

APPLICATION NOTE

AN1000

Evaluation of the SA601/SA606
demoboard

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1997 Aug 20

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INTRODUCTION

Philips Semiconductors is dedicated to playing a major role in the wireless communication market. Key to this goal is Philips' commitment for design assistance at all levels. This is the purpose of the SA601/SA606 combo-board. The SA601 is a combined RF amplifier and mixer designed for high-performance low-power communication systems from 800-1200MHz. The SA606 is a low-voltage high performance monolithic FM IF system that, when combined with the SA601, results in a high performance double down-conversion FM receiver. To better support this type of application, Philips has combined the SA601 and SA606 ICs onto a single board which highlights how well the SA601 and the SA606 work together. This application note explains how to overcome many of the technical problems that might arise, and shows how to achieve the best possible performance from the SA601 and SA606. Test results are also included.

This application note is divided into four main sections:

- I. Overview of the SA601/SA606 combination board
- II. Layout
 - A. Schematic, Components Specifics and Parts List
 - B. Impedance Matching
- III. Performance
 - A. Test Setup and Procedures
 - B. Test Data and Results
- IV. Conclusion
 - A. Q/A section

I. OVERVIEW

Both the SA601 and the SA606 are designed for portable, low voltage, low power communication applications. For a better understanding of what is involved in combining these boards, or for more information regarding the individual boards, please review application notes AN1777 (for the SA601) and AN1993-AN1996 (for the Second-IF ICs) which can be found in the Philips RF/Wireless Communications Data Handbook, IC17.

The SA601/SA606 demoboard is designed to meet AMPS specifications. Section 2 of the EIA Interim Standard, "Recommended Minimum Standard for 800MHz Cellular Subscriber Units" (EIA/IS-19-B), was consulted as a guide. Specific sections used were:

- 2.3.1 RF Sensitivity
- 2.3.2 Adjacent and Alternate Channel Desensitization
- 2.3.3 Intermodulation Spurious-Response Interference
- 2.3.4 Protection Against Spurious Response

Measured results demonstrate that the SA601/SA606 demoboard successfully meets and surpasses the specifications listed above.

Although the SA601/SA606 demoboard is designed to meet AMPS cellular specifications, it can be modified for other analog cellular specifications such as TACS, ETACS, and NAMPS. The demoboard could also be configured for ISM band (902MHz – 928MHz) applications.

II. LAYOUT

The layout of any high frequency board is critical and always challenging. As stated previously, understanding each board separately is the key to combining them. Before a single-board layout was attempted, the SA601 and the SA606 individual

demoboards were cascaded together, along with an RF SAW filter and a 1st IF SAW filter. The performance with this configuration was satisfactory, thus permitting the next step of combining everything on one board (Figure 2). As with the original SA601 and SA606 individual demoboards, the majority of the components are on one side of the board.

The SA601/SA606 demoboard layout can be configured to provide two different types of matching to the IF SAW filter (Figure 1). It can be configured as a 50 Ω impedance match, or a high impedance match to the 83.161MHz SAW filter. The 50 Ω impedance matching network allows a designer to evaluate or troubleshoot each individual block. For example, a designer can find conversion gain measurements of the SA601 or measure SINAD for only the SA606 block.

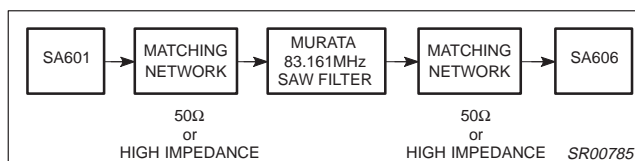


Figure 1. Block Diagram: Matching 1st IF SAW Filter

The 50 Ω impedance match can also be used as a reference for the high impedance match. Because 50 Ω impedance matching requires more components, a high impedance match is preferred. Matching for high impedance can be difficult, but since each block is optimized through a 50 Ω impedance match, the designer has a target/reference. For example, if 12dB SINAD = -120dBm for a 50 Ω impedance matched system, ideally a high impedance match should yield the same results, if not better.

The majority of the single-board layout was adapted from the individual application demoboards, except for the two SAW filters (the image rejection filter centered at 881MHz and the 83.161MHz SAW filter). The layout for the two filters required additional design work. The 881MHz image-rejection SAW filter was placed between the LNA-Out and the Mixer-In of the SA601. Placement of the 881MHz image reject SAW filter, whether it was on the top or bottom of the board, did not have a dramatic impact on performance. This was because isolation between the LNA-Out and the Mixer-In trace had already been considered in the SA601 demoboard. However, because of its high Q, narrowband, and high impedance, the 83.161MHz SAW filter was much more difficult to position. Its placement was critical in passing AMPS specification 2.3.4 Protection Against Spurious-Response Interference. The specification was met with margin to spare by moving the Mixer-Out (Pins 13 and 14) of the SA601 as far away as possible from RF-In (Pin 1) of the SA606.

Schematic, Components Specifics, and Parts List

The schematic shown in Figure 3 is for both 50 Ω impedance matching and high impedance matching to the 83.161MHz SAW filter. The schematic shows the configuration for 50 Ω impedance matching. By making the modifications listed in the box on the bottom right of the schematic (Figure 3), the board can be configured for a high impedance match.

Table 1 lists the basic function of each external component for the schematic shown in Figure 3. This may help answer any questions that arise about the specifics of the board.

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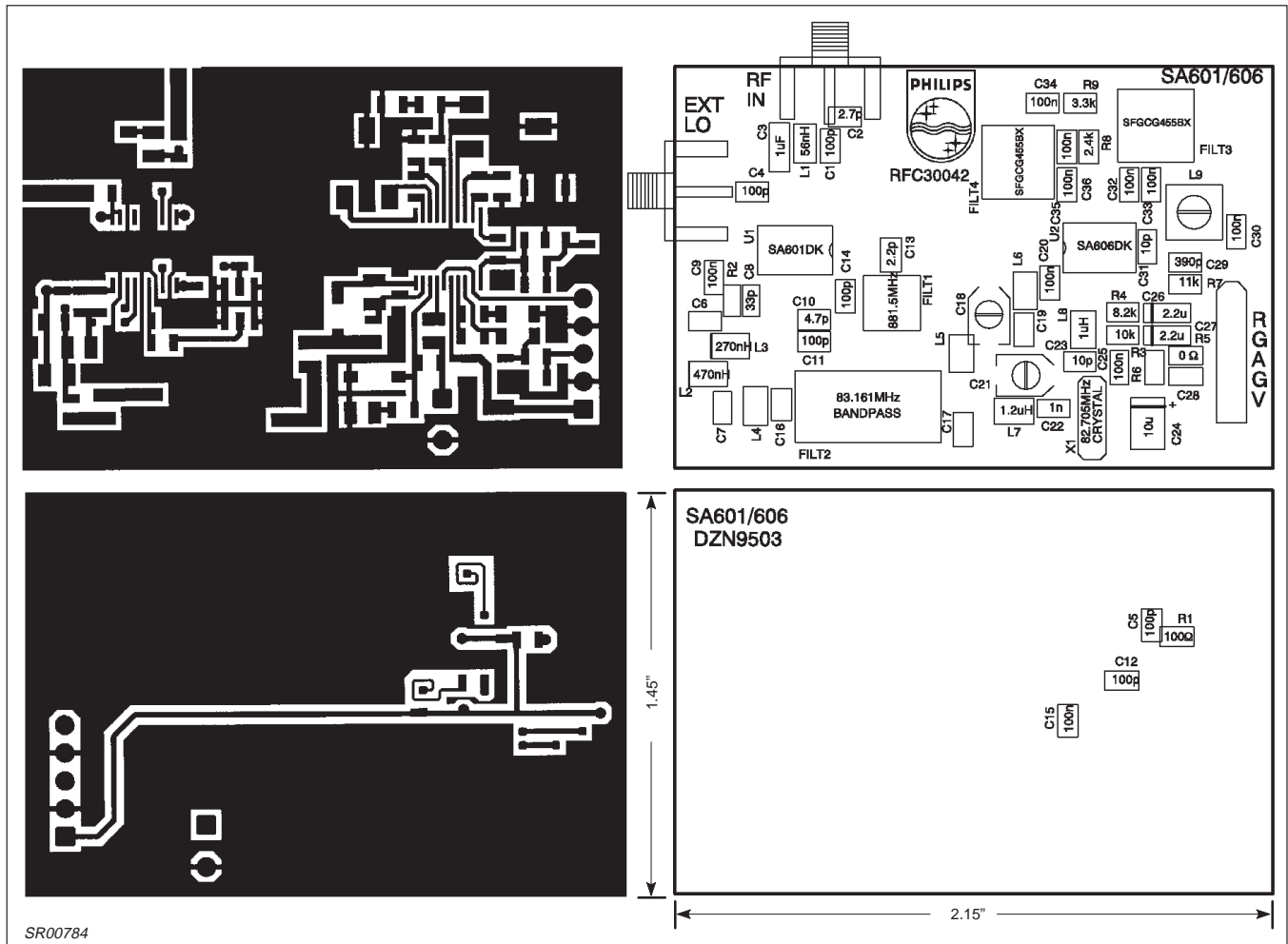
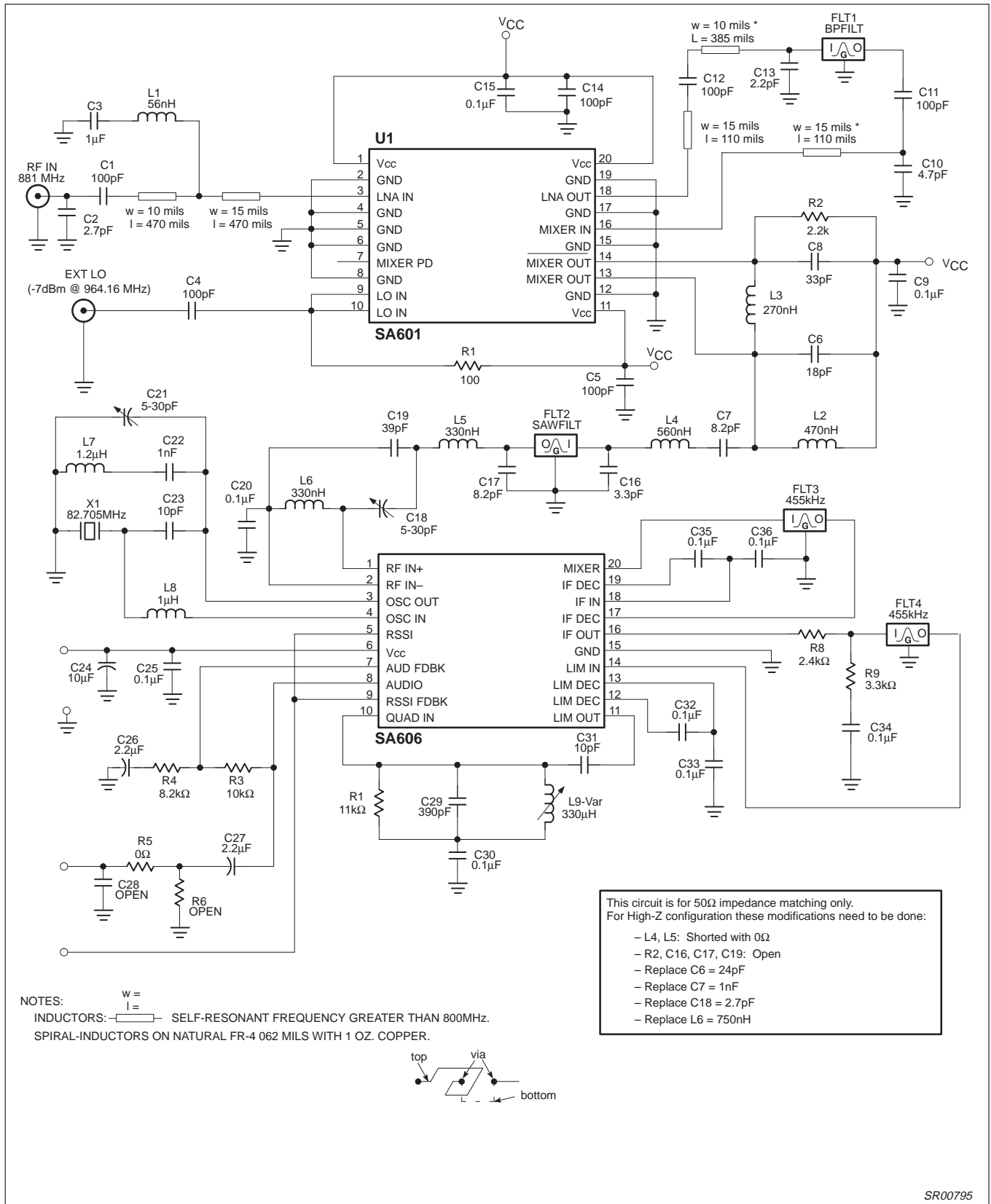


Figure 2. Layout of the SA601/SA606 Demoboard (Not Actual Size)

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Figure 3. Schematic of the SA601/SA606 Demoboard

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Table 1. Components List: Description of Functionality

Part #	Description
C1	LNA Mixer input DC blocking cap
C2	Part of the matching network that optimizes the return loss while minimizing the degradation of the noise figure
C3	Voltage compensation cap for the LNA
C4	LO DC blocking cap
C5, C9, C14, C15, C24, C25	Supply bypassing
C6, C8, L3	Part of the differential to single-ended translation circuit of the mixer out
C7, L2	Part of the matching network of the mixer output
C10, C13	Part of the matching network that optimizes the return loss while minimizing the degradation of the noise figure
C11	Mixer Input DC blocking cap
C12	LNA Output DC blocking cap
C16, C17, L4, L5	Part of the matching network of the 83.161MHz SAW filter
C18, C19, L6	Part of the tapped-C network that matches the RF input of the SA606
C20	AC grounds Pin 2, the RF input of the SA606
C21, C22, C23, L7, L8	Colpitts oscillator network
C26, C34	AC de-coupling cap
C27	DC blocking cap
C28, R5, R6	Part of the filter network that filters 3kHz-15kHz on the SA7025 (Low-voltage 1GHz fractional-N synthesizer). This network is only used on the 7025 IC production tester.
C29, L9	Quad tank component that resonates at 455kHz
C30	AC grounds the quad tank
C31	Provides the 90° phase shift to the phase detector
C32, C33	IF limiter decoupling cap
C35, C36	IF amp decoupling cap
R1	DC pull-up resistor that provides isolation (reduces IF to LO and RF to LO leakage)
R2	Sets output impedance of the Mixer Output
R3	Part of the Audio op-amp that sets a gain of 2dB thus stabilizing distortion
R4	Part of the Audio op-amp that sets a gain of 2dB thus stabilizing distortion
R7	Lowers the Q of the quad tank and thus lowers the S-Curve slope
R8, R9	Part of a network to control linearity of the RSSI
L1	Voltage compensation to LNA
FILT1	Murata SAFC881.5MA70N-TC 881.5MHz bandpass SAW filter: This is a 869MHz to 894MHz bandpass filter. It is used to reject the image frequency (LO + 83.16MHz in our case) and to attenuate the transmit signal (RF-45MHz) leaking through the duplexer so that the SA601 mixer doesn't reach its 1dB compression point from a strong signal leaking through. Some electrical characteristics from Murata are provided (Table 2).
FILT2	Murata SAFC83.161MA51X-TC 83.161MHz SAW filter: 1st-IF filter for attenuating adjacent and alternate channel spurs. The filter plays a larger role in achieving the high performance of the receiver in areas such as dynamic range, spurious performance, and data communication accuracy. The 83.16MHz SAW filter provides a 30kHz bandpass characteristic utilizing electrodes deposited on a piezoelectric substrate. These electrodes form an inter-digitated pattern on the substrate and serve as transducers to launch an acoustic wave. When an RF voltage is applied to one set of transducers, an electric field is generated and causes the acoustic waves to propagate along the surface to an opposite transducer where an output voltage is produced. (See Reference 8, Alan Victor). The Electrical Characteristics for the Murata SAW filter are shown in Table 3.
FILT3, 4	Murata SFGCG455BX-TC 455kHz bandpass filter (30kHz bandwidth).
X1	An 82.705MHz crystal from either HY-Q or Reeves Hoffman is a 3rd overtone crystal used to generate the LO for the SA606

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Table 2. Electrical Characteristics of the Murata SAFC881.5MA70N-TC

Tested at 20 ±2°C. Standard condition: Temp = 20 ±2°C. Humidity = 65 ±5%; Applicable condition: Temp = 5 ~ 35°C. Humidity = 45 ~ 85%.

	Item	Requirements	Typical at 20°C (Reference Value in Standard Condition)
6 – 1	Nominal Center Frequency (f ₀)	881.5 MHz	–
6 – 2	Insertion Loss		
	I) within 869 ~ 894 MHz (Pass Bandwidth)	4.5 dB max.	3.5 dB
	II) within DC ~ 780 MHz	40 dB max.	48 dB
	III) within 824 ~ 849 MHz (Duplex Freq. Range)	20 dB min.	30 dB
	IV) within 970 ~ 2000 MHz	35 dB min.	40 dB
6 – 3	Ripple Deviation (within 869 to 894 MHz)	2.0 dB max.	1.0 dB
6 – 4	V.S.W.R. (within 869 to 894 MHz)	2.5:1 max.	1.7:1
6 – 5	Input / Output Impedance (nominal)	50Ω // 0pF	–

Table 3. Electrical Characteristics of the Murata SAFC83.161MA51X-TC

	Item	Requirements
1.1	Nominal Center Frequency (f ₀)	83.161 MHz
1.2	3 dB Bandwidth (from 83.161 MHz)	±15 kHz min.
1.3	Stop Band Attenuation (from Peak Level)	
	1.3.1 f ₀ – 1000 kHz to f ₀ – 930 kHz	40 dB min.
	1.3.2 f ₀ – 930 kHz to f ₀ – 890 kHz	70 dB min.
	1.3.3 f ₀ – 890 kHz to f ₀ – 700 kHz	40 dB min.
	1.3.4 f ₀ – 700 kHz to f ₀ – 400 kHz	30 dB min.
	1.3.5 f ₀ – 400 kHz to f ₀ – 120 kHz	40 dB min.
	1.3.6 f ₀ – 120 kHz to f ₀ – 60 kHz	20 dB min.
	1.3.7 f ₀ + 60 kHz to f ₀ + 120 kHz	20 dB min.
	1.3.8 f ₀ + 120 kHz to f ₀ + 150 kHz	40 dB min.
	1.3.9 f ₀ + 150 kHz to f ₀ + 400 kHz	30 dB min.
1.3.10 f ₀ + 400 kHz to f ₀ + 1000 kHz	40 dB min.	
1.4	Insertion Loss (at minimum loss point)	5.0 dB max.
1.5	Ripple (within f ₀ = 15 kHz)	1.5 dB max.
1.6	Group Delay Deviation (within f ₀ ± 11 kHz)	10 μs max.
1.7	Intermodulation	
	Input Signal : f ₀ + 60 kHz, f ₀ + 120 kHz Input Level : –20 dBm	–90 dBm max.

A complete SA601/SA606 demoboard parts list is provided in Table 14 at the end of this document. The parts list includes vendor names and part numbers as a convenience to designers.

Impedance Matching

Matching of the 83.16MHz SAW filter is an involved task. This is because the HP8753C Network Analyzer can only be calibrated for 50 Ω impedance and the 83.16MHz SAW filter has a specified impedance of 850 // -2pF. Refer to Philips application note AN1777 for an explanation of how to setup the calibration for high-impedance. Although calibration at higher impedance is not as accurate as at 50Ω impedance, the results were close enough to get a good impedance match.

Improved impedance matching yields better sensitivity performance because matching of the 83.16MHz SAW filter suppresses unwanted group delay distortion. The response of the 83.16MHz SAW filter is shown in Figure 4. When the filter response is flat, the SAW filter is matched; when it is not, group delay distortion, represented by the hump, is apparent (Figure 4).

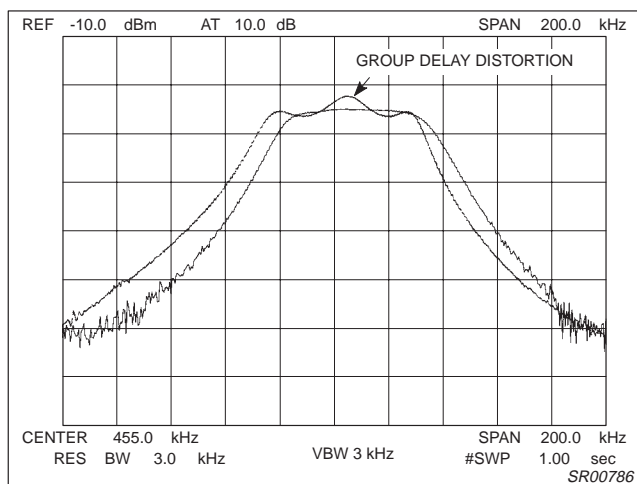


Figure 4. Group Delay Distortion

The steps to match the 83.16MHz SAW filter to a high impedance are as follows:

1. Separate the board into three sections by making two cuts in the trace. Cut 1 is between the Mixer out of the SA601 and the input of the SAW filter. Cut 2 is between the SAW filter output and the RF input of the SA606. (see Figure 5)

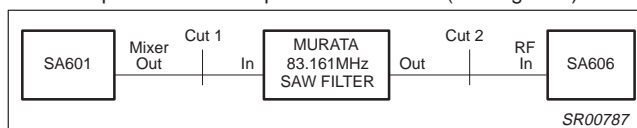


Figure 5. Three Sections of Demoboard

2. Start with SAW filter input of Figure 6 and terminate that side with an 850 Ω resistor.

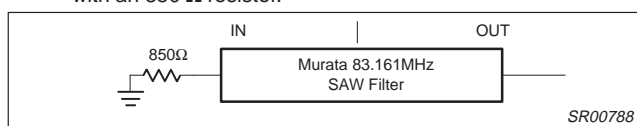


Figure 6. Termination of SAW Filter

3. Measure the impedance of the output of the SAW filter by placing an SMA connector on the trace and marking the corresponding impedance on the Smith Chart.

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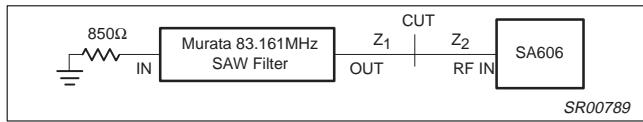


Figure 7. Termination Matching of SAW Filter

- After identifying the impedance of the SAW filter output indicated by Z_1 in Figure 7, the RF input impedance, Z_2 , must be adjusted to provide a conjugate match to Z_1 . Z_2 is found on the Smith Chart by reflecting Z_1 about the purely resistive axis represented by the horizontal line running through the center of the Smith Chart.

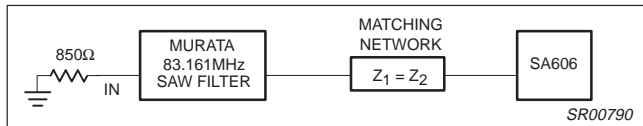


Figure 8. Impedance Matching from SAW Filter to SA606

- After a conjugate match between Z_1 and Z_2 has been achieved, connect the output of the SAW filter to the matching network. (Figure 8)

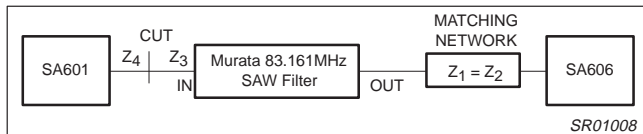


Figure 9. Impedance Matching from SA601 to SAW Filter

- Remove the 850Ω resistor and measure the impedance at the SAW filter input, Z_3 .
- Obtain a conjugate match to Z_3 at the SA601 mixer output, Z_4 , and then connect together (Figure 9).

To double check the matching, remove the 2nd-IF filter from the mixer-out of the SA606 and check the frequency response for any group delay distortion. Figure 4 shows a matched SAW-filter response (flat curve) and a poorly matched response that has group delay distortion.

To make a quick visual check of the frequency response of the board up to the SA606 Mixer output, use the FM modulation of the HP signal generator and spectrum analyzer, as follows:

- Leave the frequencies (LO and RF) at their respective values. (example: RF = 881MHz and LO = 964.16MHz)
- Set the FM deviation to 200kHz and the FM modulation to 200Hz on the RF's signal generator.
- Remove the 2nd-IF filter connected to Pin 20 of the SA606.
- Set the Spectrum Analyzer sweep time to 1 second, set the center frequency to the 2nd IF frequency (455kHz), and probe Pin 20 with a FET probe. The results should look like the flat response in Figure 4.

III. PERFORMANCE EVALUATION

Procedures

The AMPS specification was used as a guide to test the SA601/SA606 demo board. Sections 2.3.1 through 2.3.4 of the IS-19-B EIA Interim Standard were the procedures used for testing

the SA601/SA606 demoboard. These tests were crucial in determining performance of the demoboard.

Figure 10 shows the block diagram of the test setup following the procedures outlined in the AMPS specification.

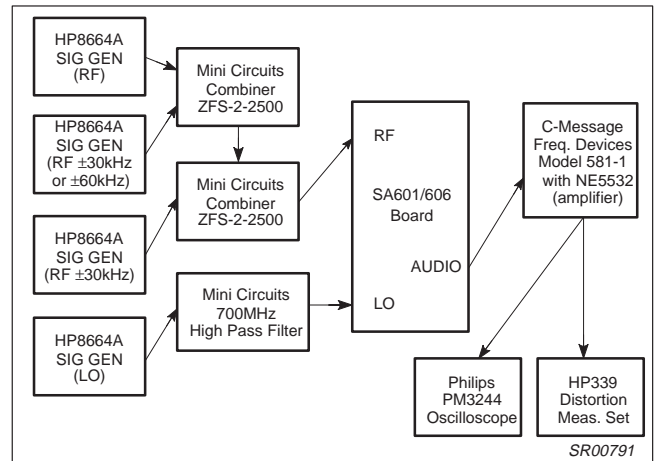


Figure 10. Test Setup for Measuring RF Sensitivity, Adjacent and Alternate Channel Rejection and Spurious Rejection

Transmitter desensitization occurs when the transmit signal from the handset is degrading the performance of the receiver.

To measure transmitter (Tx) desensitization, do the following:

- Configure the test equipment as shown in Figure 11.
- Set the Tx signal 45MHz below the RF signal.
- Measure the Tx power at the Ant of the duplexer on the HP8920A Radio Test Set.
- Measure 12dB SINAD on the HP8920A Radio Test Set when the Tx signal is on and again when it is off.
- If there is degradation in sensitivity when the Tx signal is on, the difference of the 12dB SINAD readings is the Tx desensitization.

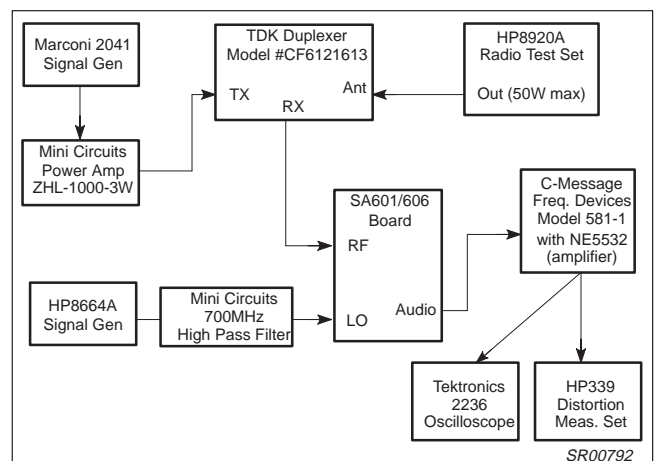


Figure 11. Test Setup for Measuring Transmitter Desensitization

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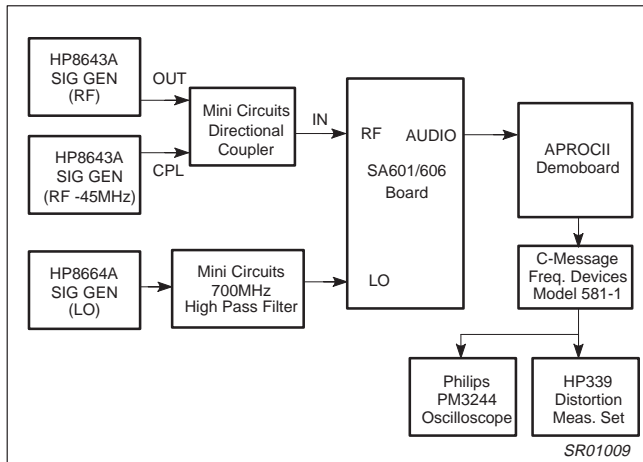


Figure 12. Test Setup for Measuring Transmitter Desensitization Without Duplexer

Because customers' preferences for duplexers vary, Tx desensitization was done another way to evaluate the performance of the SA601/SA606 demoboard.

1. The setup can be configured as shown in Figure 12. Set RF = 869MHz, LO = 957.16MHz and Tx = 824MHz.
2. Set the transmit power to -10dBm because we are assuming that the Tx leakage through the Rx port is that much.
3. Record 12dB SINAD.
4. Reduce the transmit power by 1dB and repeat Step 3.
5. Repeat Step 4 until Tx power reaches -30dBm.
6. Repeat all steps for RF, LO Tx frequencies at mid band (RF = 881MHz, LO = 964.16MHz, Tx = 836MHz) and high band (RF = 894MHz, LO = 977.16MHz, Tx = 849MHz)

Data and Results

Adjacent Channel, Alternate Channel and Intermodulation Spurious Response

The data provided in Tables 4 to 6 shows the sensitivity, adjacent channel, alternate channel, and intermodulation spurious response of the demoboard. The data was taken at V_{CC} = 3V, 4V, and 5V, as well as at three different frequencies.

The data taken was recorded without a duplexer. Adding a duplexer before the RF input will cause sensitivity to decrease by about 3 dB. This board is well within the specified parameters for adjacent channel, alternate channel and intermodulation spurious response rejection in accordance with AMPS specifications.

Protection Against Spurious Response Interference

The next set of data shown is also part of the AMPS specification 2.3.4 Protection Against Spurious Response Interference (Tables 7 to 9). The frequencies tested were the image frequencies that could cause degradation in performance. When using a TDK duplexer (TDK BandPass Filter Model CF6121613), the image frequencies are attenuated, so the image spurs (1047.32MHz) will not degrade the performance of the demoboard. The 2nd IF image frequency is the only frequency that caused problems. This frequency is above the RF by exactly twice the 2nd IF (2 × 455kHz = 910kHz). The problem occurs because, when RF + 910kHz mixes with the 1st LO (964.16MHz), the frequency produced is (RF + 910kHz - 1st LO = 82.25MHz). This is equal to the 2nd IF image frequency. When the

2nd IF image frequency is mixed with the crystal oscillator, the frequency produced is the 2nd-IF frequency. The SA606 will demodulate this unwanted frequency, as well as the desired signal.

Example:

RF = 881MHz
 LO = 964.16MHz
 2nd LO = 82.705MHz
 881MHz + 910kHz = 881.91MHz
 881.910MHz mixes with the LO (964.16MHz) = 82.25MHz
 82.25MHz mixes with the 2nd LO (82.705MHz) = 455kHz

To resolve this problem, the 83.161MHz SAW filter must be isolated. The unwanted frequency was leaking around the SAW filter and into the RF input of the SA606. So the distance between the SA601 mixer out to the RF input of the SA606 was increased by rotating the SAW filter. This solved the problem and the board met the protection against spurious response specification with at least 14dB to spare.

Transmitter desensitization

Another issue was to evaluate how the SA601/SA606 performs with the transmit section of a radio on (transmitter desensitization). Transmitter desensitization will degrade the sensitivity of the receiver if the strong Tx signal is allowed to pass through and cause the SA601 to reach its 1dB compression point in the LNA and the Mixer. Tables 10 to 12 show the results of three test boards for transmitter desensitization as the transmit power is increased from 100mW to 1W.

Using a TDK duplexer (TDK BandPass Filter Model CF6121613), the board performed well. At most, the board degraded by 2dB from the transmitter desensitization.

Since most customers will not want to use the TDK duplexer, Tx desensitization was done another way, as explained in the procedures. Table 13 show the results. The results show that with a duplexer that has Tx leakage of -14dBm or less through the Rx port, the SA601/SA606 will meet the sensitivity requirement according to IS-19-B (-116dBm for 12 dB SINAD), assuming the duplexer has 3dB of loss.

RSSI, AM Rejection, THD, Noise, Audio Output Level

The next set of data shows RSSI performance at 3V, 4V, and 5V (Figure 13) and AM rejection, THD, Noise, and Audio output level (Figure 14).

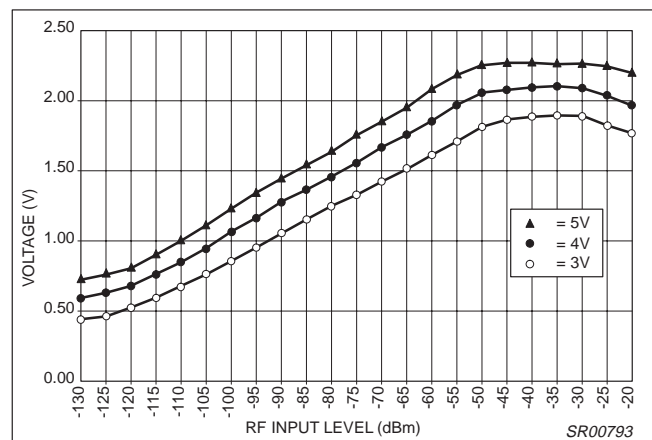


Figure 13. RSSI (Average of Three Boards)

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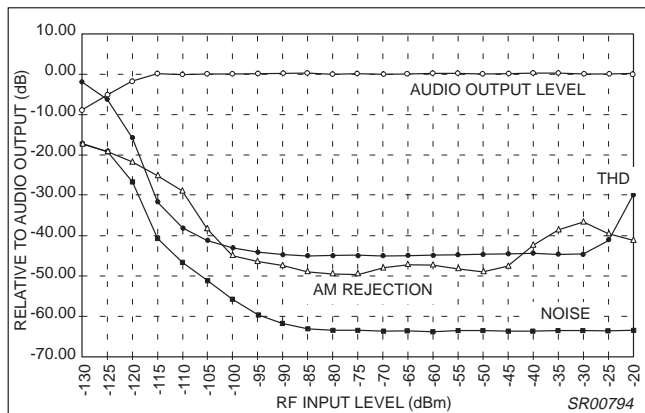


Figure 14. Receiver Performance (Average of Three Boards)

IV. CONCLUSION

The SA601/SA606 application demoboard demonstrates how well the two chips perform together. Meeting the stated AMPS cellular specifications is a good test of a receiver's performance. Not all receivers can meet these stringent requirements. The SA601/SA606 demoboard not only meets, but exceeds, the criteria of sensitivity with 12dB SINAD of about -122dBm, which is 3dB better than AMPS specification, assuming 3dB loss from the duplexer. Adjacent channel exceeds the requirement by 33dB, Alternate channel exceeds the requirement by 7.5dB, Intermodulation Spurious Response exceeds the requirement by 4.5dB, and Protection Against Spurious Response Interference exceeds the requirement by 11dB.

Many key factors such as board layout and impedance matching help the performance exceed the receiver specifications for AMPS. Many issues looked at in this application note will help answer customers' questions as Philips customers design greater and better things.

Questions and Answers

- Q.** What is the difference between the 50 Ω demoboard and the high-impedance demoboard?
- A.** Visually, the 50 Ω boards have more components near the 83.161MHz SAW filter. The 50 Ω boards have two 5-30pF trim capacitors. The high-impedance board out performs the 50 Ω board by 1dB on sensitivity. Keep in mind that the 50 Ω board allows troubleshooting of each block.
- Q.** What do I do if I don't achieve the sensitivity as the data shows?
- A.** Here is a check list you can follow:
1. Check the solder connections.
 2. Make sure the LO drive level is -5dBm to -7dBm to the SA601 mixer.
 3. Check for the 700MHz high pass filter (see Figure 10).
 4. Check the C-Message filter. (An active C-Message filter with 10dB of gain was used for sensitivity tests.)
 5. Probe for signals from the SA601 inputs down to the SA606 limiter-out. Check to see if there are significant losses. The probe points are:
 - a. RF input of the SA601
 - b. LO input of the SA601
 - c. LNA-out of the SA601
 - d. Before the 881MHz SAW filter

- e. After the 881MHz SAW filter
- f. Mixer-in of the SA601
- g. Mixer-out of the SA601
- h. Before the 83.161MHz SAW filter
- i. After the 83.161MHz SAW filter
- j. RF input of the SA606
- k. The 82.705MHz crystal
- l. Mixer-out of the SA606
- m. IF-in of the SA606
- n. IF-out of the SA606
- o. Limiter-in of the SA606
- p. Limiter-out of the SA606

- Q.** What is the difference between the 1008HS and the 1008CS inductors from Coilcraft?
- A.** There is no difference in performance between the two types of inductors. The only external difference is the packaging.
- Q.** What should I do if I don't meet the specification for Protection Against Spurious-Response?
- A.** Make sure that all the grounds of the 83.161MHz SAW filter are connected, especially the grounds closest to the input and output. Shield each section which will isolate each block and improve performance.
- Q.** Why do you use an IF of 83.16MHz instead of 45MHz?
- A.** 83.16MHz is used as the IF because, at 45MHz, serious problems may result because of the existence of spurious performance degradation and potential interference due to the half-IF mixer spurious content. The half-IF (RF + 22.5MHz) is only a problem with IF frequencies which are less than twice the receiver bandwidth. An AMPS receiver with 45MHz 1st IF can have a half-IF problem, while at 83.16MHz it will not because the half-IF, at 45MHz for example, will be 891.50MHz (869MHz + 22.5MHz). Since 891.5MHz falls in the pass band, this signal will desensitize the receiver. Also, at 83.16MHz, the image frequency is further away than 45MHz. (See Reference 8)
- Q.** Will phase noise of the signal generator cause performance degradation when testing Tx desensitization?
- A.** Yes it will because, when doing the Tx desensitization test without a duplexer, sensitivity dramatically improved as levels on the signal generator were decremented. Also, when cascading two duplexers together, the noise was attenuated and sensitivity improved. In most handsets, a bandpass filter (center frequency at 836MHz) is placed before the power amplifier; therefore, the out-of-band noise is attenuated before being amplified. This attenuation will lower the phase noise and allow less Tx desensitization.

- Q.** What spurs will effect the sensitivity of the receiver? How can these spurs be rejected?
- A.** Consult table below for unwanted spurs:

Spurs	EQ. ¹	Range (MHz)	Rejected by...
1st Image	RF+2(IF1)	1035.32–1060.32	Duplexer
2nd Image	RF+2(IF2)	869.91–894.91	83.16MHz SAW
Half IF	RF+.5(IF1)	910.58–935.58	Duplexer
Tx Intermod ²	Tx–45MHz	779–804	Duplexer
Tx Isolation ²	Tx + IF1	907.16–932.16	Duplexer

- NOTES:**
1. IF1 = 83.16MHz; IF2 = 455kHz
 2. Not measured

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V. REFERENCES

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Table 4. RF Sensitivity, Adjacent and Alternate Channel Rejection, and Intermodulation Spurious Response Rejection at $V_{CC} = 3V$

All data taken without a duplexer.

Frequency	12 dB SINAD	Adjacent Channel Above (+30kHz)	Adjacent Channel Below (-30kHz)	Alternate Channel Above (+60kHz)	Alternate Channel Below (-60kHz)	Intermodulation Spurious Response (+60 & +120 kHz)	Intermodulation Spurious Response (-60 & -120 kHz)
High Impedance Board #1: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	55 dB	53 dB	86 dB	88 dB	71.5 dB	70.5 dB
RF = 869MHz; LO = 952.161MHz	-122 dBm	49 dB	50 dB	88 dB	87 dB	70.5 dB	70.5 dB
RF = 894MHz; LO = 977.161MHz	-122 dBm	51 dB	54 dB	88 dB	87 dB	71.5 dB	70 dB
High Impedance Board #2: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122.5 dBm	51.5 dB	52.5 dB	71.5 dB	77.5 dB	71 dB	71 dB
RF = 869MHz; LO = 952.161MHz	-123 dBm	52 dB	51 dB	72 dB	82 dB	70.5 dB	70.5 dB
RF = 894MHz; LO = 977.161MHz	-122.5 dBm	51.5 dB	50.5 dB	72.5 dB	77.5 dB	69.5 dB	69.5 dB
High Impedance Board #3: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	49 dB	54 dB	91 dB	87 dB	73 dB	71 dB
RF = 869MHz; LO = 952.161MHz	-123 dBm	50 dB	56 dB	93 dB	88 dB	73 dB	71 dB
RF = 894MHz; LO = 977.161MHz	-122 dBm	50 dB	55 dB	92 dB	89 dB	72 dB	71 dB

Requirements per IS-19-B:

- 2.3.1 RF Sensitivity: -116dBm or better
- 2.3.2 Adjacent and Alternate Channel Desensitization: 16dBm min for adjacent channel; 60dB min for alternate channel.
- 2.3.3 Intermodulation Spurious Response Interference: 65dB min.

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Table 5. RF Sensitivity, Adjacent and Alternate Channel Rejection, and Intermodulation Spurious Response Rejection at $V_{CC} = 4V$

All data taken without a duplexer.

Frequency	12 dB SINAD	Adjacent Channel Above (+30kHz)	Adjacent Channel Below (-30kHz)	Alternate Channel Above (+60kHz)	Alternate Channel Below (-60kHz)	Intermodulation Spurious Response (+60 & +120 kHz)	Intermodulation Spurious Response (-60 & -120 kHz)
High Impedance Board #1: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	51 dB	52 dB	88 dB	86 dB	71.5 dB	69.5 dB
RF = 869MHz; LO = 952.161MHz	-122 dBm	50 dB	51 dB	88 dB	87 dB	72.5 dB	69.5 dB
RF = 894MHz; LO = 977.161MHz	-122 dBm	51 dB	51 dB	87 dB	87 dB	72 dB	70 dB
High Impedance Board #2: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122.5 dBm	51.5 dB	51.5 dB	70.5 dB	67.5 dB	70.5 dB	69.5 dB
RF = 869MHz; LO = 952.161MHz	-122.5 dBm	52.5 dB	50.5 dB	71.5 dB	80.5 dB	69 dB	69 dB
RF = 894MHz; LO = 977.161MHz	-122 dBm	52 dB	51 dB	72 dB	76 dB	70 dB	76 dB
High Impedance Board #3: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	50 dB	55 dB	91 dB	87 dB	73 dB	71 dB
RF = 869MHz; LO = 952.161MHz	-123 dBm	50 dB	54 dB	93 dB	88 dB	73 dB	70 dB
RF = 894MHz; LO = 977.161MHz	-123 dBm	50 dB	53 dB	91 dB	87 dB	72 dB	70 dB

Requirements per IS-19-B:

- 2.3.1 RF Sensitivity: -116dBm or better
- 2.3.2 Adjacent and Alternate Channel Desensitization: 16dBm min for adjacent channel; 60dB min for alternate channel.
- 2.3.3 Intermodulation Spurious Response Interference: 65dB min.

Table 6. RF Sensitivity, Adjacent and Alternate Channel Rejection, and Intermodulation Spurious Response Rejection at $V_{CC} = 5V$.

All data taken without a duplexer.

Frequency	12 dB SINAD	Adjacent Channel Above (+30kHz)	Adjacent Channel Below (-30kHz)	Alternate Channel Above (+60kHz)	Alternate Channel Below (-60kHz)	Intermodulation Spurious Response (+60 & +120 kHz)	Intermodulation Spurious Response (-60 & -120 kHz)
High Impedance Board #1: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	50 dB	52 dB	86 dB	85 dB	71.5 dB	69.5 dB
RF = 869MHz; LO = 952.161MHz	-122 dBm	49 dB	52 dB	87 dB	86 dB	71.5 dB	69 dB
RF = 894MHz; LO = 977.161MHz	-122 dBm	52 dB	51 dB	86 dB	86 dB	72 dB	70 dB
High Impedance Board #2: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-122 dBm	52 dB	50 dB	70 dB	76 dB	70.5 dB	69.5 dB
RF = 869MHz; LO = 952.161MHz	-122.5 dBm	52.5 dB	49.5 dB	70.5 dB	78.5 dB	69 dB	69 dB
RF = 894MHz; LO = 977.161MHz	-121.5 dBm	52.5 dB	50.5 dB	71.5 dB	75.5 dB	70 dB	68 dB
High Impedance Board #3: Adjacent and Alternate channel; FM dev = ± 8 kHz, FM mod = 400Hz							
RF = 881MHz; LO = 964.161MHz	-121.5 dBm	49.5 dB	53.5 dB	90.5 dB	86.5 dB	73 dB	70 dB
RF = 869MHz; LO = 952.161MHz	-122.5 dBm	52.5 dB	49.5 dB	87.5 dB	91.5 dB	73 dB	70 dB
RF = 894MHz; LO = 977.161MHz	-121 dBm	50 dB	53 dB	91 dB	87 dB	72 dB	70 dB

Requirements per IS-19-B:

- 2.3.1 RF Sensitivity: -116dBm or better
- 2.3.2 Adjacent and Alternate Channel Desensitization: 16dBm min for adjacent channel; 60dB min for alternate channel.
- 2.3.3 Intermodulation Spurious Response Interference: 65dB min.

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Table 7. Protection Against Spurious Response Interference $V_{CC} = 3V$

All test measured with TDK duplexer (Model CF6121613D)

Frequency	Interfering Frequency (MHz)	Board #1	Board #2	Board #3
RF = 881MHz; LO = 964.161MHz		-121 dBm for 12 dB SINAD	-121 dBm for 12 dB SINAD	-121 dBm for 12 dB SINAD
	881.91	82.5 dB	76.5 dB	78.5 dB
	922.58	108.5 dB	108.5 dB	108.5 dB
	1005.74	108.5 dB	108.5 dB	108.5 dB
	1047.32	99.5 dB	97.5 dB	92.5 dB
RF = 869MHz; LO = 952.161MHz		-119.5 dBm for 12 dB SINAD	-121 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD
	869.91	81 dB	73.5 dB	75.5 dB
	910.58	108 dB	108.5 dB	107.5 dB
	993.74	108 dB	108.5 dB	107.5 dB
	1035.32	98 dB	95.5 dB	88.5 dB
RF = 894MHz; LO = 977.161MHz		-119 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD	-119.5 dBm for 12 dB SINAD
	894.91	79.5 dB	82.5 dB	79 dB
	935.58	108.5 dB	110.5 dB	108 dB
	1018.74	108.5 dB	110.5 dB	108 dB
	1060.32	99.5 dB	100.5 dB	96 dB

Requirements per IS-19-B:

2.3.4 Protection Against Spurious Response Interference: 60dB min.

Table 8. Protection Against Spurious Response Interference $V_{CC} = 4V$

All test measured with TDK duplexer (Model CF6121613D)

Frequency	Interfering Frequency (MHz)	Board #1	Board #2	Board #3
RF = 881MHz; LO = 964.161MHz		-121 dBm for 12 dB SINAD	-121 dBm for 12 dB SINAD	-121.5 dBm for 12 dB SINAD
	881.91	84.5 dB	74.5 dB	79 dB
	922.58	108.5 dB	108.5 dB	109 dB
	1005.74	108.5 dB	108.5 dB	109 dB
	1047.32	101.5 dB	98.5 dB	93 dB
RF = 869MHz; LO = 952.161MHz		-120 dBm for 12 dB SINAD	-120.5 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD
	869.91	80.5 dB	71 dB	73.5 dB
	910.58	107.5 dB	108 dB	107.5 dB
	993.74	107.5 dB	108 dB	107.5 dB
	1035.32	95.5 dB	93 dB	88.5 dB
RF = 894MHz; LO = 977.161MHz		-119.5 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD
	894.91	80 dB	78.5 dB	81.5 dB
	935.58	108 dB	108.5 dB	107.5 dB
	1018.74	108 dB	108.5 dB	107.5 dB
	1060.32	100 dB	99.5 dB	95.5 dB

Requirements per IS-19-B:

2.3.4 Protection Against Spurious Response Interference: 60dB min.

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Table 9. Protection Against Spurious Response Interference $V_{CC} = 5V$

All test measured with TDK duplexer (Model CF6121613D)

Frequency	Interfering Frequency (MHz)	Board #1	Board #2	Board #3
RF = 881MHz; LO = 964.161MHz		-121 dBm for 12 dB SINAD	-121 dBm for 12 dB SINAD	-121.5 dBm for 12 dB SINAD
	881.91	84.5 dB	74 dB	77.5 dB
	922.58	108.5 dB	109 dB	108.5 dB
	1005.74	108.5 dB	109 dB	108.5 dB
	1047.32	108.5 dB	97 dB	104.5 dB
RF = 869MHz; LO = 952.161MHz		-120 dBm for 12 dB SINAD	-120.5 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD
	869.91	79.5 dB	71 dB	71 dB
	910.58	107.5 dB	108 dB	108 dB
	993.74	107.5 dB	108 dB	108 dB
	1035.32	101.5 dB	94 dB	93 dB
RF = 894MHz; LO = 977.161MHz		-119.5 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD	-120 dBm for 12 dB SINAD
	894.91	80.5 dB	77 dB	81.5 dB
	935.58	107.5 dB	108 dB	111.5 dB
	1018.74	107.5 dB	108 dB	111.5 dB
	1060.32	106.5 dB	100 dB	106.5 dB

Requirements per IS-19-B:

2.3.4 Protection Against Spurious Response Interference: 60dB min.

Evaluation of the SA601/SA606 demoboard

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Table 10. Transmit desensitization – Board #1

Frequency	Transmit Power (mW)	12 dB SINAD without Tx (dBm)	12 dB SINAD with Tx (dBm)	Tx desensitization (dB)
RF = 881MHz; LO = 964.161MHz, Tx = 836MHz	100	-120	-119.5	0.5
	200	-120	-119.5	0.5
	300	-120	-119	1
	400	-120	-119	1
	500	-120	-119	1
	600	-120	-119	1
	700	-120	-119	1
	800	-120	-118	2
	900	-120	-118	2
	1000	-120	-118	2
RF = 869MHz; LO = 952.161MHz, Tx = 824MHz	100	-119.5	-119.5	0
	200	-119.5	-119.5	0
	300	-119.5	-119.5	0
	400	-119.5	-119.5	0
	500	-119.5	-119.5	0
	600	-119.5	-119.5	0
	700	-119.5	-119.5	0
	800	-119.5	-119.5	0
	900	-119.5	-119.5	0
	1000	-119.5	-119.5	0
RF = 894MHz; LO = 977.161MHz, Tx = 849MHz	100	-119	-119	0
	200	-119	-119	0
	300	-119	-119	0
	400	-119	-119	0
	500	-119	-119	0
	600	-119	-119	0
	700	-119	-119	0
	800	-119	-119	0
	900	-119	-119	0
	1000	-119	-119	0

Requirements per IS-19-B:

2.3.1 RF Sensitivity: -116dBm or better

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Table 11. Transmit desensitization – Board #2

Frequency	Transmit Power (mW)	12 dB SINAD without Tx (dBm)	12 dB SINAD with Tx (dBm)	Tx desensitization (dB)
RF = 881MHz; LO = 964.161MHz, Tx = 836MHz	100	-120	-119.5	0.5
	200	-120	-119.5	0.5
	300	-120	-119	1
	400	-120	-119	1
	500	-120	-119	1
	600	-120	-119	1
	700	-120	-119	1
	800	-120	-118	2
	900	-120	-118	2
	1000	-120	-118	2
RF = 869MHz; LO = 952.161MHz, Tx = 824MHz	100	-119.5	-119.5	0
	200	-119.5	-119.5	0
	300	-119.5	-119.5	0
	400	-119.5	-119.5	0
	500	-119.5	-119.5	0
	600	-119.5	-119.5	0
	700	-119.5	-119.5	0
	800	-119.5	-119.5	0
	900	-119.5	-119.5	0
	1000	-119.5	-119.5	0
RF = 894MHz; LO = 977.161MHz, Tx = 849MHz	100	-119.5	-119.5	0
	200	-119.5	-119.5	0
	300	-119.5	-119.5	0
	400	-119.5	-119.5	0
	500	-119.5	-119.5	0
	600	-119.5	-119	0.5
	700	-119.5	-119	0.5
	800	-119.5	-119	0.5
	900	-119.5	-119	0.5
	1000	-119.5	-119	0.5

Requirements per IS-19-B:

2.3.1 RF Sensitivity: -116dBm or better

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Table 12. Transmit desensitization – Board #3

Frequency	Transmit Power (mW)	12 dB SINAD without Tx (dBm)	12 dB SINAD with Tx (dBm)	Tx desensitization (dB)
RF = 881MHz; LO = 964.161MHz, Tx = 836MHz	100	-119.8	-119.3	0.5
	200	-119.8	-119.3	0.5
	300	-119.8	-118.8	1
	400	-119.8	-118.8	1
	500	-119.8	-118.8	1
	600	-119.8	-118.8	1
	700	-119.8	-118.8	1
	800	-119.8	-117.8	2
	900	-119.8	-117.8	2
	1000	-119.8	-117.8	2
RF = 869MHz; LO = 952.161MHz, Tx = 824MHz	100	-119	-117	0
	200	-119	-117	0
	300	-119	-117	0
	400	-119	-117	0
	500	-119	-117	0
	600	-119	-117	0
	700	-119	-117	0
	800	-119	-117	0
	900	-119	-117	0
	1000	-119	-117	0
RF = 894MHz; LO = 977.161MHz, Tx = 849MHz	100	-119	-119	0
	200	-119	-119	0
	300	-119	-119	0
	400	-119	-119	0
	500	-119	-119	0
	600	-119	-118.5	0.5
	700	-119	-118.5	0.5
	800	-119	-118.5	0.5
	900	-119	-118.5	0.5
	1000	-119	-118.5	0.5

Requirements per IS-19-B:

2.3.1 RF Sensitivity: -116dBm or better

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Table 13. Transmit desensitization Without Duplexer

Tx Level (dBm)	Board #1			Board #2			Board #3		
	12dB SINAD (dBm)			12dB SINAD (dBm)			12dB SINAD (dBm)		
	824MHz	836MHz	849MHz	824MHz	836MHz	849MHz	824MHz	836MHz	849MHz
-10	-118.5	-117.5	-117	-119	-118.5	-117.5	-119	-118.5	-117.5
-11	-118.5	-118	-117	-119	-118.5	-117.5	-119	-118.5	-117.5
-12	-118.5	-118	-117	-119.5	-118.5	-118	-119.5	-119	-117.5
-13	-119	-118.5	-117.5	-119.5	-119	-118	-119.5	-119	-118
-14	-120	-119.5	-119	-120.5	-120	-119.5	-121	-120.5	-119
-15	-120	-120	-119	-121	-120.5	-119.5	-121	-120.5	-119.5
-16	-120.5	-120	-119.5	-121	-120.5	-120	-121	-121	-120
-17	-120.5	-120	-119.5	-121	-121	-120.5	-121	-121	-120
-18	-120.5	-120.5	-120	-121	-121	-120.5	-121.5	-121	-120.5
-19	-121	-121	-120.5	-122	-121.5	-121.5	-122	-122	-121
-20	-121.5	-121	-121	-122	-122	-121.5	-122	-122	-121.5
-21	-121.5	-121	-121	-122	-122	-121.5	-122.5	-122	-121.5
-22	-121.5	-121.5	-121	-122	-122	-122	-122.5	-122.5	-121.5
-23	-121.5	-121.5	-121.5	-122.5	-122	-122	-122.5	-122.5	-121.5
-24	-122	-122	-121.5	-122.5	-122.5	-122	-122.5	-122.5	-121.5
-25	-122	-122	-121.5	-122.5	-122.5	-122.5	-123	-123	-121.5
-26	-122	-122	-121.5	-122.5	-122.5	-122.5	-123	-123	-122
-27	-122	-122	-122	-123	-122.5	-122.5	-123	-123	-122
-28	-122	-122	-122	-123	-122.5	-122.5	-123	-123	-122
-29	-122.5	-122	-122	-123	-123	-122.5	-123	-123	-122.5
-30	-122.5	-122	-122	-123	-123	-122.5	-123	-123	-122.5
OFF	-122.5	-122	-122	-123	-123	-122.5	-123	-123	-122.5

Requirements per IS-19-B:

2.3.1 RF Sensitivity: -116dBm or better

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Table 14. Customer Application Component List for SA601/SA606

Qty.	Part Value	Part Reference	Part Description	Vendor	Mfg	Part Number
**** Surface Mount Capacitors ****						
1	2.2pF	C13	NPO Ceramic 0805 \pm .25pF	Garrett	Philips	0805CG229C9BB0
1	2.7pF	C2	NPO Ceramic 0805 \pm .25pF	Garrett	Philips	0805CG279C9BB0
1	2.7pF	C18 for Hi Z board	NPO Ceramic 1206 \pm .25pF	Garrett	Rohm	1206MCH315A2R7CK
1	3.3pF	C16	NPO Ceramic 0805 \pm .25pF	Garrett	Philips	0805CG339C9BB0
1	4.7pF	C10	NPO Ceramic 0805 \pm .25pF	Garrett	Philips	0805CG479C9BB0
2	8.2pF	C7, C17	NPO Ceramic 0805 \pm 5pF	Garrett	Philips	0805CG829C9BB0
2	10pF	C23, C31	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG100J9BB0
1	18pF	C6	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG180J9BB0
1	24pF	C6 for Hi Z board	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG240J9BB0
1	33pF	C8	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG330J9BB0
1	39pF	C19	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG390J9BB0
6	100pF	C1, C4, C5, C11, C12, C14	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG101J9BB0
1	390pF	C29	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG391J9BB0
2	1nF	C22, (C7 for Hi Z board)	NPO Ceramic 0805 \pm 5%	Garrett	Philips	0805CG102J9BB0
10	100nF	C9, C15, C20, C25, C30, C32, C33, C34, C35, C36	Z5U Ceramic 0805 \pm 20%	Garrett	Philips	08052E104M9BB0
1	1 μ F	C3	Tant Chip Cap \pm 10%	Garrett	Philips	49MC105A016KOAS
2	2.2 μ F	C26, C27	Tant Chip Cap \pm 10%	Garrett	Philips	49MC225A010KOAS
1	10 μ F	C24	Tant Chip Cap \pm 10%	Garrett	KOA Speer	TMC-M1AB106KLRH
2	5-30pF	C18, C21	SMT Trimmer Cap	Jaco	Kyocera	CTZ3S-30C-B
**** Resistors ****						
1	0 Ω	R5	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F000
1	100 Ω	R1	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F101
1	2.2k Ω	R2	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F222
1	2.4k Ω	R8	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F242
1	3.3k Ω	R9	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F332
1	8.2k Ω	R4	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F822
1	10k Ω	R3	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F103
1	11k Ω	R7	Res. chip 0805 1/10W \pm 5%	Garrett	KOA Speer	RM73B2A-F113
**** Inductors ****						
1	56nH	L1	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-560 \pm 10%
1	270nH	L3	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-271 \pm 10%
2	330nH	L5, L6	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-331 \pm 10%
1	470nH	L2	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-471 \pm 10%
1	560nH	L4	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-561 \pm 10%
1	750nH	L6 Hi Z board	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-751 \pm 10%
1	1.2 μ H	L7	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-122 \pm 10%
1	330 μ H	L9	Variable SMT Inductor	Digikey	Toko	TKS2272CT-ND \pm 3%
1	1 μ H	L8	Chip Inductor \pm 10%	Coilcraft	Coilcraft	1008CS-102 \pm 10%
**** Filters ****						
1	881.5MHz	FILT1	881.5MHz SAW Bandpass	Murata	Murata	SAFC881.5MA70N-TC
1	83.161MHz	FILT2	83.161MHz SAW Bandpass	Murata	Murata	SAFC83.161MA51X-TC
2	455kHz	FILT3, FILT4	455kHz FM IF Filter	Murata	Murata	SFGCG455BX-TC
**** IC ****						
1	SA601	U1	Low Voltage LNA & Mixer	Philips	Philips	SA601DK
1	SA606	U2	Low Voltage FM IF System	Philips	Philips	SA606DK
**** Miscellaneous ****						
1	82.705MHz	X1	82.705MHz crystal	Hy-Q International or Reeves-Hoffman 82.705MHz		
2			SMA Gold Connector	Digikey J502-ND		EF Johnson 142-0701-801
1			5 Pins Gold Test point	Digikey		3M929647-01-36-ND
1			Printed circuit board	RF# 30042		Excel 601/606 #30042