Wireless Components

Mixer and IF Vector Modulator

PMB 2208 Version V1.2

Specification August 1999

preliminary

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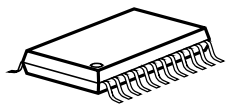
Product Info

General Description

The PMB 2208 contains a direct quadrature modulator and an up/down-conversion mixer with corresponding bias circuitry.

Package



Features

- Direct quadrature modulator and up/down-conversion mixer on one chip
- Modulator:
  - LO input frequency range from 200MHz to 550MHz corresponds to an output frequency range from 100MHz to 275MHz
  - Generation of orthogonal carriers without external elements and without trimming
  - typ. 48dB carrier suppression with $1V_{pp}$ baseband level
  - typ. 49dB SSB suppression with $1V_{pp}$ baseband level
  - typ. 51dB rejection of third-order intermodulation products with $1V_{pp}$ baseband level
  - Low output noise floor
- Mixer:
  - Double-balanced Gilbert cell
  - RF and IF frequency range from DC to 2.5GHz
  - typ 39dB carrier suppression
  - Low noise
- Supply voltage range from 2.7 to 4.5V
- Power-down mode
- Temperature range -30 to 85°C

Application

- Vector-modulated digital mobile cellular systems, such as GSM, PDC-800, PDC-1.5, PHS, DAMPS, DCS1800, WLAN, etc.
- Various modulation schemes, such as PM, PSK, FSK, QAM, QPSK, GMSK, etc.
- Analog systems with FM and AM modulation
- Space- and power-saving optimizations of existing discrete transmitter circuits

Ordering Information

Type	Ordering Code	Package
PMB 2208		P-TSSOP-24

1 Table of Contents

2 Product Description

Contents of this Chapter

2.1 Overview

The PMB 2208 contains a direct quadrature modulator and an up/down-conversion mixer with corresponding bias circuitry.

The modulator splits the signal at the LO/LOX input into two orthogonal carriers. The frequency of these carriers is half of the LO/LOX input frequency. The carriers are multiplied with the baseband modulation signals at the A/AX and B/BX inputs. The outputs of the multipliers are added and amplified by a linear output stage. The modulated signal is available at the E/EX output. A reference voltage is available at the TREF output, which can be used to bias the baseband inputs.

The mixer combines the signals at the RF/RFX and IF/IFX inputs; the resulting signal is available at the MO/MOX output. The IF/IFX input is suitable for the lower-frequency signal because of its linear transfer function to the output. The higher-frequency signal is applied to the RF/RFX input, which operates in switched mode. In a typical application, the output signal of the modulator is band-pass filtered and then fed to the IF/IFX input of the mixer.

The modulator and mixer have separate power supplies, and can be powered down independently. The power-down concept enables the modulator to be used with or without the mixer.

2.2 Features

- Direct quadrature modulator and up/down-conversion mixer on one chip
- Modulator:
  - LO input frequency range from 200MHz to 550MHz corresponds to an output frequency range from 100MHz to 275MHz
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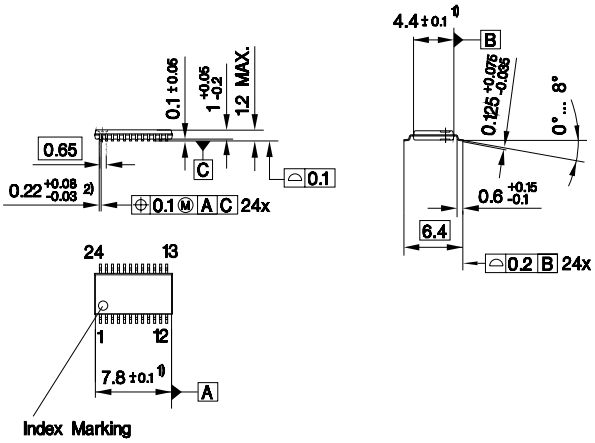
- Power-down mode
- P-TSSOP-24 package
- Temperature range -30 to 85°C

2.3 Applications

- Vector-modulated digital mobile cellular systems, such as GSM, PDC-800, PDC-1.5, PHS, DAMPS, DCS1800, WLAN, etc.
- Various modulation schemes, such as PM, PSK, FSK, QAM, QPSK, GMSK, etc.
- Analog systems with FM and AM modulation
- Space- and power-saving optimizations of existing discrete transmitter circuits

2.4 Package Outlines

P-TSSOP-24



1) Does not include plastic or metal protrusion of 0.15 max. per side
2) Does not include dambar protrusion of 0.08 max. per side

3 Functional Description

Contents of this Chapter

3.1 Pin Configuration

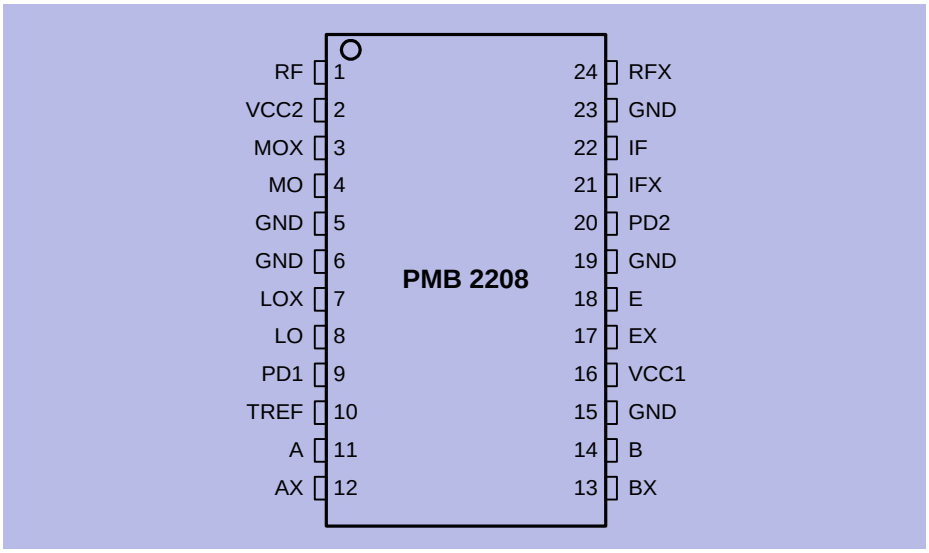


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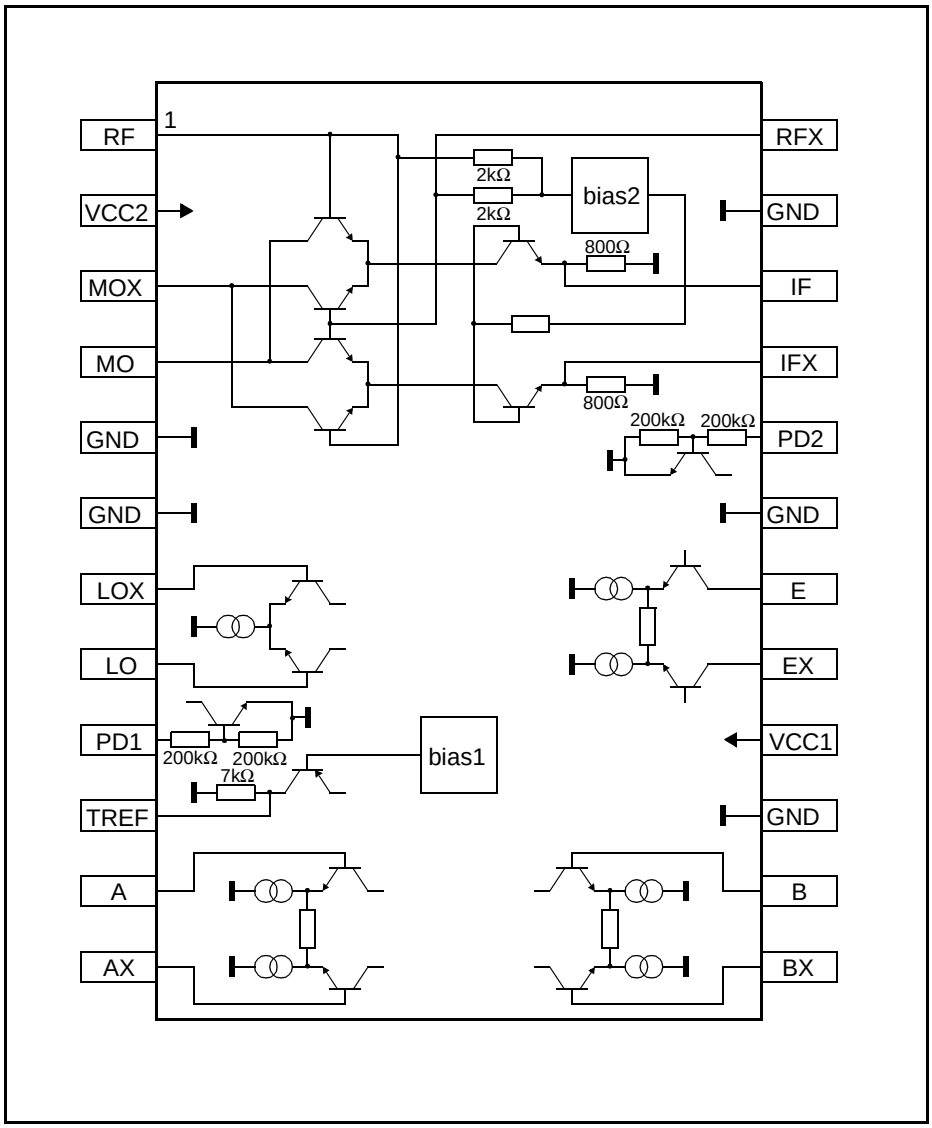
Figure 3-1 Pin Configuration

3.2 Pin Definition and Function

Table 3-1 Pin Definition and Function

Pin No.	Symbol	Function
1	RF	RF input (base)
2	VCC2	Mixer supply voltage
3	MOX	Inverted mixer output (open collector)
4	MO	Mixer output (open collector)
5	GND	Ground
6	GND	Ground
7	LOX	Inverting modulator LO input
8	LO	Modulator LO input
9	PD1	Modulator power-down
10	TREF	Reference voltage output (DC bias for A, AX, B, BX)
11	A	Modulation input A
12	AX	Inverting modulation input A
13	BX	Inverting modulation input B
14	B	Modulation input B
15	GND	Ground
16	VCC1	Modulator supply voltage
17	EX	Inverted modulator output (open collector)
18	E	Modulator output (open collector)
19	GND	Ground
20	PD2	Mixer power-down
21	IFX	Inverting IF input (emitter)
22	IF	IF input (emitter)
23	GND	Ground
24	RFX	Inverting RF input (base)

3.3 Internal Input/Output Circuits



3.4 Functional Block Diagram

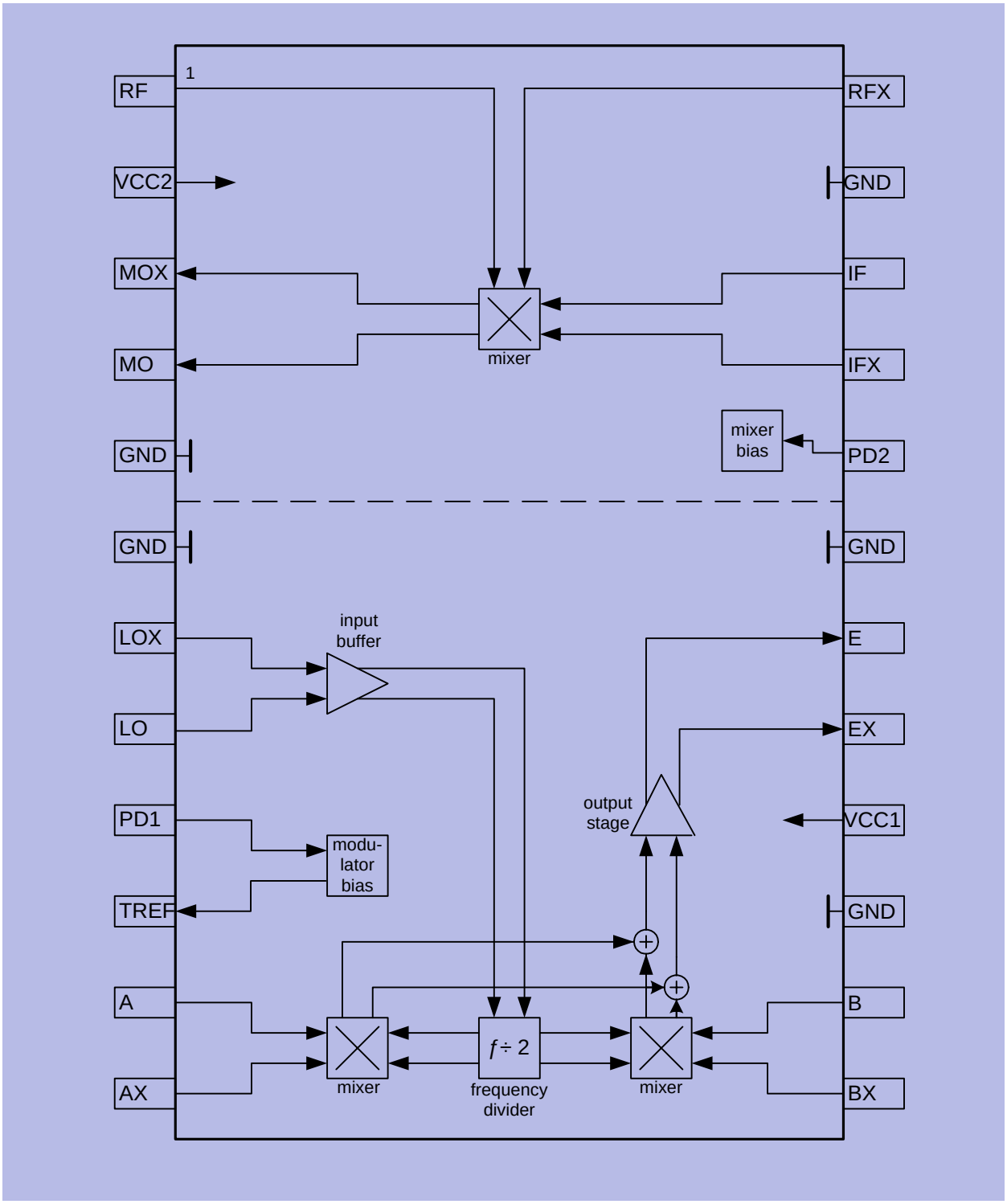


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Figure 3-2 Functional Block Diagram

3.5 Circuit Description

The modulator performs a direct quadrature modulation. The LO signal is connected to an emitter-coupled transistor pair. The LO signal is split internally into two orthogonal carriers at half of the LO/LOX input frequency. The accuracy of the internal 90° phase shift requires a balanced input signal and depends on the accuracy of the 50% duty cycle of the LO/LOX signal. The modulator has two Gilbert cell mixers, in which the baseband modulation signals at the A/AX and B/BX inputs are multiplied with the orthogonal carriers. The outputs of the two Gilbert cells are added and amplified by a linear output stage. The modulated transmit signal is available at the high-impedance, open-collector output E/EX. It can be band-pass filtered and fed to the IF/IFX input of the mixer.

At the TREF output, a reference voltage is available, which should be capacitively decoupled to ground. TREF can be used to set the DC bias of the baseband inputs using external resistors. Alternatively, the DC level can be set independently of TREF, provided it is within the specified operational range.

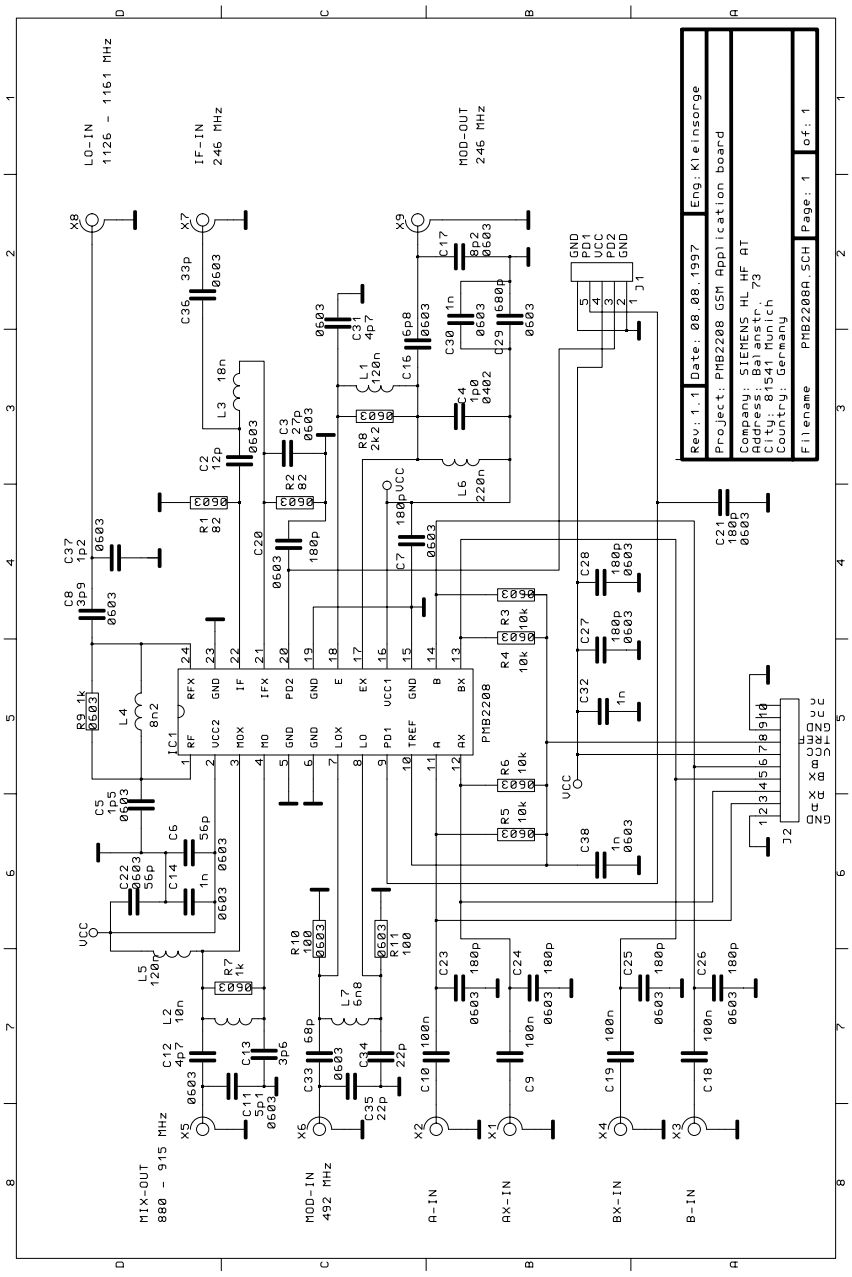
The up/down-conversion mixer is a fully-balanced Gilbert cell. The transfer function from the low-impedance emitter input IF/IFX to the output is linear for input levels below the 1dB compression point. For improved intermodulation, the mixer current can be increased with external resistors to ground at IF/IFX. The high-impedance input RF/RFX is directly connected to the bases of the switching transistors. The input level should be high enough to ensure proper switching. The output signal of the mixer is available at the high-impedance, open-collector outputs MO/MOX.

The modulator and the mixer have separate supply and power-down pins: VCC1, PD1 for the modulator and VCC2, PD2 for the mixer. Applying a logic LOW to PD1 or PD2 powers down the corresponding part of the chip, including its bias circuitry. Depending on the application, the power-down pins can be combined or separately fixed to supply rails.

4 Applications

Contents of this Chapter

4.1 Circuits



Appl_circuit.eps

Figure 4-1 Application Circuit

4.2 Hints

5 Reference

Contents of this Chapter

5.1 Electrical Data

5.1.1 Absolute Maximum Ratings

WARNING

The maximum ratings may not be exceeded under any circumstances, not even momentarily and individually, as permanent damage to the IC will result.

Table 5-1 Absolute Maximum Ratings

Parameter	Symbol	Limit Values		Unit	Remarks
		min	max		
Supply voltage	V_{CC}	-0.5	5.0	V	
Input voltage (except IF, IFX)	V_I	-0.5	V_{CC}+0.5 5.0	V	$V_{CC} \leq 4.5V$ $V_{CC} > 4.5V$
Input voltage IF, IFX	V_{IF}		2	V	
Input current IF, IFX	I_{IF}		10	mA	
Differential input voltage	$V_I - V_{IX}$	-2	2	V	
Output voltage TREF	V_{TREF}	-0.5	V_{CC}+0.5 5.0	V	$V_{CC} \leq 4.5V$ $V_{CC} > 4.5V$
Output voltage MO, MOX	V_{MO}	-0.5	V_{CC}+1.0 5.5	V	$V_{CC} \leq 4.5V$ $V_{CC} > 4.5V$
Output voltage E, EX	V_E	V_{CC}–1.0	V_{CC}+1.0 5.5	V	$V_{CC} \leq 4.5V$ $V_{CC} > 4.5V$
Junction temperature	T_j		125	°C	
Storage temperature	T_S	-55	125	°C	
Thermal resistance (junction to lead)	R_{thJL}		140	K/W	
ESD integrity *	V_{ESD}	-1000	1000	V	according MIL-STD 883D, method 3015.7 and EOS/ESD assn. standard S5.1 - 1993

* The RF pins 3, 4, 17 and 18 are not protected against voltage stress > 300V (versus VS or GND). The high frequency performance prohibits the use of adequate protective structures.

5.1.2 Operating Range

Table 5-2 Operating Range, Supply voltage V_{CC}=2.7V to 4.5 V, ambient temperature T_A= -30 to 85°C

Parameter	Symbol	Limit Values min	Limit Values max	Unit	Remarks	Item
Control inputs PD1, PD2						
LOW input voltage	V_{IL}	0	0.8	V		1
HIGH input voltage	V_{IH}	2.1	V_{CC}	V		2
Mixer						
RF, RFX input frequency	f_{RF}	DC	2.5	GHz		3
RF, RFX input level	P_{RF}		0	dBm		4
IF, IFX input frequency	f_{IF}	DC	2.5	GHz		5
IF, IFX input level	P_{IF}		0	dBm		6
MO, MOX output frequency	f_{MO}	DC	2.5	GHz		7
Minimum resistive load at IF, IFX to GND	R_2, R_3 in Test Circuit 1	33		Ω		8
Modulator						
LO, LOX input frequency	f_{LO}	200	550	MHz		9
LO, LOX input level	P_{LO}	-15 -10	0 0	dBm dBm	f_{LO}=200MHz f_{LO}=550MHz	10
Suppression of the even harmonics at the LO, LOX input	a_{Hn2}	40		dB		11
A, AX, B, BX input frequency	$f_{A\text{-}AX}$, $f_{B\text{-}BX}$	0	10	MHz		12
A, AX, B, BX input level	V_A, V_{AX}, V_B, V_{BX}	1.4	V_{CC}– 0.6	V	DC	13
A-AX, B-BX differential input signal level	$V_{A\text{-}AX}$, $V_{B\text{-}BX}$		1	V_{pp}	AC	14
Decoupling capacitance at TREF	C_{TREF}	1		nF		15
Load current at TREF	I_{TREF}		1.0	mA		16

Note 1: Power levels are referred to an impedance of 50Ω.

5.1.3 AC/DC Characteristics

AC/DC characteristics involve the spread of values guaranteed within the specified supply voltage and ambient temperature range. Typical characteristics are the median of the production.

Table 5-3 AC/DC Characteristics with T_A =+25 °C, V_{CC} =2.7 to 4.5V

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Supply Currents								
Supply current when all powered up	I_{VCC1} I_E+I_{EX} I_{VCC2} I_{MO}+I_{MOX} [1]	9 10 0.3 5	11 12 0.6 7	14 16 1.0 9	mA mA mA mA	PD1,PD2=H		1
Supply current when all powered down	I_{VCC1} I_E+I_{EX} I_{VCC2} I_{MO}+I_{MOX}			2 2 2 2	µA µA µA µA	PD1,PD2=L		2
Control inputs PD1, PD2								
LOW input current	I_{IL}		2	4	µA	V_{IL}=0.8V		3
HIGH input current	I_{IH}		9	18	µA	V_{IH}=2.1V		4
Power-up settling time for modulator	t_{PU} [2]		2		µs	1nF at TREF	*	5
Mixer input IF/IFX								
Internal DC voltage	V_{IF} [3]		0.3		V			6
Mixer input RF/RFX								
Internal DC voltage	V_{RF}		2.0		V			7
Mixer output MO/MOX:								
Output power	P_{MO}	-12	-9	-6	dBm	P_{RFIN} = -5dBm f_{RFIN} = 1.4GHz P_{IFIN} = -5dBm f_{IFIN} = 400MHz		8
Gain with power matching	G_{MO} [4]		+3		dB	Application Circuit	■	9
1dB compression point	P_{IF1dB} [4]		-7		dBm	P_{RFIN} > -4dBm Application Circuit	■	10
Noise figure	N_{IF} [4]		8		dB	DSB noise, f=1GHz Application Circuit	■	11
Carrier suppression	a_C	25	39		dB	P_{RFIN} = -5dBm f_{RFIN} = 1.4GHz P_{IFIN} = -5dBm f_{IFIN} = 400MHz		12

Table 5-3 AC/DC Characteristics with T_A =+25 °C, V_{CC} =2.7 to 4.5V (continued)

	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Modulator inputs A/AX and B/BX: $V_A = V_{AX} = V_B = V_{BX}$ = 1.75V								
Differential input Resistance	$R_{A\text{-}AX}$, $R_{B\text{-}BX}$		250		kΩ	f=100kHz	■	13
Differential input Capacitance	$C_{A\text{-}AX}$, $C_{B\text{-}BX}$		1		pF	f=100kHz	■	14
Input DC current	I_A, I_{AX}, I_B, I_{BX}	2.5	5.0	10	µA	Differential input voltage = 0V		15
Differential input offset current	I_{OSA}, I_{OSB}	-1		1	µA			16
Modulator inputs LO/LOX:								
Differential input Resistance	$R_{LO\text{-}LOX}$		4		kΩ	f_{LO} =350MHz	■	17
Differential input Capacitance	$C_{LO\text{-}LOX}$		0.4		pF	f_{LO} =350MHz	■	18
Reference voltage output TREF for A/AX and B/BX inputs:								
Output voltage	V_{TREF}	1.65	1.75	1.85	V			19
Modulator output E/EX: P_{LO} = -10dBm, $f_{A\text{-}AX} = f_{B\text{-}BX}$ = 455kHz, $V_{A\text{-}AX} = V_{B\text{-}BX}$ = 1V_{pp}, 90° phase shift								
Output power	P_E	-7	-4	-1	dBm			20
Output power with power matching	P_E [4]		0		dBm	Application circuit	■	21
Carrier suppression	a_C [6]	33	48		dB			22
Single sideband supression	a_{SSB}	35	49		dB			23
Suppression of third order intermodulation products	a_{IM3} [7]	45	51		dB			24
Output noise floor	P_N [5]		-144		dBc/ Hz	20MHz from carrier Application circuit	■	25
Differential output resistance	$R_{E\text{-}EX}$		20		kΩ	f_E =175MHz	■	26
Differential output capaci-tance	$C_{E\text{-}EX}$		0.4		pF	f_E =175MHz	■	27
RMS phase error of output signal	ϕ_e		0.4	1.0	Degree			28

■ This value is only measured in lab.
* guaranteed by design

1) The mixer current decreases when no external resistors to ground are connected at IF and IFX. In this case the typical value of $I_{MO}+I_{MOX}$ is 1mA.

2) Design hint. The settling time is determined by the time required to charge the external capacitors.

3) Note: There are external resistors (82 Ohms) at IF and IFX to ground.

4) Application hint

5) Design hint

6) The carrier suppression can be optimized for a particular application using offset voltages at the baseband inputs A/AX and B/BX. The optimum values can be found iteratively by adjusting the A/AX and B/BX offsets alternately until the carrier disappears into the noise floor. If the actual offset voltages differ from their optimum values by ΔV_{OSA} and ΔV_{OSB}, the carrier suppression in dB is given by

$$a_c = 20 \cdot \log_{10}\left[\frac{V_m}{\sqrt{(\Delta V_{OSA})^2 + (\Delta V_{OSB})^2}}\right]$$

where V_m is the peak value of the signal voltage at A/AX and B/BX.

7) a_{IM3} can be increased by reducing the amplitude of the modulator inputs $V_{A\text{-}AX}$ and $V_{B\text{-}BX}$.

5.2 S-Parameters and Input/Output Impedances

The S-parameters provided in this section are based on measurements at the supply voltage of VCC = 3.6V. Via the internal bias tees of the NWA the capacitive coupling is done and the open collector pins are connected to VCC.

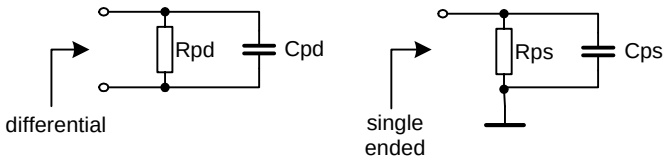
The S-parameters have to be considered as application hints.

Table 5-4

Test	Frequency [MHz]	Port 1	Port 2	Output levels
RF-Input impedance	50 - 2500	RF	RFX	-5 dBm
IF-Input impedance	50 - 2500	IF	IFX	-30 dBm
MO-Output impedance	50 - 2500	MO	MOX	-30 dBm

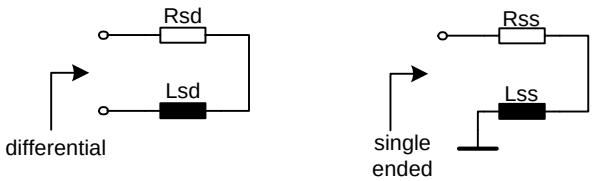
The input/output impedances are calculated from these parameters. The impedances are given as equivalent circuit with lumped elements for differential and single ended in-/outputs.

As equivalent circuit for these in-/outputs a resistor Rp parallel to a capacitance Cp is derived:



S_Parameter.wmf

The IF-Input impedance is given as a equivalent circuit of a resistor Rs serial to a inductivity Ls:



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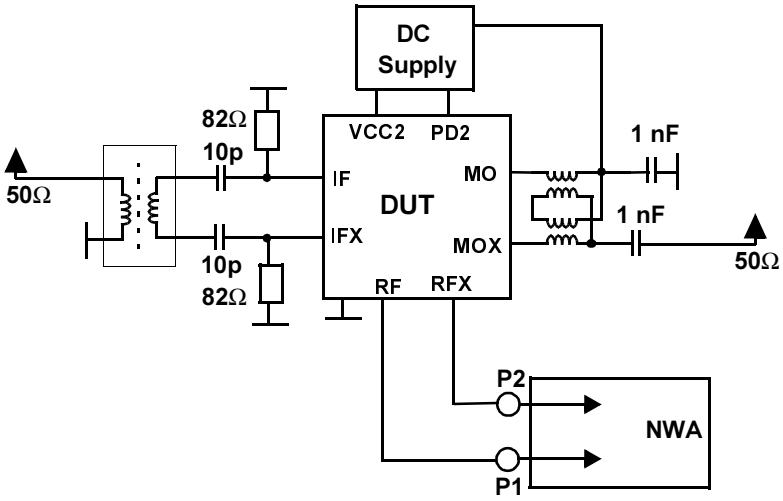
5.2.1 Mixer Input RX/RFX

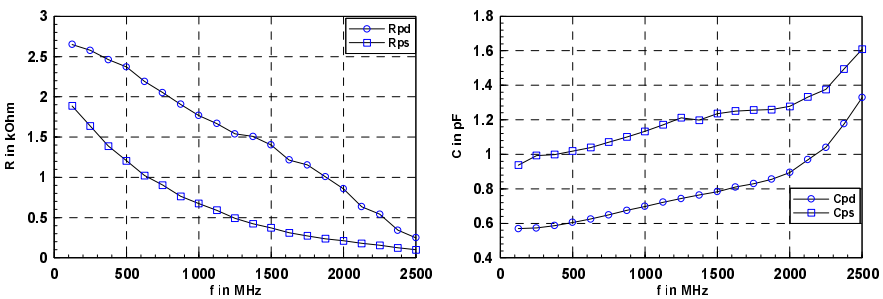
Circuit for measurement:



Mixer Input RF/RFX S-Parameters:

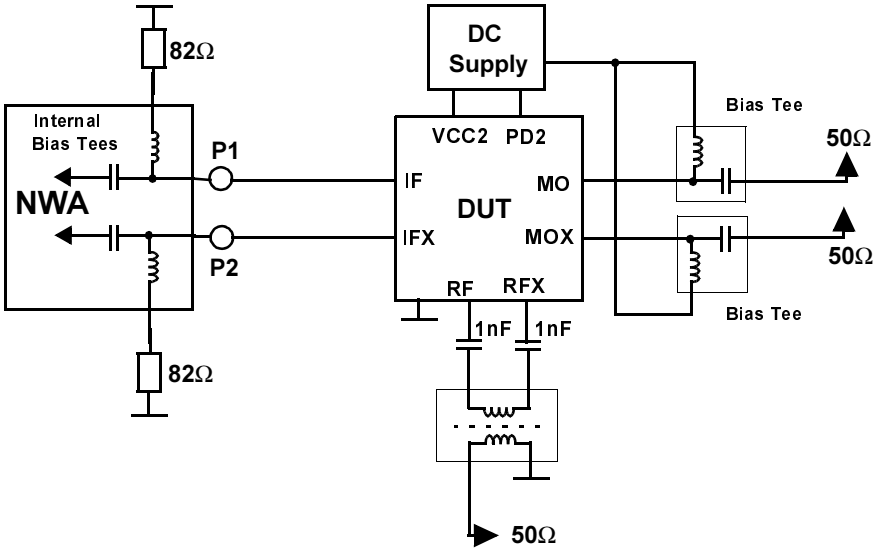
f	S11		S21		S12		S22	
MHz	mag	ang	mag	ang	mag	ang	mag	ang
50	0.943	-1.8	0.027	0.4	0.006	48.4	0.965	-1.5
250	0.941	-8.9	0.029	57.9	0.032	49.0	0.939	-8.4
500	0.920	-18.2	0.063	69.5	0.057	73.0	0.921	-17.5
750	0.896	-28.4	0.099	66.1	0.094	70.9	0.902	-27.7
1000	0.866	-39.4	0.137	59.4	0.132	66.3	0.878	-38.9
1250	0.832	-51.5	0.161	54.0	0.158	62.7	0.852	-50.9
1500	0.795	-61.5	0.192	47.9	0.195	56.2	0.839	-62.2
1750	0.747	-71.2	0.220	41.9	0.230	50.7	0.817	-73.7
2000	0.701	-80.4	0.250	34.8	0.265	42.5	0.786	-85.6
2250	0.647	-92.4	0.284	24.8	0.301	31.4	0.746	-100.6
2500	0.586	-109.3	0.297	12.3	0.317	21.4	0.682	-120.6

Mixer Input RX/RFX Impedances:



5.2.2 Mixer Input IF/IFX

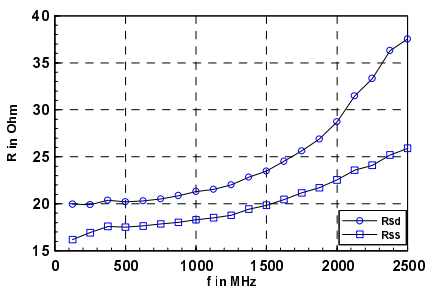
Circuit for measurement:

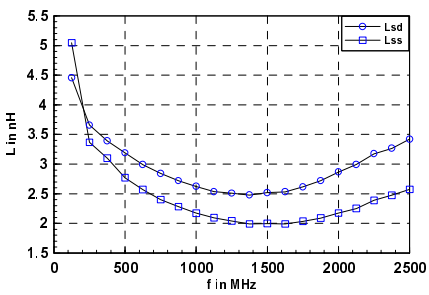


Mixer Input IF/IFX S-Parameters:

f	S11		S21		S12		S22	
MHz	mag	ang	mag	ang	mag	ang	mag	ang
50	0.443	172.5	0.310	10.8	0.253	11.8	0.406	168.2
250	0.317	149.8	0.403	11.4	0.398	11.5	0.310	150.9
500	0.289	143.0	0.421	4.1	0.421	4.6	0.286	144.7
750	0.294	138.2	0.418	0.6	0.418	1.2	0.288	141.0
1000	0.312	134.0	0.399	-1.4	0.401	-0.6	0.298	137.5
1250	0.330	129.4	0.383	-3.2	0.388	-2.3	0.310	133.8
1500	0.344	123.6	0.365	-5.4	0.372	-4.0	0.322	128.0
1750	0.370	116.4	0.337	-7.2	0.347	-5.5	0.338	122.3
2000	0.413	107.3	0.300	-7.7	0.318	-6.1	0.367	113.0
2250	0.472	96.4	0.263	-3.7	0.290	-4.4	0.407	102.3
2500	0.515	86.7	0.255	-1.0	0.271	-5.0	0.441	93.2

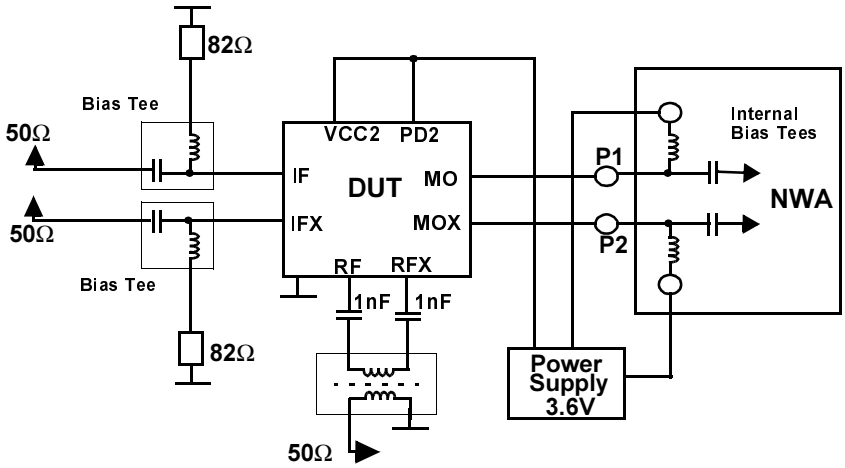
Mixer Input IF/IFX Impedances:





5.2.3 Mixer Output MO/MOX

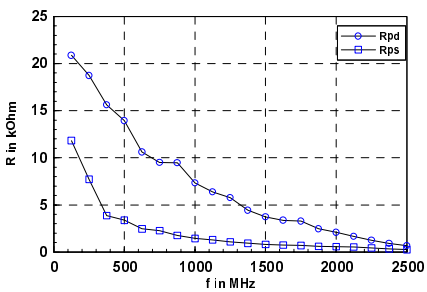
Circuit for measurement:

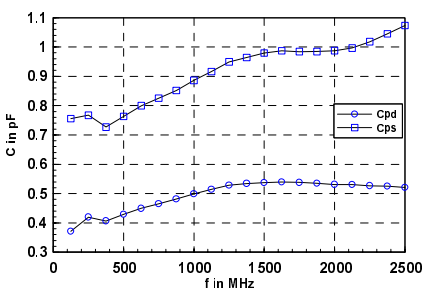


Mixer Output MO/MOX S-Parameters:

f	S11		S21		S12		S22	
MHz	mag	angle	mag	angle	mag	angle	mag	angle
50	1.041	-1.5	0.005	52.7	0.014	-38.3	1.032	0.4
250	0.987	-6.9	0.010	97.3	0.015	117.8	0.992	-6.9
500	0.971	-13.7	0.037	101.9	0.034	107.5	0.967	-13.4
750	0.958	-22.1	0.056	96.4	0.054	108.0	0.939	-22.0
1000	0.935	-31.3	0.076	90.4	0.080	94.1	0.926	-30.7
1250	0.919	-41.2	0.088	87.0	0.091	90.8	0.903	-40.9
1500	0.900	-50.0	0.092	86.5	0.097	92.3	0.869	-50.1
1750	0.892	-57.4	0.093	84.1	0.103	89.1	0.855	-58.2
2000	0.881	-64.2	0.074	85.4	0.089	89.7	0.843	-66.3
2250	0.864	-72.0	0.050	119.9	0.074	108.5	0.816	-76.2
2500	0.797	-81.1	0.103	159.3	0.092	145.8	0.761	-89.1

Mixer Output MO/MOX Impedances:





5.3 Test Circuit

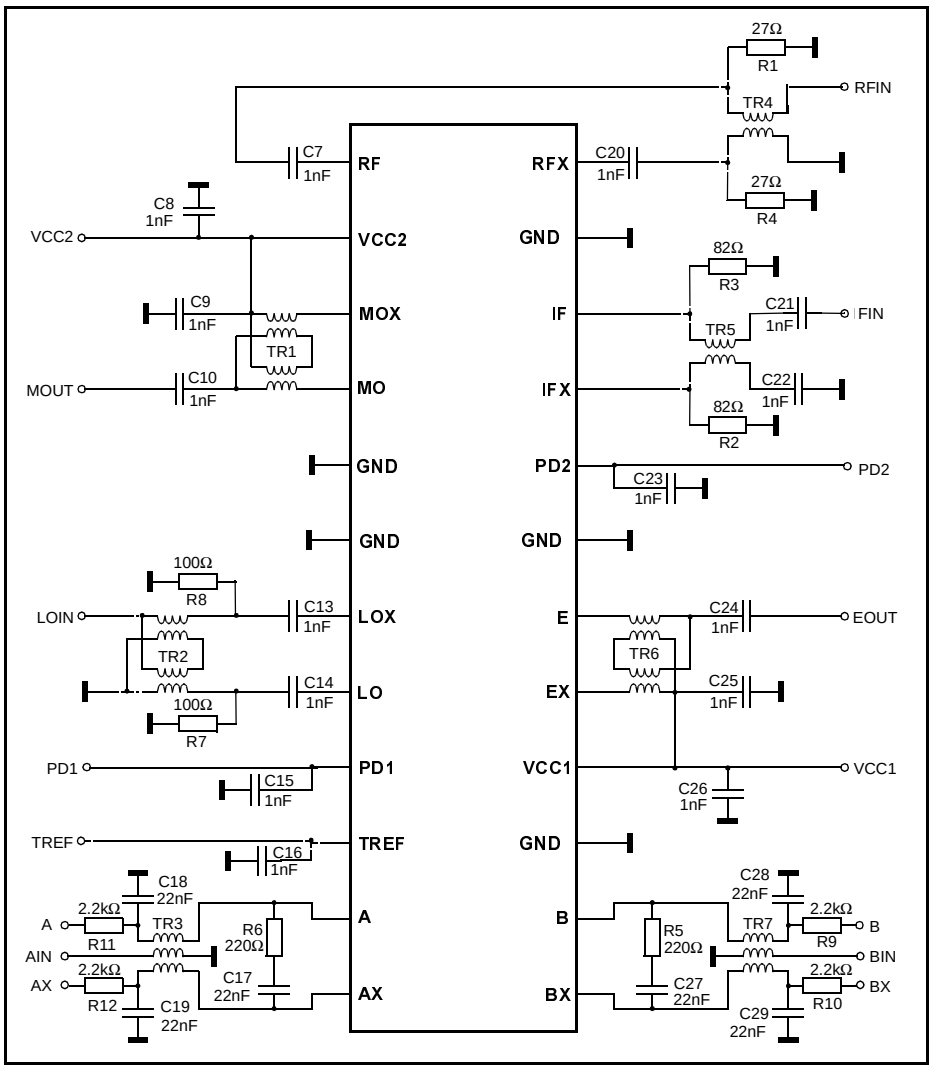


Figure 5-1 Test Circuit