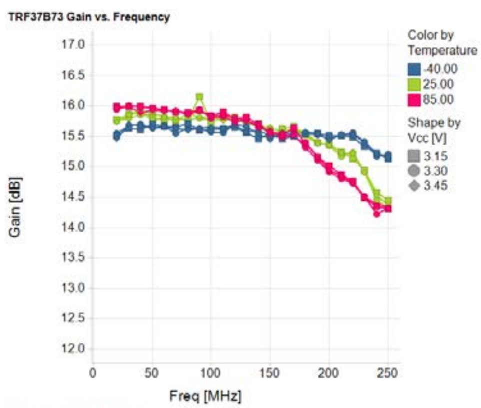
# Appendix B: Low Frequency Performance with LF Circuit Values over Temp, Vcc

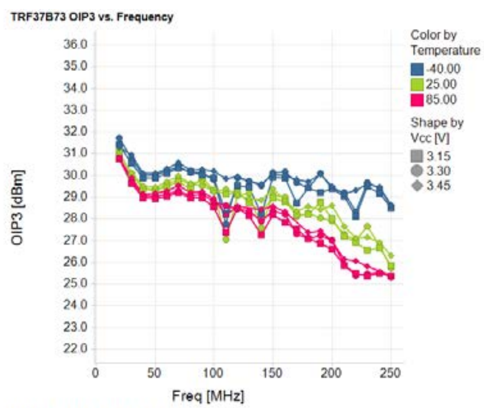


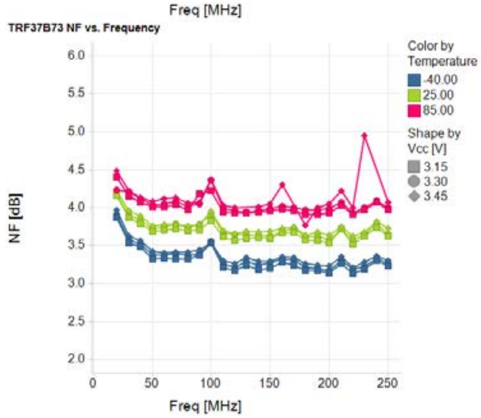



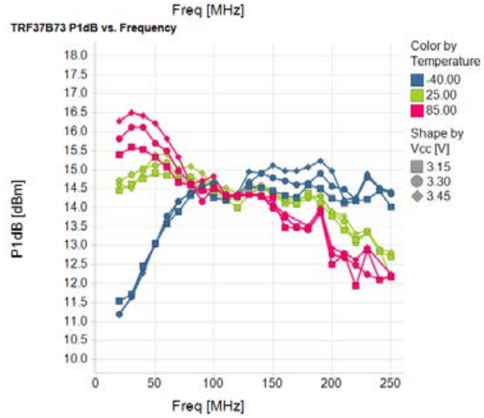



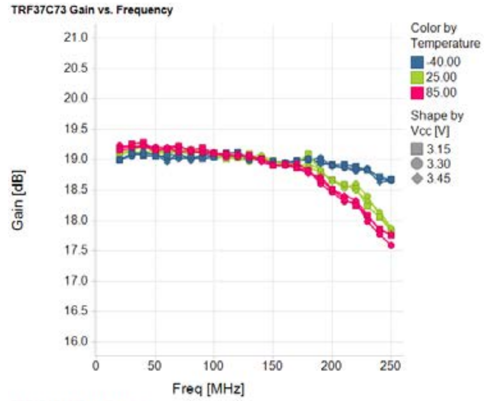




TRF37C73 Gain vs. Frequency
Gain [dB]
Freq [MHz]
Color by Temperature
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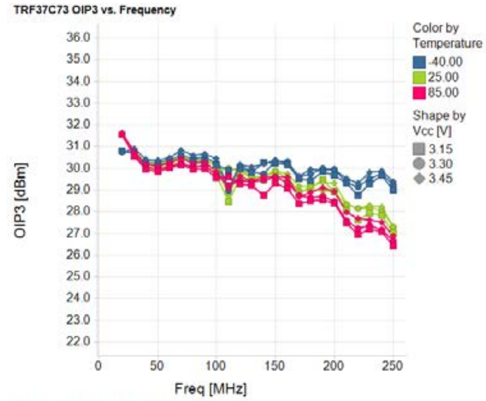
25.00
85.00
Shape by Vcc [V]
3.15
3.30
3.45


TRF37C73 OIP3 vs. Frequency
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85.00
Shape by Vcc [V]
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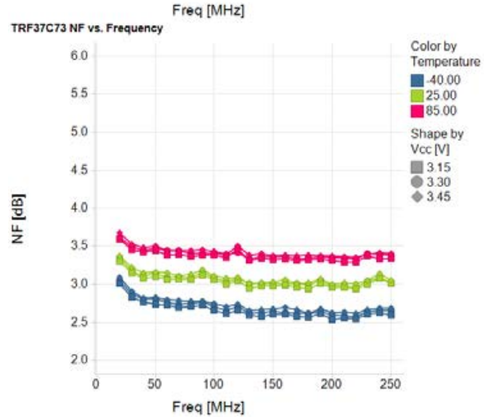
3.30
3.45


TRF37C73 NF vs. Frequency
NF [dB]
Freq [MHz]
Color by Temperature
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Shape by Vcc [V]
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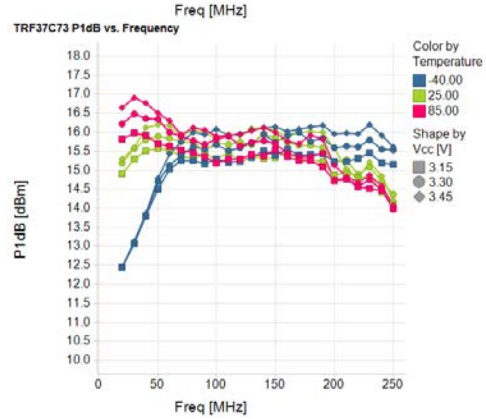
TRF37C73 P1dB vs. Frequency
P1dB [dBm]
Freq [MHz]
Color by Temperature
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Shape by Vcc [V]
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3.30
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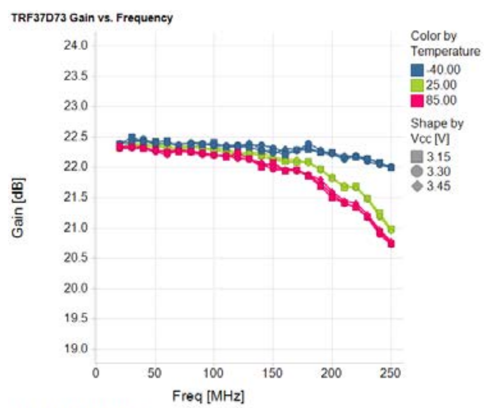
TRF37D73 Gain vs. Frequency
Gain [dB]
Freq [MHz]
Color by Temperature
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Shape by Vcc [V]
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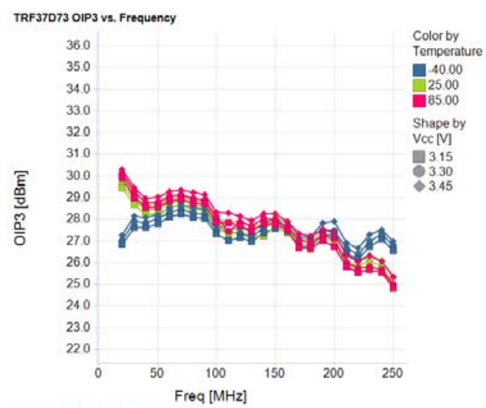
TRF37D73 OIP3 vs. Frequency
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Freq [MHz]
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Shape by Vcc [V]
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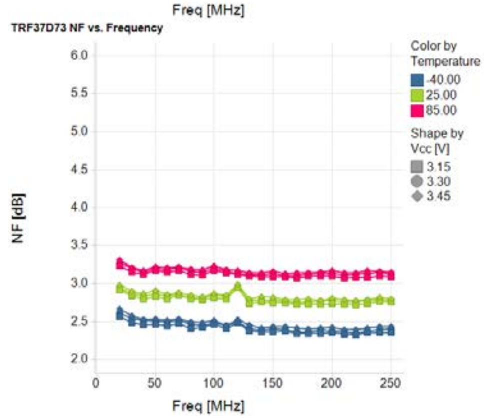
TRF37D73 NF vs. Frequency
NF [dB]
Freq [MHz]
Color by Temperature
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Shape by Vcc [V]
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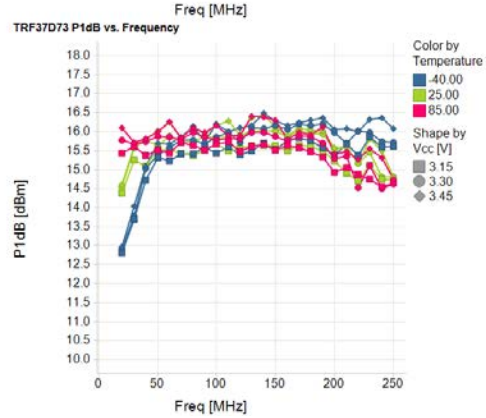
TRF37D73 P1dB vs. Frequency
P1dB [dBm]
Freq [MHz]
Color by Temperature
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Shape by Vcc [V]
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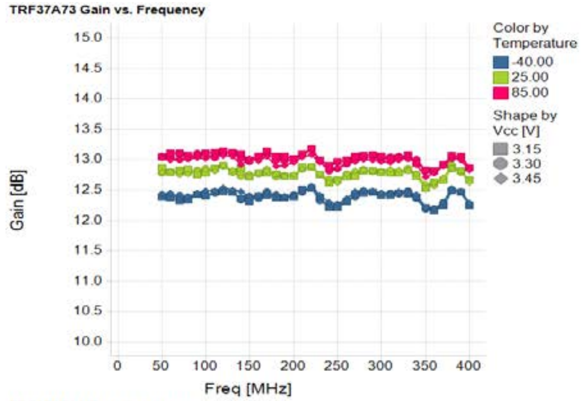
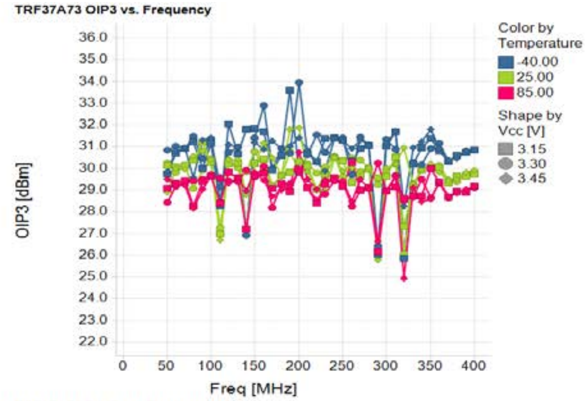
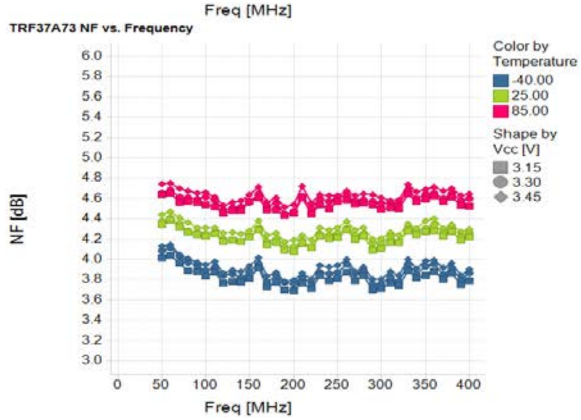
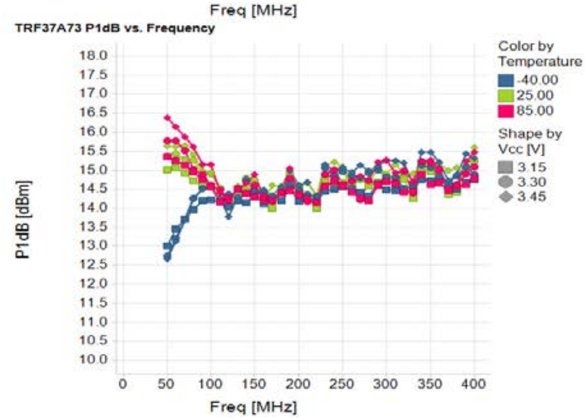
3.45

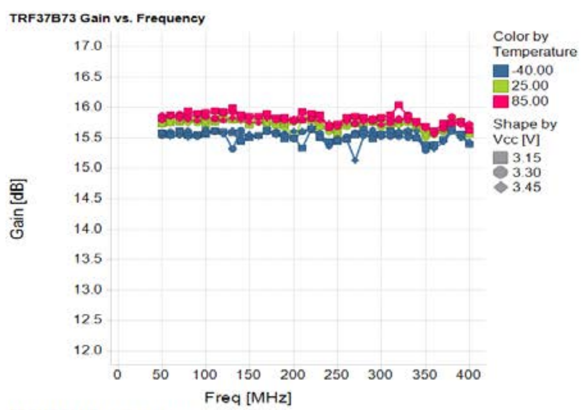
# Appendix C: Low Frequency Performance with IF Circuit Values over Temp, Vcc

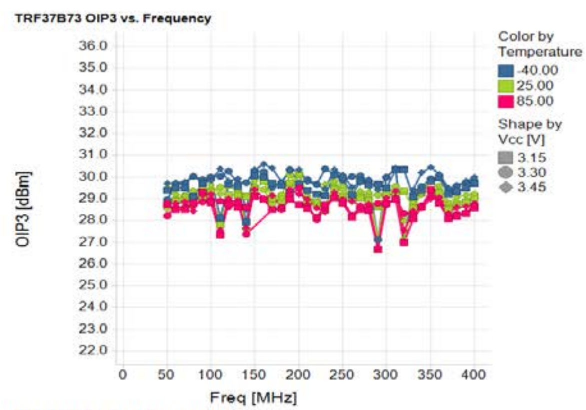


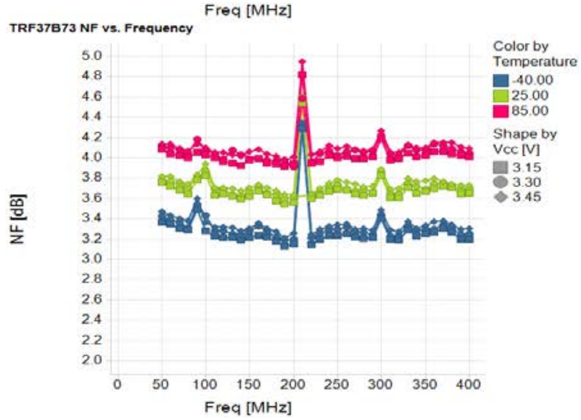



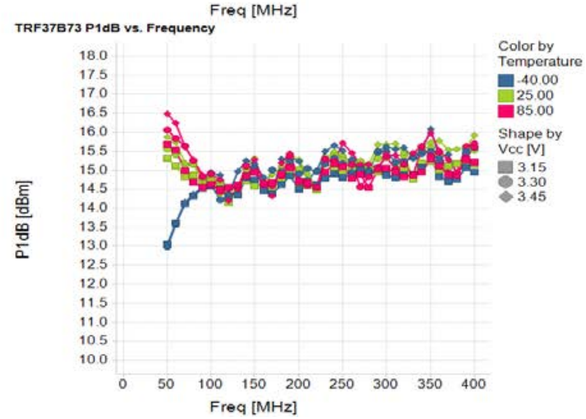



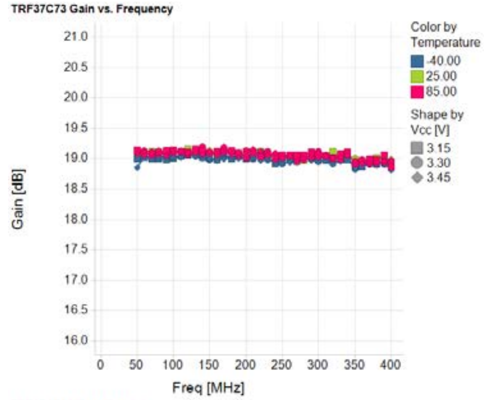



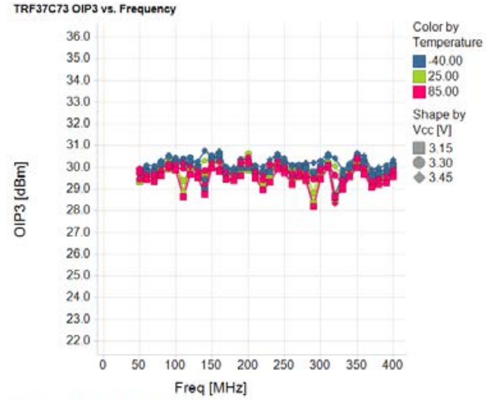



TRF37C73 Gain vs. Frequency




TRF37C73 OIP3 vs. Frequency

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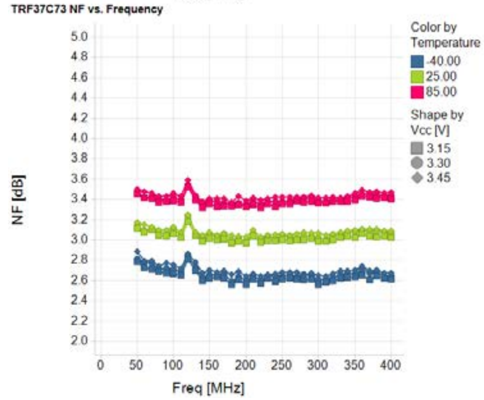
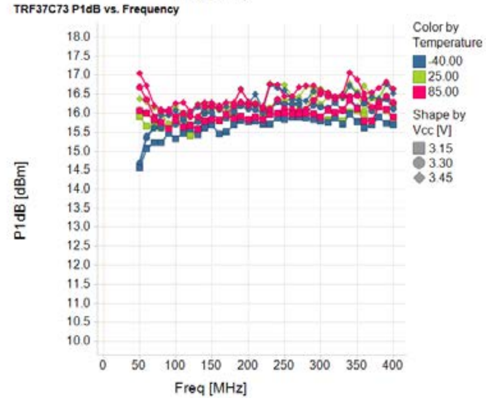



TRF37C73 P1dB vs. Frequency

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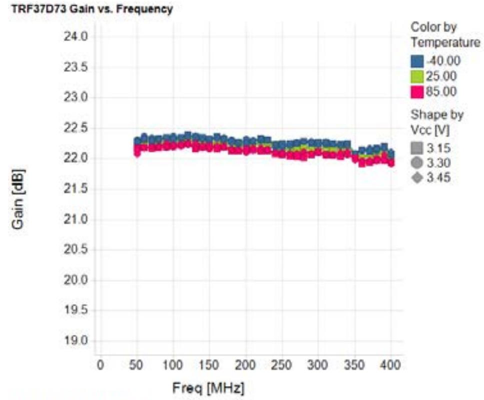
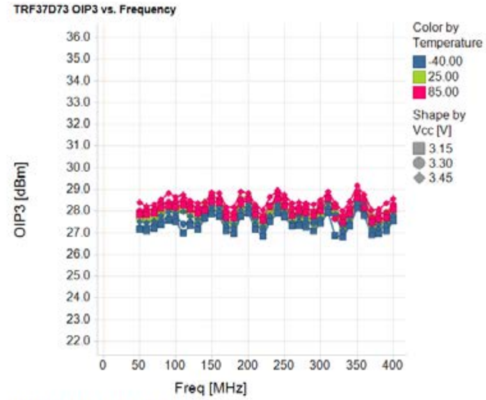
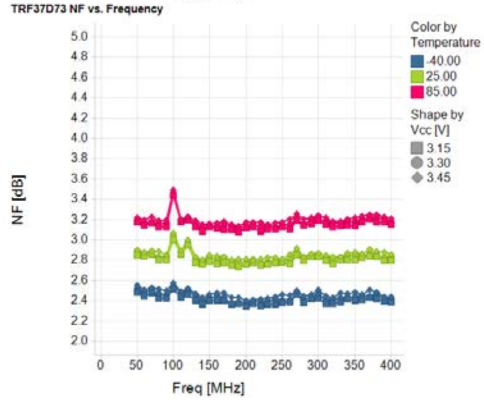


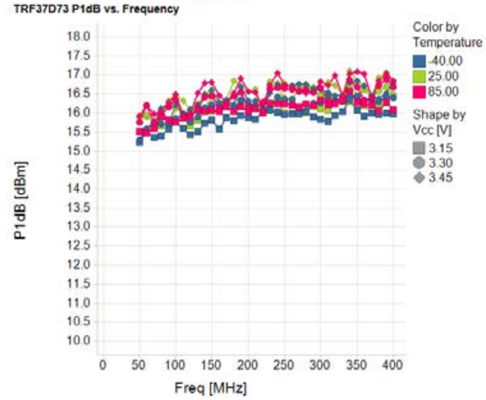

TRF37D73 OIP3 vs. Frequency




TRF37D73 NF vs. Frequency




TRF37D73 P1dB vs. Frequency



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