ANALOG DEVICES

AN-764
APPLICATION NOTE

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ADF7020 RF Port Impedance Values for Matching Purposes

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SCOPE OF THIS DOCUMENT

The ADF7020 is a fully integrated transceiver IC targeted at operation in the US/EU ISM band at 915 MHz, 868 MHz, and 433 MHz, respectively. The IC has a differential LNA input and a single-ended PA output. To achieve optimum performance, both the LNA input and PA output need to be matched to the source/load impedance under consideration of the properties of the printed circuit board on which the IC is assembled. This task is most effectively accomplished by using a dedicated RF simulation package, such as Ansoft Designer™, Eagleware Genesys™, AWR Microwave Office®, or CST Microwave Studio®. To enable customers to use these design tools, models for the different RF ports must be provided. This application note provides the necessary information.

INTRODUCTION

The ADF7020 has two RF ports: an LNA input and a PA output. The properties and function of these RF ports depends on the operating mode of the transceiver, i.e., Tx mode or Rx mode. The ports and the different states are

- PA output (single-ended, ground-referred)
  - Tx mode: optimum PA load impedance
  - Rx mode: PA idle impedance
- LNA input (differential, ground-referred)
  - Rx mode:
  - Gain = 30x: LNA input match
  - Gain = 10x: LNA input match
  - Tx mode: Rx/Tx switch impedance

The need for complex broadband models is avoided by providing simple lumped-element models for each RF port. This simplification has the disadvantage of the models being valid in a narrow frequency band only. In this document the following frequency bands are considered:

- 433 MHz, 2 MHz bandwidth
- 868 MHz, 2 MHz bandwidth
- 915 MHz, 26 MHz bandwidth

The ADF7020 port model has been extracted with an approach based on fixture modeling. The de-embedding procedure eliminates the impact of the solder pads underneath the package on the printed circuit board. Therefore, the pads need to be included in a possible simulation of the ADF7020.

MEASUREMENT RESULTS

LNA Input, Rx Mode

Figure 1 shows the assumed lumped-element model of the LNA input. The simplified model reflects the measured port impedance values with an equivalent circuit of the lowest possible complexity. A section with results is given for both high sensitivity mode (LNAGAIN = 30) and low current mode (LNAGAIN = 10).

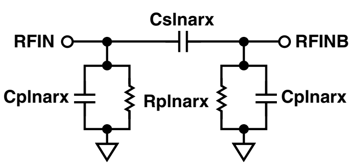

Figure 1. LNA Lumped-Element Model, Rx Mode

For best sensitivity, the source impedance should be matched with the recommended CLC structure to maximize the differential voltage swing across the terminals RFIN and RFINB. This task should be accomplished by means of an RF simulator with built-in optimizer. The matching condition typically results in a slightly reactive input reflection coefficient.

LNA Input, Rx Mode, LNAGAIN = 30

Table 1 lists the component values of the equivalent circuit shown in Figure 1 applicable for Rx mode and LNAGAIN = 30 ([R9.DB20, R9.DB21] = [1,0]).

Table 1. Elements of LNA Equivalent Circuit (Figure 1) in Rx Mode, LNAGAIN = 30

Frequency (MHz)	Rplnarx (Ω)	Cplnarx (pF)	Cslnarx (pF)
433 to 435	300	2.0	0.1
868 to 870	180	2.3	0.1
902 to 928	175	2.3	0.1

Since the capacitance Cslnarx is comparably low, the LNA input impedance may be approximated as two independent impedance elements between RFIN to GND and RFINB to GND, respectively. This simplified model is sufficient for the majority of matching problems. The impedance values are listed in Table 2.

Table 2. Ground-Referred Input Impedance of LNA in Rx Mode, LNAGAIN = 30

Frequency (MHz)	Zlnarx_gnd (Ω)
433 to 435	71 – j128
868 to 870	26 – j63
902 to 928	24 – j60

LNA Input, Rx Mode, LNAGAIN = 10

Table 3 lists the component values of the equivalent circuit shown in Figure 1 applicable for Rx mode and LNAGAIN = 10 ([R9.DB20, R9.DB21] = [0,1]).

Table 3. Elements of LNA Equivalent Circuit (Figure 1) in Rx Mode, LNAGAIN = 10

Frequency (MHz)	Rplnarx (Ω)	Cplnarx (pF)	Cslnarx (pF)
433 to 435	200	2.0	0.1
868 to 870	125	2.4	0.1
902 to 928	120	2.4	0.1

Again, a simplification of the model is possible if the components in the coupling branch between input RFIN and RFINB are reflected in two single-ended, ground-referred branches. The values are given in Table 4.

Table 4. Ground-Referred Input Impedance of LNA in Rx Mode, LNAGAIN = 10

Frequency (MHz)	Zlnarx_gnd (Ω)
433 to 435	82 – j98
868 to 870	30 – j53
902 to 928	28 – j51

LNA Input, Tx Mode

When the ADF7020 enters Tx mode, the Rx/Tx switch is closed, providing a low impedance path between pins RFIN and RFINB. For the design of the matching network, the LNA input impedance in Tx mode may be modeled as shown in Figure 2.

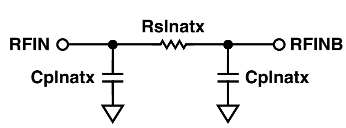

Figure 2. LNA Lumped-Element Model, Tx Mode

Table 5 lists the estimated component values for the three frequency bands of interest.

Table 5. Elements of LNA Equivalent Circuit (Figure 2) in Tx Mode

Frequency (MHz)	Cplnatx (pF)	Rslnatx (Ω)
433 to 435	2.2	10
868 to 870	2.6	10
902 to 928	2.6	10

PA Output, Rx Mode

In Rx mode the parasitic capacitance of the biased PA output is of interest for the design of the combined Rx/Tx matching network. Figure 3 shows the lumped-element model of the biased PA in Rx mode using the minimum number of components. Since the ground connection of the PA block is bonded directly to the paddle of the IC package, the ground impedance is very low if multiple vias are used between the paddle ground and the ground plane of the printed circuit board. Therefore, the impedance between the RFGND pin and the idealized common ground node of the printed circuit board may be neglected. Frequency-dependent component values applicable for the equivalent circuit of Figure 3 are listed in Table 6. A bias voltage of 3 V has been used. The PA port impedance shows a slight dependency on the bias voltage.

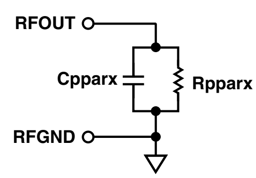

Figure 3. PA Lumped-Element Model for Rx Mode

Table 6. Elements of PA Equivalent Circuit (Figure 3) in Rx Mode

Frequency (MHz)	Rpparx (Ω)	Cpparx (pF)
433 to 435	2000	2.2
868 to 870	680	2.1
902 to 928	650	2.1

PA Output, Tx Mode, Optimum Load Impedance

The PA load impedance values have been optimized to yield an output power of 10 dBm at the lowest possible current consumption at a supply voltage of 3.0 V by means of stub tuner-based approach.

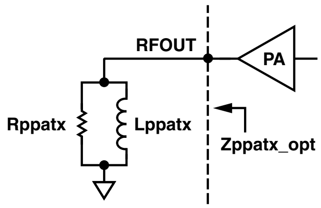

Figure 4. Definition of the Optimum PA Load Impedance and Lumped-Element Model

Table 7. Optimum PA Load Impedance (Figure 4) for P_O = 10 dBm at V_{DD} = 3.0 V

Frequency (MHz)	Zppatx_opt (Ω)
433 to 435	54 + j94
868 to 870	48 + j54
902 to 928	39 + j61

Table 7 lists optimum PA load impedance values for each frequency band, which satisfies the condition stated earlier. Figure 4 illustrates the definition of the optimum load impedance and a lumped-element equivalent circuit. The component values that represent the optimum load impedance are listed in Table 8.

Table 8. Lumped Element Model of Optimum PA Load Impedance (Figure 4)

Frequency (MHz)	Rppatx (Ω)	Lppatx (pF)
433 to 435	218	46
868 to 870	110	18
902 to 925	134	15

SUMMARY

This application note presents measured port impedance values for the ADF7020. The measurements cover the LNA input in different modes for the most important frequencies and different gain settings. The PA port impedance is characterized in its idle state in Rx mode. For operation in Tx mode, the optimum PA load impedance has been quantified. The provided data satisfies the requirements for the design of the combined Rx/Tx matching network.

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