AN1995

Evaluating the SA605 SO and SSOP demo board

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Document information

Info	Content
Keywords	SO package, SSOP package, 12 dB SINAD, RSSI, quad tank, S-curve
Abstract	This application note discusses the layout and circuit design techniques used in the SA605D (SO-16 package) and SA605DK (SSOP-20 package) demo boards. It does not cover the basic functionality of the SA605 but instead focuses more on the layout constraints and passive component selection. This application note also provides a trouble-shooting chart to aid the RF circuit designer in evaluating the SA605 and in optimizing the layout and circuit design for best performance.

Revision history

Rev	Date	Description
2	20140903	Application note; second release Modifications: • The format of this application note has been redesigned to comply with the new identity guidelines of NXP Semiconductors. • Legal texts have been adapted to the new company name where appropriate. • Removed references to DIP package. • Sections rearranged to improve readability.
1.0	19971029	Application note; initial release

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1. Introduction

With the increasing demand for smaller and lighter equipment, designers are forced to reduce the physical size of their systems. There are several approaches to solving the size problem. A designer needs to look for sophisticated integrated single chip solutions, chips that are smaller in size, and chips that require minimum external components.

NXP Semiconductors offers all of these solutions in their SA605. The SA605 single-chip receiver converts the RF signal to audio and is available in two packages: SO and SSOP. This offers total flexibility for layout considerations. The SSOP package is the smaller of the two packages, and allows the designer the flexibility to reduce the overall size of a layout.

When working with a smaller and tighter layout in a receiver design, it becomes important to follow good RF techniques. This application note shows the techniques used in the SO and SSOP demo board. It does not cover the basic functionality of the SA605 but instead focuses more on the layout constraints. This application note also has a trouble-shooting chart to aid the designer in evaluating the SO and SSOP demo board. For a complete explanation of the SA605, please refer to application note AN1994 which describes the basic block diagrams, reviews the common problems encountered with the SA605, and suggests solutions to them. Reading AN1994 is highly recommended before attempting the SO and SSOP layout.

The recommended layout demonstrates how well the chip can perform. But it should be pointed out that the combination of external parts with their tolerances plays a role in achieving maximum sensitivity.

The minimum and maximum 12 dB SINAD measurement for both boards is –118 dBm and –119.7 dBm, respectively. A typical reading taken in the lab for both SO and SSOP demo-boards is –119 dBm.

There were two different design approaches for both layouts. For the SO layout, there are inductive tuning elements (except for the LO section); for the SSOP layout there are capacitive tuning elements. This approach was taken to show the designer that both ways can be used to achieve the same 12 dB SINAD measurement. However, it is worth mentioning that capacitive tuning elements are less expensive than the inductive tuning elements.

2. SA605 demo boards

The SA605 demo board schematics, BOMs, recommended layouts and the performance curves for the SO and SSOP are shown in this application note.

2.1 SA605D SO demo board

2.1.1 SA605 SO demo board schematic

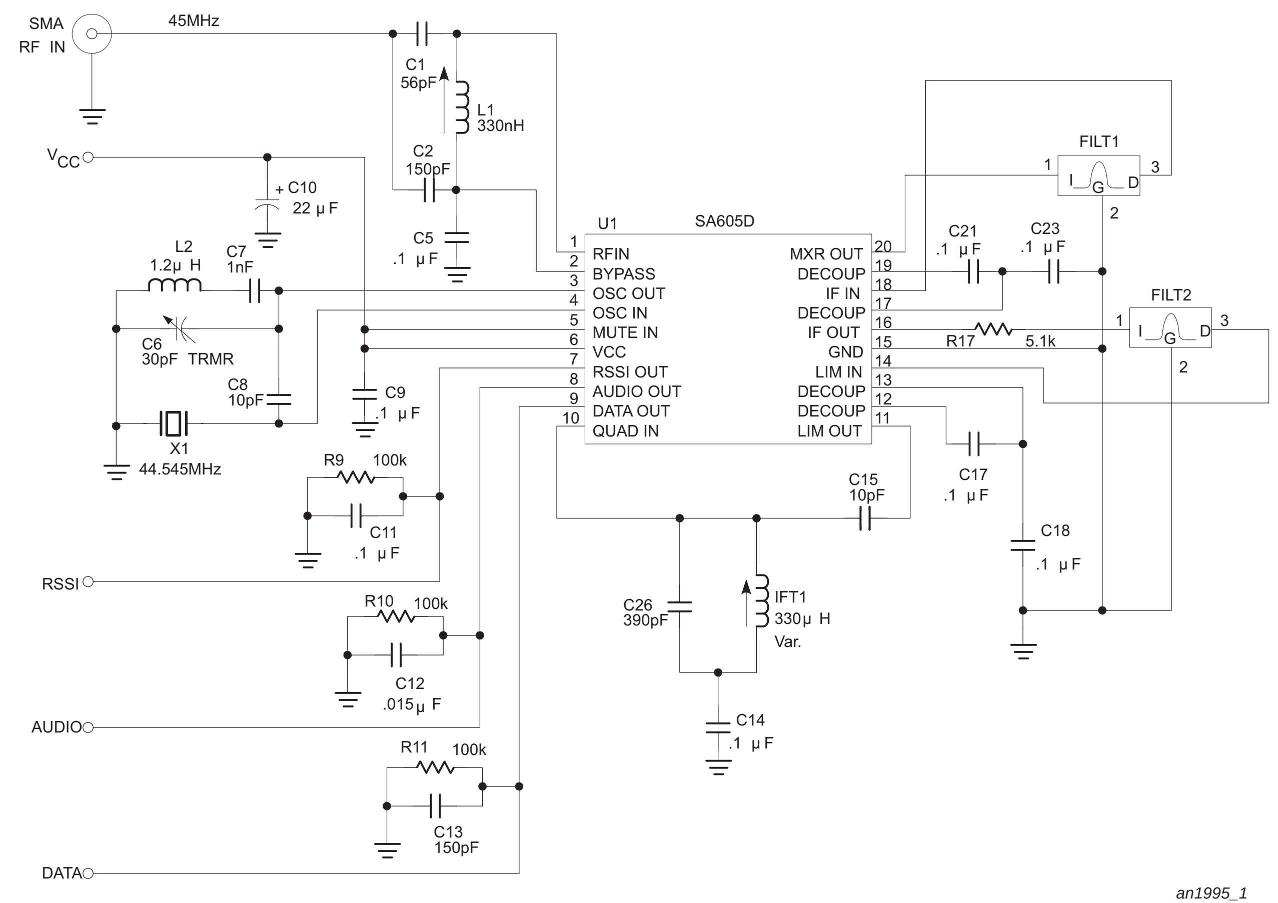


Fig 1. SA605 schematic for the SO layout

2.1.2 SA605D SO BOM

Table 1. SO layout schematic component list

Component	Description
C1	Part of the tapped-C network to match the front-end
C2	Part of the tapped-C network to match the front-end
C5	Used as an AC short to pin 2
C6	Used to tune the LO for the Colpitts oscillator
C7	Used as part of the Colpitts oscillator
C8	Used as part of the Colpitts oscillator
C9	Supply bypassing
C10	Supply bypassing
C11	Used as filter
C12	Used as filter
C13	Used as filter
C14	Used to AC ground the Quad tank
C15	Used to provide the 90° phase shift to the phase detector
C17	IF limiter decoupling cap
C18	IF limiter decoupling cap
C21	IF amp decoupling cap
C23	IF amp decoupling cap
C26	Quad tank component
L1	Part of tapped-C network to match the front-end TOKO 5CB-1320Z
L2	Part of the Colpitts oscillator Coilcraft 1008CS-122
R9	Used to convert the current into the RSSI voltage
R10	Converts the audio current to a voltage
R11	Converts the data current to a voltage
R17	Used to achieve the −12 dB insertion loss
IFT1	Inductor for the Quad tank TOKO 303LN-1130
FILT1	Murata SFG455A3 455 kHz bandpass filter
FILT2	Murata SFG455A3 455 kHz bandpass filter
X1	Standard 44.545MHz crystal in QC38 package

2.1.3 SA605D SO layout

The recommended SO layout is found in Figure 2 and should be used as an example to help designers get started with their projects.

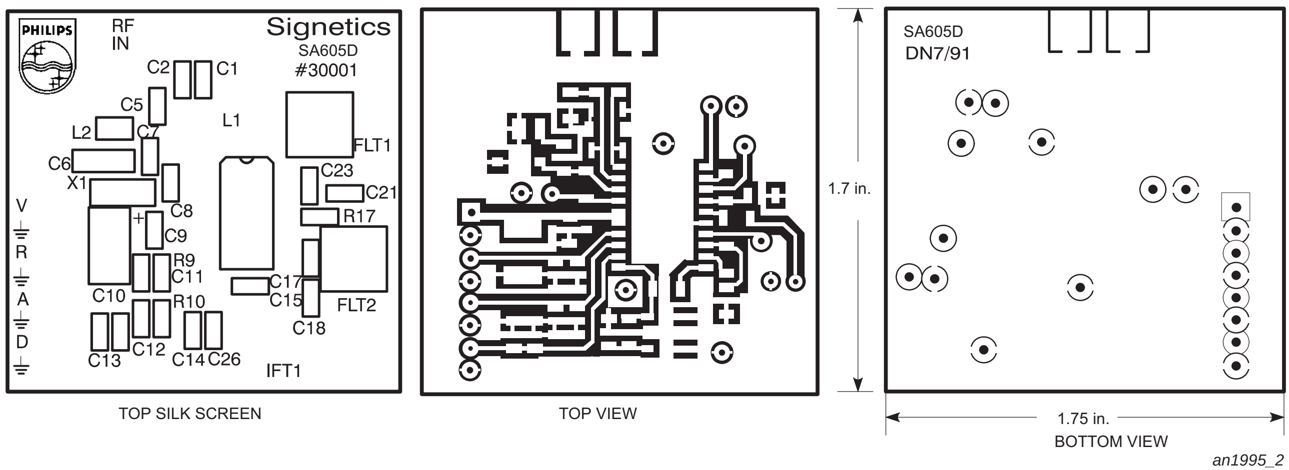


Fig 2. SA605 SO demo board layout (not actual size)

2.1.4 SA605D SO performance curves

The SA605D SO board performance graphs are found in Figure 3.

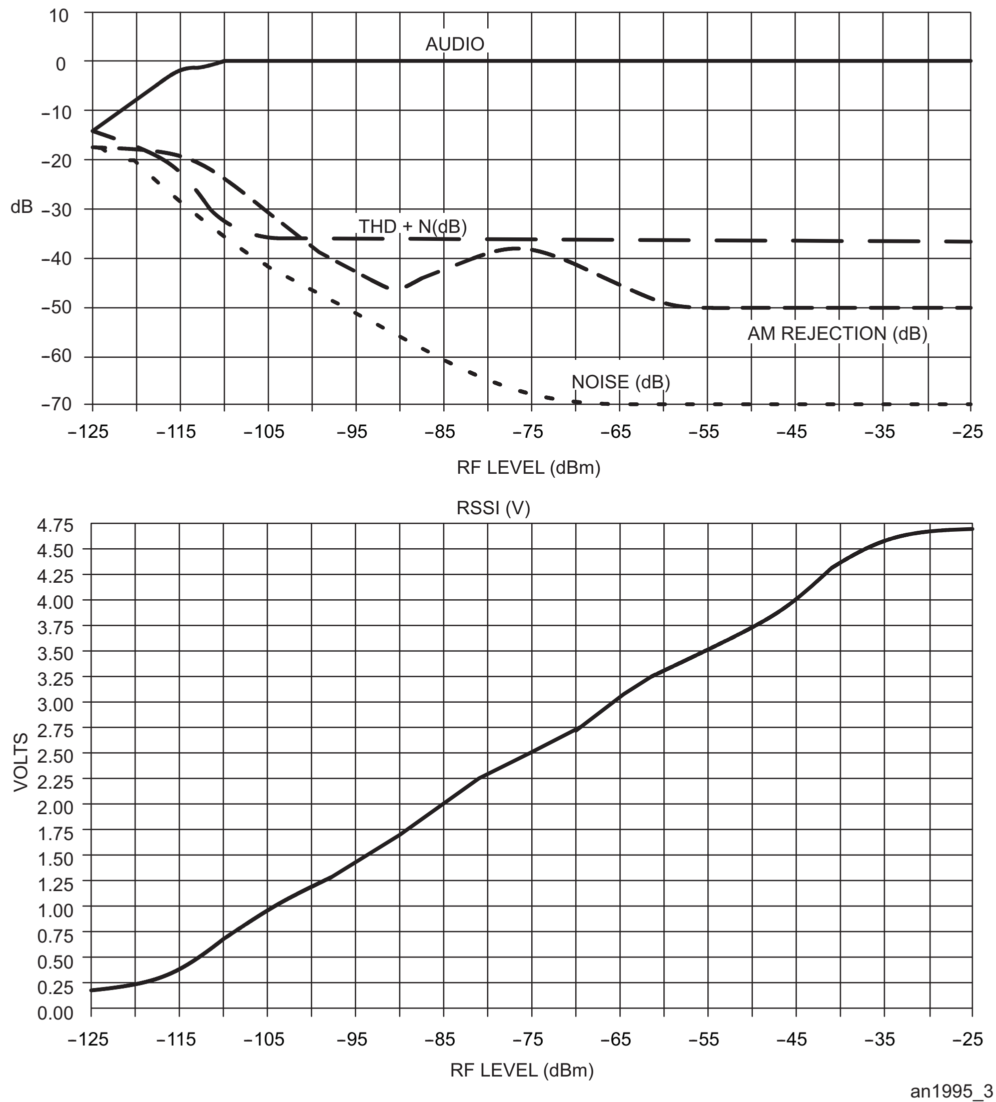


Fig 3. SA605 SO performance curves

2.2 SA605DK SSOP demo board

2.2.1 SA605DK SSOP demo board schematic

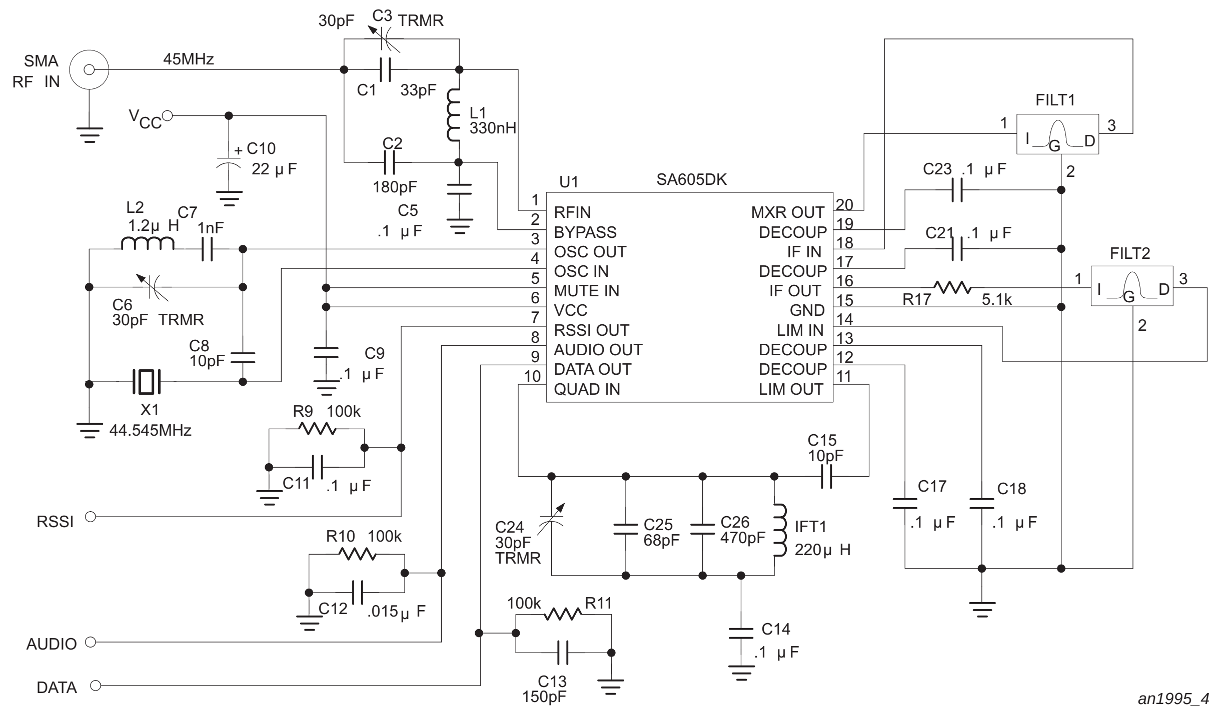


Fig 4. SA605 schematic for the SSOP layout

2.2.2 SA605DK SSOP demo board BOM

Table 2. SSOP layout schematic component list

Component	Description
C1	Part of the tapped-C network to match the front-end
C2	Part of the tapped-C network to match the front-end
C3	Part of the tapped-C network to match the front-end
C5	Used as an AC short to pin 2
C6	Used to tune the LO for the Colpitts oscillator
C7	Used as part of the Colpitts oscillator
C8	Used as part of the Colpitts oscillator
C9	Supply bypassing
C10	Supply bypassing
C11	Used as filter
C12	Used as filter
C13	Used as filter
C14	Used to AC ground the Quad tank
C15	Used to provide the 90° phase shift to the phase detector
C17	IF limiter decoupling cap

Table 2. SSOP layout schematic component list *…continued*

Component	Description
C18	IF limiter decoupling cap
C21	IF amp decoupling cap
C23	IF amp decoupling cap
C24	Part of the Quad tank
C25	Part of the Quad tank
C26	Part of the Quad tank
L1	Part of tapped-C network to match the front-end Coilcraft 1008CS-331
L2	Part of the Colpitts oscillator Coilcraft 1008CS-122
R9	Used to convert the current into the RSSI voltage
R10	Converts the audio current to a voltage
R11	Converts the data current to a voltage
R17	Used to achieve the −12 dB insertion loss
IFT1	Inductor for the Quad tank Mouser ME435-2200
FILT1	Murata SFGCC455BX 455 kHz bandpass filter
FILT2	Murata SFGCC455BX 455 kHz bandpass filter
X1	Standard 44.545MHz crystal

2.2.3 SA605DK demo board layout

The SSOP layout is found in Figure 5.

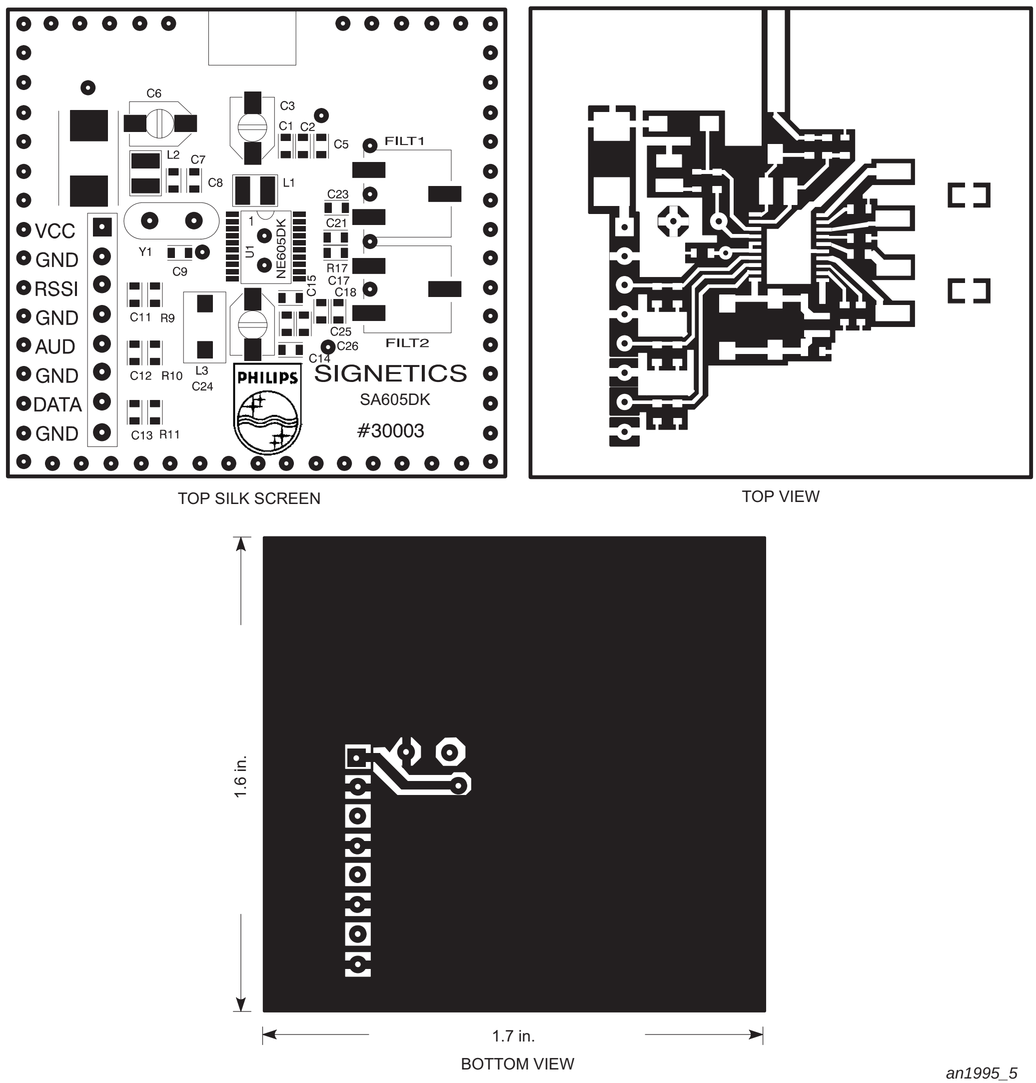


Fig 5. SA605 SSOP demo board layout (not actual size)

2.2.4 SA605DK demo board performance curves

The SA605DK board performance graphs are found in Figure 6.

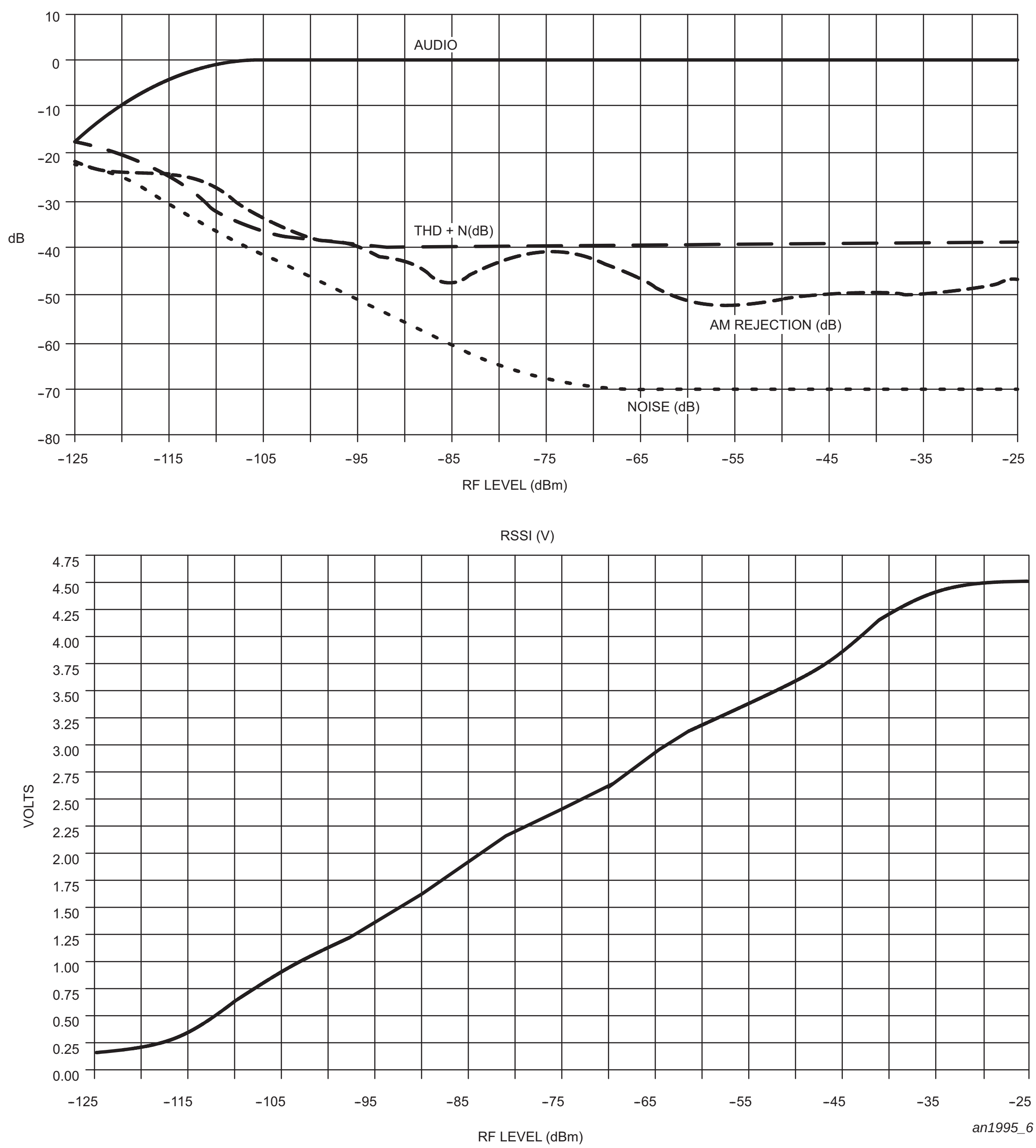


Fig 6. SA605 SSOP performance graphs

2.3 Differences between SO and SSOP demo boards

The main difference between the SO and SSOP demo boards is that the SSOP demo board incorporates the low profile 455 kHz Murata ceramic filter. It has an input and output impedance of 1.0 kΩ. This represents a mismatch to our chips, but we have found that the overall performance is similar to that when we use the “blue” Murata filters that have the proper 1.5 kΩ input and output impedance.

3. How to tune the SA605 demo board

Figure 7 and Figure 8 show a troubleshooting chart for the SA605. It can be used as a general guide to tune the SO and SSOP demo boards. Below are some of the highlights from the troubleshooting chart that are explained in more detail.

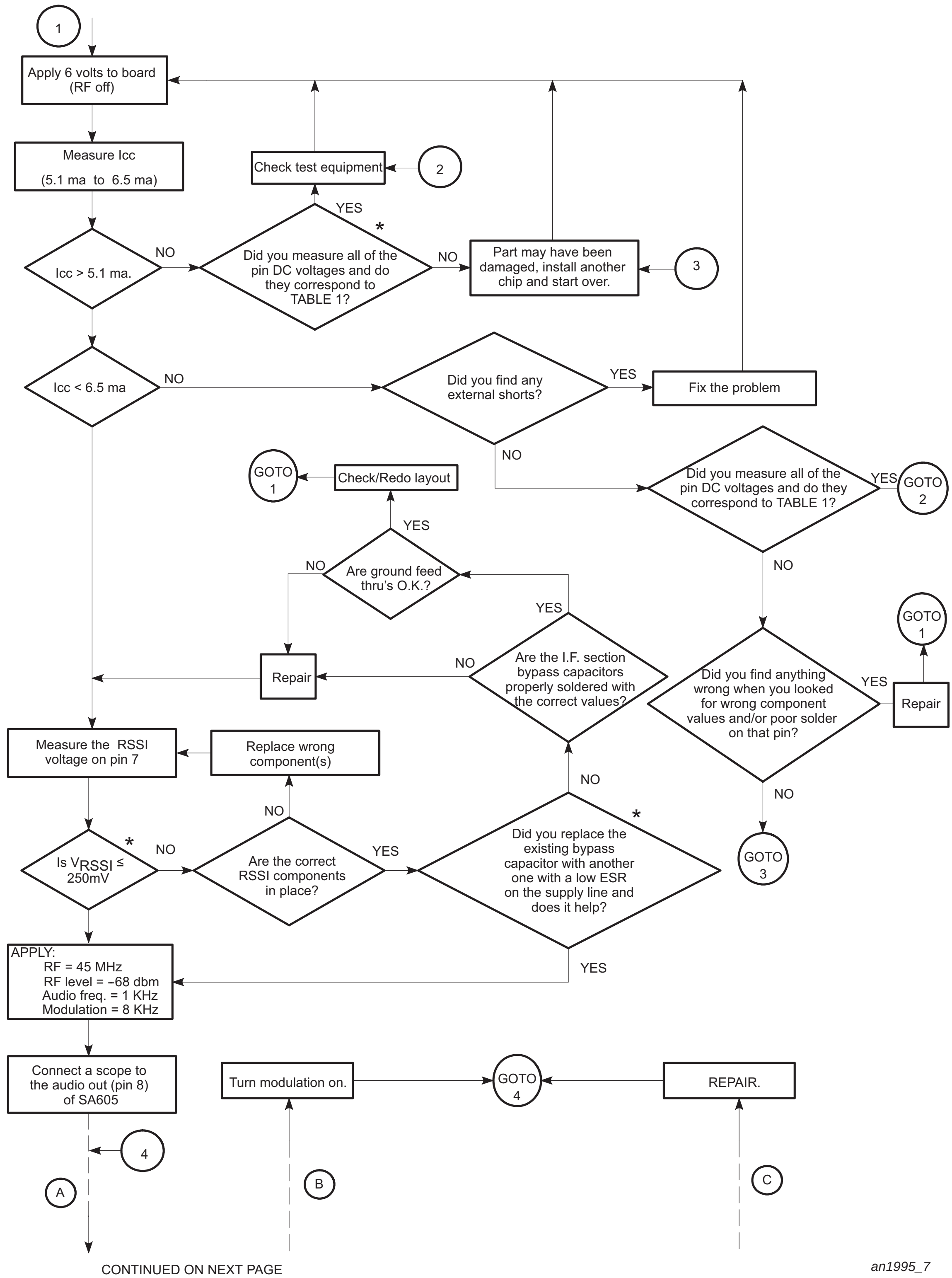


Fig 7. Troubleshooting chart for the SA605 demo board (1 of 2)

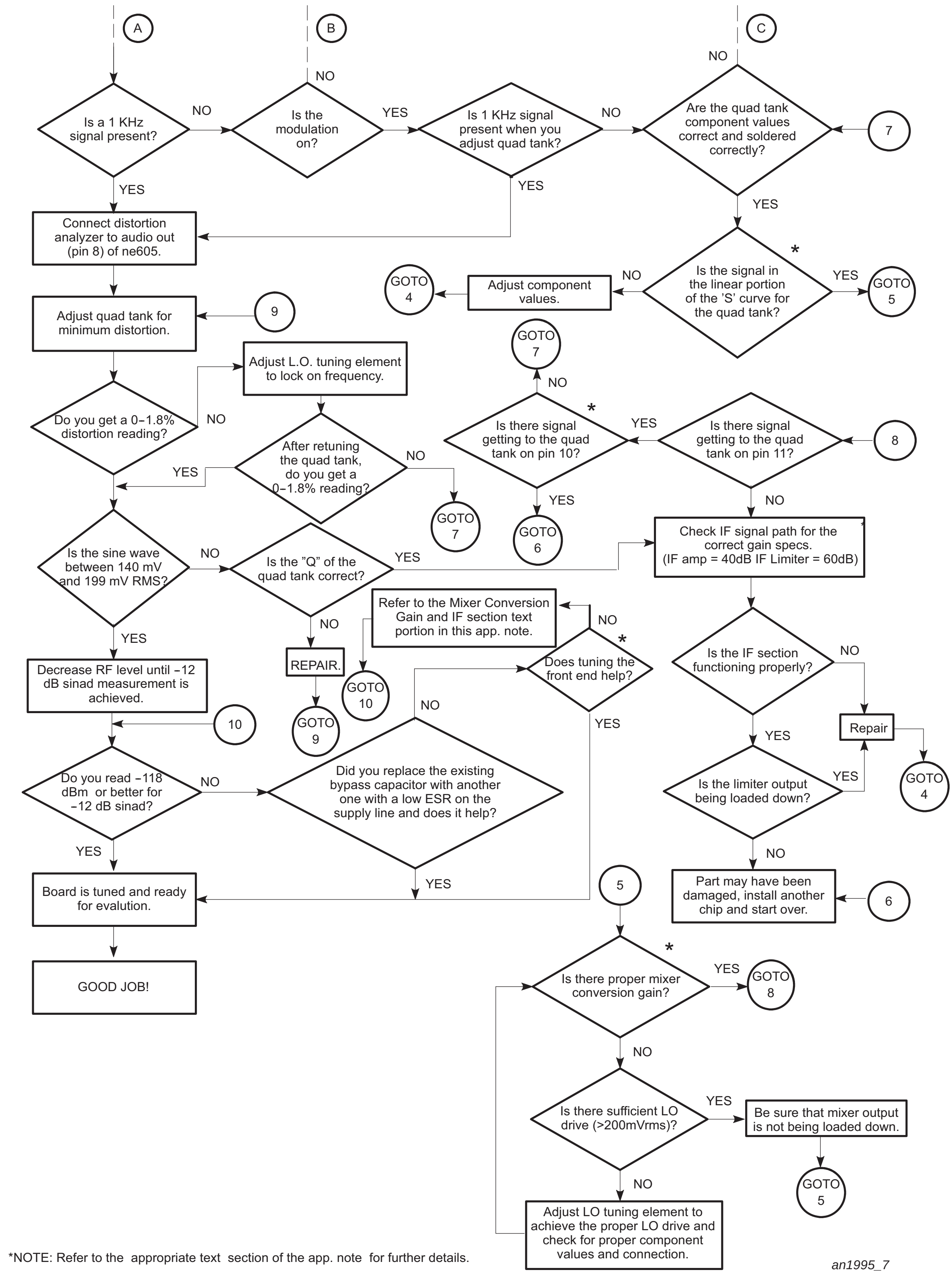


Fig 8. Troubleshooting chart for the SA605 demo board (2 of 2)

3.1 How to tell when a part is damaged

Since most SO and SSOP sockets hinder the maximum performance of the SA605, it is advisable to solder the packages directly to the board. By this approach, one will be able to evaluate the part correctly. However, it can be a tedious chore to switch to another part using the same layout. Therefore, to be absolutely certain that the chip is damaged, one can measure the DC voltages on the SA605. Table 3 shows the DC voltages that each pin should roughly have to be a good part.

Table 3. Approximate DC Voltages for the SA605

Pin number	DC voltage (V)[1]
1	1.37
2	1.37
3	5.16
4	5.94
5	n/a[2]
6	6.00 (V_{CC})
7	n/a[3]
8	2.00
9	2.00
10	3.49
11	1.59
12	1.59
13	1.59
1	1.65
15	0.00 (GND)
16	1.60
17	1.60
18	1.60
19	1.60
20	4.87

[1] If any of the DC voltages are way off in value, and you have followed the troubleshooting chart, the part needs to be changed.

[2] The DC voltage on Pin 5 is not specified because it can either be V_{CC} or ground depending if the audio is muted or not (Connecting ground on Pin 5 mutes the audio on Pin 8, while V_{CC} on Pin 5 unmutes the audio).

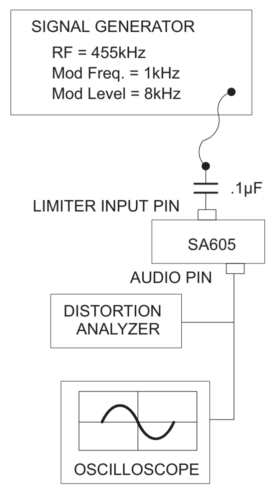
[3] The DC voltage on Pin 7 is not specified because its DC voltage depends on the strength of the RF signal getting to the input of the SA605. It also can be used as a stability indicator.

3.2 RSSI indicator

The next important highlight is using the RSSI pin as a stability indicator. With power connected to the part and no RF signal applied to the input, the DC voltage should read 250mV or less on Pin 7. Any reading higher than 250mV, indicates a regeneration problem. To correct for the regeneration problem, one should check for poor layout, poor bypassing, and/or poor solder joints. Bypassing the SA605 supply line with a low equivalent series resistance (ESR) capacitor to reduce the RSSI reading can improve the 12 dB SINAD measurement by 8 dB, as found in the lab. If the regeneration problem still exists, read AN1994.

3.3 Quad tank and S-Curve

As briefly mentioned in the chart, it is important to measure the Q of the quad tank if a distortion reading of 1.8 % or less cannot be measured. Recall that if the Q of the quad tank is too high for the deviation, then premature distortion will occur. However, if the Q is too low for the deviation, the audio level will be too low. The audio level coming out of the audio pin should be 140 mVRMS to 190 mVRMS.



FREQ. kHz	DC VOLTAGE (V)
400	1.66
430	1.24
455	2.13
480	3.08
510	2.88
⋮	⋮

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Fig 9. Test set-up to measure S-Curve of the Quad Tank

If the distortion reading is too high and/or the audio level is too low, then it is important to measure and plot the S-curve of the quad tank. The test set-up used in the lab can be seen in Figure 9.

The following steps were taken to measure the S-curve for the SO and SSOP demo-boards.

1. Remove the second IF ceramic filter from the demo board.
2. Connect a signal generator to the limiters input through a DC blocking capacitor.
3. Connect a DC voltmeter and an oscilloscope to the audio output pin.
4. Set the signal generator to a 455 kHz signal and be sure that the modulation is on (RF = 455 kHz Mod Freq = 1 kHz Mod Level = 8 kHz). Apply this 455 kHz signal to the limiter input such that there is a sinewave on the oscilloscope screen. Adjust the

quad tank for maximum sinewave amplitude on the oscilloscope or for lowest distortion. Additionally, adjust the supply input signal to the SA605 such that the 1 kHz sinewave reaches its maximum amplitude.

5. Turn off the modulation and start taking data. Measure the Frequency vs DC voltage. Vary the frequency incrementally and measure the DC voltage coming out of the audio pin. Remember that once the modulation is turned off, the sinewave will disappear from the oscilloscope screen.
6. Plot the S-curve.

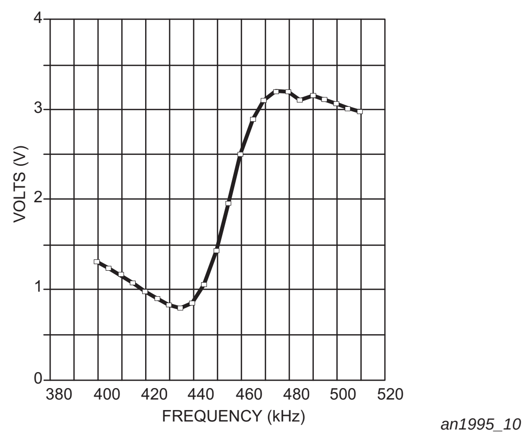

Fig 10. S-Curve for SA605 SO demo board

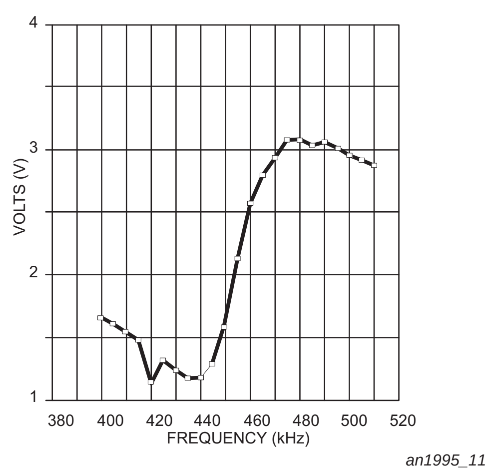

Fig 11. S-Curve for SA605 SSOP demo board

Figure 10 and Figure 11 show the S-curve measurements for the SO and SSOP demo boards. Notice that the center of the S-curve is at 455 kHz. The overall linearity determines how much deviation is allowed before premature distortion. Since our application requires ±8 kHz of deviation, our S-curve is good because it exceeds the linear range of 447 kHz to 463 kHz.

If the Q of the quad tank needs to be lowered, a designer should put a resistor in parallel with the inductor. The lower the resistor value, the more the Q will be lowered. If the Q needs to be increased, choose a higher Q component. More information on the Quad tank can be found in the SA604A data sheet.

If the linear section of the S-curve is not centered at 455 kHz, the quad tank component values need to be recalculated. The way to determine the component values is by using

$$f = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

where f should be the IF frequency. In the case of the demo-boards, the IF = 455 kHz.

3.4 Front-end tuning

The best way to tell if the front end of the SA605 is properly matched is to use a network analyzer in a S11 setting. The lower the dip, the greater the absorption of the wanted frequency. Figure 12 and Figure 13 show the S11 dip for the front end matching of the SO and SSOP demo-boards, respectively.

We have found in the lab that a –8 dB to –10 dB dip is usually sufficient to get the maximum signal transfer such that a good 12 dB SINAD reading is met. The front end circuit uses a tapped-C impedance transformation circuit which matches the 50 Ω source with the input impedance of the mixer.

In the process of matching the front end, we have found that the ratio of the two capacitors play an important role in transferring the signal from the source to the mixer input. There should be approximately a 4:1 or 5:1 ratio.

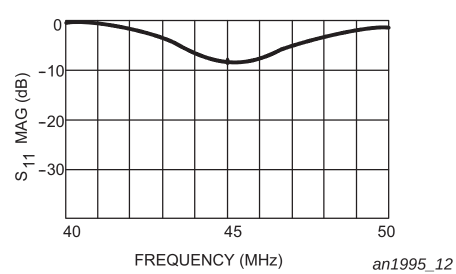

Fig 12. S11 front-end response for SO demo board

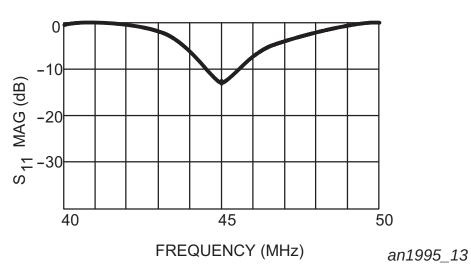

Fig 13. S11 front-end response for SSOP demo board

3.5 Checking the conversion gain of the mixer

Once the front end has been properly matched, a designer should check the conversion gain if there are problems with the SINAD measurement. Be sure to turn off the modulation when making this measurement.

The method of measuring conversion gain on the bench is fairly simple. For our demo-boards, measure the strength of the 455 kHz signal on the matching output network of the mixer with a FET probe. Then measure the 45 MHz RF input signal on the matching input network of the mixer. Subtract the two numbers and the measured conversion gain should be around 13 dB. Make sure that the input and output matching networks for the mixer have the same impedance since we are measuring voltage gain to get power gain ($P = V^2/R$). Of course this conversion gain value will change if there is a different RF input. In AN1994, Figure 16 shows how the conversion gain varies with different RF input frequencies.

3.6 Checking the gains in the IF section

If the IF section does not give 100 dB of gain, then the –118 dBm SINAD measurement cannot be achieved. In fact some symptoms of low or no audio level can be due to the IF section.

One way of checking the function of the IF section is to check the gain of the IF amplifier and the IF limiter. The IF amplifier gain should be around 40 dB and the IF limiter gain should be around 60 dB.

To check this, connect a FET probe to the output of the amplifier. Apply a strong input signal with no modulation and then slowly lower the input signal and wait for the output of the amplifier to decrease. Measure the strength of the output signal in dB and then subtract from it the strength of the input signal in dB. This resulting number indicates the maximum gain of that section. (This method assumes matched input and output impedance.)

If a designer finds one of the sections with lower gain, then one area to check are the IF bypass capacitors. Be sure that the IF bypass capacitors have a good solid connection to the pad. It was also found in the lab that the RSSI stability reading improves when the IF bypass is properly installed.

4. Questions and answers

Question: When I measure the bandpass response of the IF filters on the SSOP demo board, it appears to have a little hump compared to the SO demo board which has a flat filter response. Why is there a difference in the bandpass response when the SO and SSOP 605 chips are similar?

Answer: The answer has to do with the ceramic filters and not the package of the SA605. The reason why the SO demo board has a flat bandpass response is because it is matched properly with the filter. The SSOP demo board uses the new Murata low profile ceramic 455 kHz filter. Unfortunately, the input and output impedance is now 1 kΩ instead of 1.5 kΩ. This presents an impedance mismatch which creates the hump to occur in the bandpass response. But one does not have to worry too much about this response because the situation does not affect the overall performance that much. Additionally, the 12 SINAD measurement is similar whether using the “blue” (1.5 kΩ) or “white” (1.0 kΩ) Murata filters.

If you are worried about this, then switch to the correct “blue” Murata filters. The SSOP package will work with those filters as well. But if your design has strict height requirements, the white filters are a good solution.

Question: How much LO signal do you see at the RF port?

Answer: The worst LO leakage seen at the RF input on the SO and SSOP demo board is –40 dBm/441 mV. This seems to vary with the LO level into the base of the on board transistor. This measurement will also vary with different LO frequencies. The SA605 SO and SSOP demo-boards have a LO frequency of 44.545 MHz. Since there are so many variables, a designer needs to measure his/her own board for an accurate LO-RF isolation measurement.

There are several ways to improve the LO leakage from getting to the antenna. One can choose a higher IF frequency and tighten up the bandwidth of the front-end filter. Another solution is to add a low noise amplifier between the antenna and the mixer, and/or design a double conversion receiver and make sure the 1st mixer has a LO-RF isolation which meets the system specifications.

Question: On the SO and SSOP demo board, the LO oscillator circuit is tunable with a variable capacitor. Is this a requirement?

Answer: No. The variable capacitor is used to tune the LO freq., but one can use a fixed value. The advantage of going with a fixed value capacitor is that it is a cheaper component part and there is no need for tuning. The only advantage with a tunable LO is that a designer can optimize the performance of the receiver.

Question: I know that the IF bandwidth of the SA605 allows me to build an IF of 21.4 MHZ. Will the SA605 SSOP package perform just as good at 21.4 MHz IF as it does at 455 kHz?

Answer: Although we have not worked with SA605 SSOP at 21.4 MHZ, we believe that it would be difficult to get a 12 dB SINAD measurement at –120 dBm. The wavelengths are much smaller at 21.4 MHz than 455 kHz. Since the wavelengths are smaller, there is a higher probability of regeneration occurring in the IF section. Therefore, a designer will probably have to reduce the gain in the IF section. Additionally, the SSOP package has pins that are physically closer together than with the normal type of packaged parts which can contribute to the unstable state with higher IF frequencies.

5. References

[1] **SA605, “High performance low power mixer FM IF system” —** Product data sheet; NXP Semiconductors; www.nxp.com/documents/data_sheet/SA605.pdf

[2] **AN1994, “Reviewing key areas when designing with the SA605” —** Application note; NXP Semiconductors; www.nxp.com/documents/application_note/AN1994.pdf

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7. Contents

1 **Introduction** 3
2 **SA605 demo boards** 3
2.1 SA605D SO demo board 4
2.1.1 SA605 SO demo board schematic 4
2.1.2 SA605D SO BOM 5
2.1.3 SA605D SO layout 6
2.1.4 SA605D SO performance curves 7
2.2 SA605DK SSOP demo board 8
2.2.1 SA605DK SSOP demo board schematic 8
2.2.2 SA605DK SSOP demo board BOM 8
2.2.3 SA605DK demo board layout 10
2.2.4 SA605DK demo board performance curves . . 11
2.3 Differences between SO and SSOP demo boards 12
3 **How to tune the SA605 demo board** 12
3.1 How to tell when a part is damaged 15
3.2 RSSI indicator 15
3.3 Quad tank and S-Curve 16
3.4 Front-end tuning 18
3.5 Checking the conversion gain of the mixer . . . 19
3.6 Checking the gains in the IF section 19
4 **Questions and answers** 20
5 **References** 21
6 **Legal information** 22
6.1 Definitions 22
6.2 Disclaimers 22
6.3 Trademarks 22
7 **Contents** 23

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