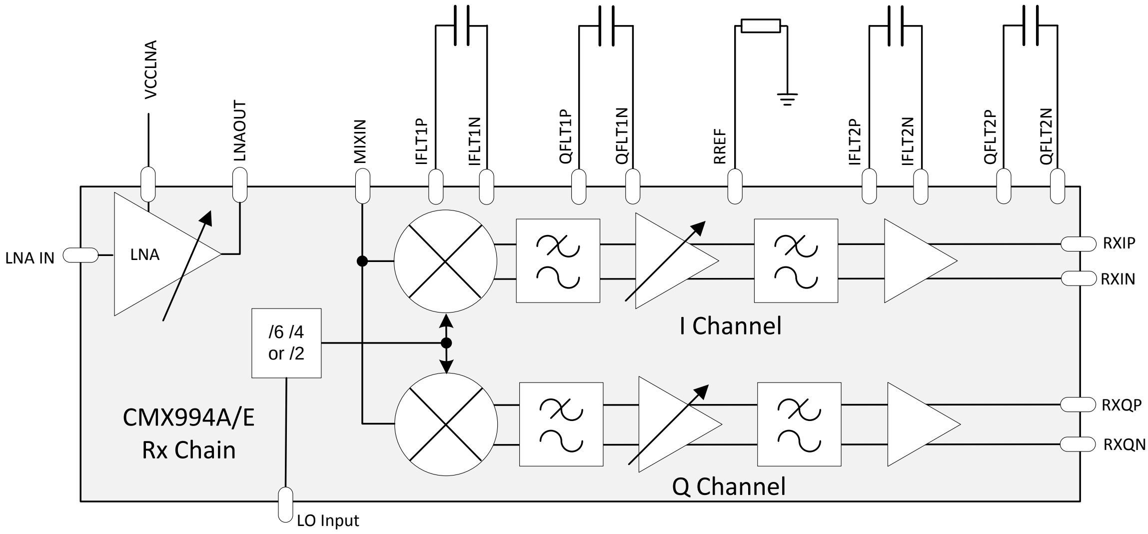
Application Note
CMX994/CMX994A/CMX994E Low Noise Amplifier (LNA) Performance and Applications

Publication: AN/RF/CMX994A/E LNA/1 November 2016



1 Introduction

The CMX994A/CMX994E integrated circuits contain a common LNA design that combines low power, small size, optimised gain, excellent linearity, gain control and low noise.

CML customers must consider if the CMX994A/E LNA performance is acceptable for a particular application but common questions are: “is the LNA acceptable in typical PMR radios?” and “does the LNA meet ETSI standards such as EN 300 086 and EN 300 113? ”. The answer to both questions is yes; this document attempts to explain more about the answers and explores the benefits of the CMX994A/E LNA.

2 History

Version	Changes	Date
1.0	New Issue	11-11-16

3 LNA Performance

Detailed LNA performance specifications can be found in the CMX994A/E datasheet and a summary is presented in Table 1.

	100MHz	450MHz	940MHz	Units
Gain (S_{21})	15	12.5	11	dB
Reverse Isolation (S_{12})	-40	-27	-19	dB
Noise Figure	2	2	3.5	dB
Third Order Intercept Point (input)	8	8	0.5	dBm
1dB Gain Compression Point (input)	-11	-12	-10	dBm
	Min.	**Typ.**	**Max.**	**Units**
Gain Control Range	–	18	–	dB
Gain Control Step Size	4	6	8	dB
Operating Frequency Range	50	–	1000	MHz
Current Consumption (50Ω Output Mode)	–	11	–	mA

Table 1 - LNA Parameters

4 System Performance

The CMX994A/E receiver, including the LNA, shows excellent performance as demonstrated by the following results.

Parameter	DE9945 Results (CMX994A+CMX7341)	EN 300 113 Limit
Sensitivity	-117.5 dBm	-110 dBm
1st Adjacent Channel Rejection	66/67 dB	60 dB
Co-Channel Rejection	10 dB	12 dB
Spurious Response	74 dB	70 dB
IMD Rejection	67 dB	65 dB
Blocking	94 dB	84 dB
Rx Conducted Spurious	<-60 dBm	-47 dBm worst case

Table 2 – Typical CMX994A System Results (DMR operation)

Signal Level / dBm	DE9945 SINAD, 12.5 kHz Channel / dB	Notes
-100	33	
-110	24	
-115	19	
-119	15	
-120	13	Requirement for TIA-603-C is -116 dBm (class A) or -113 dBm (class B).
-121	10.5	
Notes: • EN 300 086 test for 20 dB SINAD (PN weighted) is also comfortably passed (29 dB measured) • DE9945 includes input filter and switch (circa 1 dB loss) • Sensitivity measured direct to CMX994A LNA input is typically -121 dBm. • -122 dBm for 12 dB SINAD sensitivity has been observed with baseband solutions using narrower channel filters.		

Table 3 – Analogue FM Sensitivity Results (TIA-603 method)

5 Application Issues

5.1 When can I use the CMX994A/E LNA?

The CMX994A/E is applicable for most VHF and UHF radio designs (100MHz to 500MHz). Typical applications are given in **Table 4**. The table just gives examples, other applications and technologies are not excluded just because they are not listed but should be studied on a case by case basis. Operation 500MHz to 1GHz is also possible; although performance is less optimal for many applications the CMX994A/E LNA is still perfectly adequate.

Application	Technology	Standard
PMR	Analogue FM	EN 300 086 EN 300 296 TIA-603-D
Digital PMR	DMR	EN 300 113
Digital PMR	dPMR, NXDN, DCR	EN 301 166, ARIB-STD-T98 ARIB-STD-T102
Digital PMR	TETRA	EN 302 561
Digital PMR	APCO P25, C4FM	TIA-102.CAAB (Class A Mobile, Class A Portable)
dPMR446	DMR / dPMR	EN 303 405
Wireless Data, SCADA etc.	GMSK, MSK, FFSK, QAM, QPSK, PSK etc.	EN 300 113 EN 300 219 EN 300 220 EN 300 341 EN 300 390 EN 302 561
Marine	AIS Class B	IEC 62287 (CMX994E only)

Table 4 – CMX994A/E Applications

5.2 Does the CMX994A/E (including the LNA) meet the requirements of the European Union Radio Equipment Directive (Directive 2014/53/EU)?

ETSI European Norm (EN) standards were re-written during 2015/16 to become Harmonised Standards under Directive 2014/53/EU. The standards are for products and it must be noted that the CMX994A/E is just one component in a product however the CMX994A/E is designed to comply with the relevant requirements of the EN standards listed in Table 4. Thus, where an ETSI harmonised standard provides a presumption of conformity to article 3.2 essential requirements, the CMX994A/E LNA is a suitable solution.

5.3 Is the CMX994E LNA performance suitable for use in ‘Enhanced’ mode?

The simple answer is yes. With the LNA intermodulation optimisation set appropriately (see section 6.3) the LNA can be used at 450MHz while taking advantage of the improved mixer IIP3 in ‘enhanced’ mode. In this scenario a typical system IIP3 would be +2 dBm with a noise figure of 5.5 dB (system IIP3 in ‘Normal’ mode typically -1 dBm). In the ‘Enhanced’ scenario the LNA only contributes about 2 % of the total intermodulation (mixer is 96 %).

5.4 What are the advantages of using the CMX994A/E LNA?

The LNA offers good RF performance, as already documented, but other general benefits include:

- Minimum cost
- Low current
- Compact, low number of external components

- Performance optimisation modes;
- Gain optimised for best combination of noise figure and intermodulation when used with the CMX994A/E down conversion mixers
- Gain control (it is often essential to control the gain before the mixer stages in a direct conversion receiver)
- Automatic control by CML modems for dPMR, DMR, NXDN, DCR and Analogue FM (CMX7341 family)

5.5 Not using the internal LNA?

The LNA is not suitable for a few applications for example:

- High performance systems at the upper end of the operating range where gain and noise figure degrade a little;
- Designs where very broadband operation is needed, e.g. when a very broadband 50 Ω match is required (for example 100MHz to 800MHz);
- Designs where absolute maximum sensitivity is required and intermodulation rejection is less important (e.g. some satellite communication systems).

5.6 Any problems with not using the CMX994A/E LNA?

Users implementing direct conversion solutions using the CMX994A/E mixers should be aware of the need for LNA gain control in the case of high input signal levels. Gain control before the I/Q mixers minimises issues with second order intermodulation (IP2) products and local oscillator pulling. The CMX994A/E provides this gain control including automatic control from the CMX7341 family of modems. If an external LNA is to be used then provision for gain control should be considered.

6 Further Information

6.1 Impedance

The following sections show plots and tables of the LNA input (S_{11}) and output (S_{22}) impedance. Separate data is shown for the 50 Ω and 100 Ω output modes selected by $LNAZ_O$ bit in the Rx Gain Register.

6.1.1 50Ω Mode

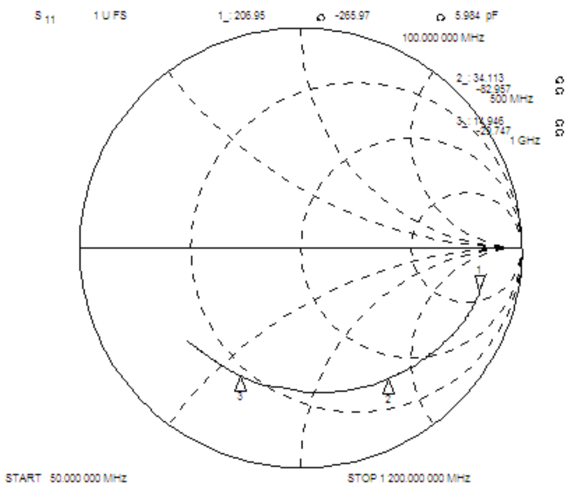


Figure 1 LNA S_{11} (50 Ω Mode)

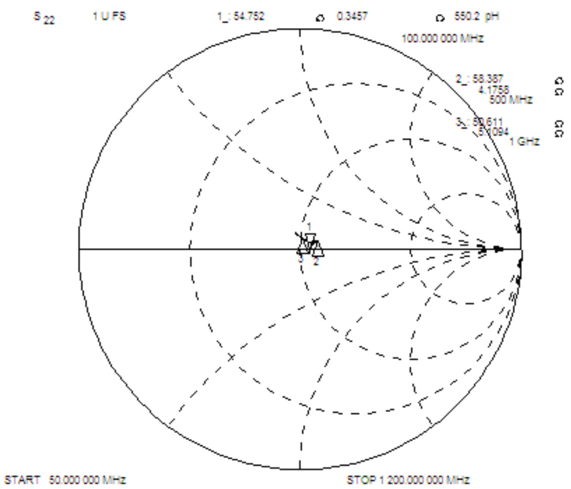


Figure 2 LNA S_{22} (50 Ω Mode)

Freq (MHz)	S_{11}		S_{22}	
	Impedance (Ω-/+jΩ)	**Equivalent Parallel Circuit (R//C)**	**Impedance (Ω-/+jΩ)**	**Equivalent Parallel Circuit (R//C)**
50	347 – j296	598.9R // 4.5pF	54.4 – j2.4	54.5R // 2.6pF
100	208 – j263	540.7R // 3.7pF	54.8 + j0.4	54.8R
150	129 – j217	496R // 3.6pF	55.3 + j1.7	55.4R
200	93 – j181	444.5R // 3.5pF	56.1 + j2.9	56.3R
250	72 – j154	401.1R // 3.4pF	56.9 + j3.5	57.1R
300	58 – j130	351R // 3.4pF	57.4 + j3.9	57.6R
350	49 – j114	318R // 3.4pF	57.7 + j4.0	58.0R
400	42 – j102	286.5R // 3.3pF	58.1 + j3.9	58.4R
450	37.7 – j91	256.3R // 3.3pF	58.4 + j4.0	58.7R
500	33.9 – j83	235.3R // 3.3pF	58.4 + j4.2	58.7R
550	29.7 – j74	211.8R // 3.4pF	58.3 + j4.1	58.6R
600	27.0 – j66	190.6R // 3.4pF	57.9 + j3.9	58.2R
650	24.7 – j61	173.1R // 3.5pF	57.3 + j3.8	57.6R
700	22.8 – j55	154.9R // 3.5pF	56.7 + j3.9	57.0R
750	21.3 – j50	136.7R // 3.6pF	55.9 + j3.7	56.1R
800	19.9 – j45	121.5R // 3.7pF	55.3 + j3.6	55.5R
850	18.7 – j41	107R // 3.8pF	54.3 + j3.6	54.5R
900	17.2 – j37.0	96.7R // 3.9pF	52.8 + j3.9	53.1R
950	15.7 – j32.9	84.6R // 4.1pF	51.5 + j4.7	51.9R
1000	14.8 – j29.1	72R // 4.3pF	50.7 + j5.1	51.2R

Table 5 LNA S_{11} and S_{22} Impedances and Parallel Equivalent Circuit in 50 Ω Mode

6.1.2 100 Ω Mode

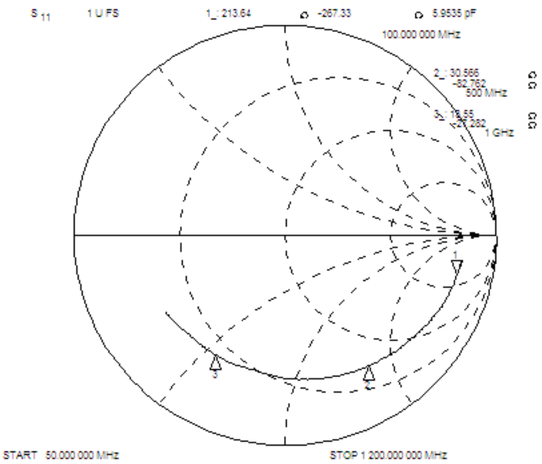


Figure 3 LNA S_{11} (100 Ω Mode)

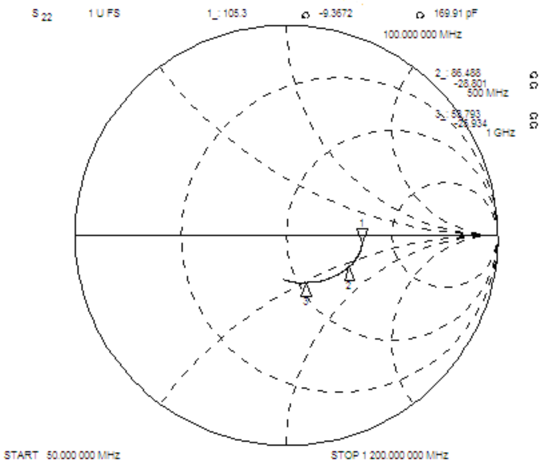


Figure 4 LNA S_{22} (100 Ω mode)

Freq (MHz)	S_{11}		S_{22}	
	Impedance (Ω-/+jΩ)	**Equivalent Parallel Circuit (R//C)**	**Impedance (Ω-/+jΩ)**	**Equivalent Parallel Circuit (R//C)**
50	355 – j291	592.6R // 4.4pf	106 – j7.35	106.6R // 2.1pF
100	210 – j267	549.1R // 3.7pF	105 – j9.5	106R // 1.4pF
150	128 – j222	510.6R // 3.6pF	104 – j2.8	105.7R // 1.2pF
200	92 – j186	469.9R // 3.4pF	103 – j15.7	105.3R // 1.2pF
250	70 – j157	422.4R // 3.4pF	101 – j18.6	104.4R // 1.1pF
300	56 – j134	376.9R // 3.4pF	98 – j21.4	103R // 1.1pF
350	45 – j117	345.3R // 3.4pF	96 – j23.9	101.5R // 1.1pF
400	38 – j103	313.1R // 3.4pF	93 – j26.2	99.9R // 1.1pF
450	34.1 – j91	279.2R // 3.4pF	90 – j27.8	98.3R // 1.1pF
500	30.5 – j82	253R // 3.4pF	87 – j28.9	96.1R // 1.1pF
550	26.4 – j73	228.9R // 3.5pF	83 – j29.7	93.7R // 1.1pF
600	24.0 – j66	203.6R // 3.6pF	80 – j30.5	91.3R // 1.1pF
650	21.7 – j59	183.3R // 3.7pF	76 – j30.7	88.6R // 1.1pF
700	19.9 – j53	162.3R // 3.8pF	73 – j30.5	85.6R // 1.1pF
750	18.7 – j47.7	140.8R // 3.9pF	69 – j30.5	82.6R // 1.1pF
800	17.5 – j42.8	122.2R // 4pF	66 – j30.0	79.7R // 1.1pF
850	16.5 – j38.3	105.5R // 4.1pF	63 – j29.5	76.7R // 1.2pF
900	15.4 – j34.4	92.2R // 4.3pF	60 – j28.4	73R // 1.2pF
950	14.2 – j30.5	79.6R // 4.5pF	57 – j27.1	69.5R // 1.2pF
1000	13.4 – j26.7	66.6R // 4.8pF	54 – j26.0	66.3R // 1.2pF

Table 6 LNA S11 and S22 Impedances and Parallel Equivalent Circuit in 100Ω Mode

6.2 Matching

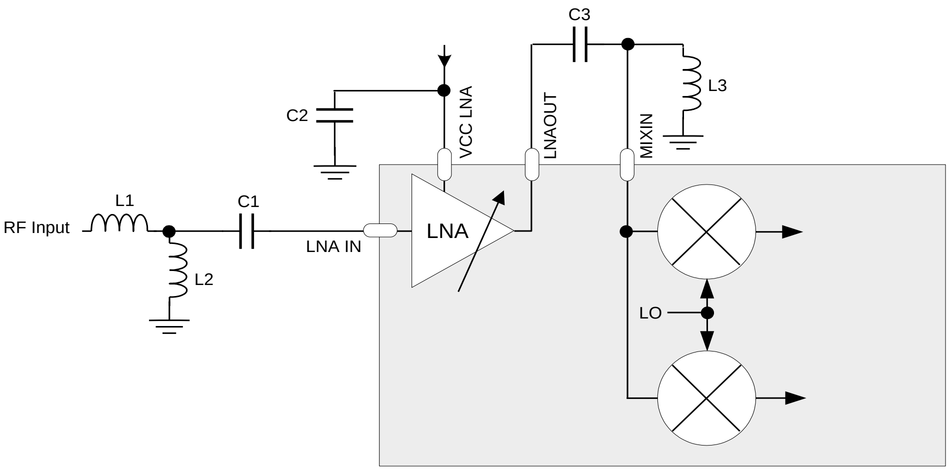


Figure 5 Recommended LNA Configuration and Inter-stage Match

C1	1nF	L1	560 nH
C2	33 pF // 10nF	L2	12 pF (capacitor)
C3	1nF	L3	Not Fitted

Table 7 50MHz LNA and Inter-stage Components (100Ω mode)

C1	1nF	L1	150nH
C2	33pF // 10nF	L2	2.7pF (capacitor)
C3	18pF	L3	150nH

Table 8 150MHz LNA and Inter-stage Components (100Ω output mode)

C1	1nF	L1	39nH
C2	33pF // 10nF	L2	82nH
C3	10pF	L3	27nH

Table 9 450MHz LNA and Inter-stage Components (100Ω output mode)

C1	100pF	L1	12nH
C2	33pF //10nF	L2	8.7nH
C3	4.7pF	L3	5.6nH

Table 10 900MHz LNA and Inter-stage Components (50Ω output mode)

6.3 LNA Intermodulation Optimisation

The intermodulation (IMD) performance of the LNA can be optimised using the IM bits in the IM Control register ($14).

At higher frequencies, typically 400MHz and above, optimum IMD performance is with the IM bits set to maximum, i.e. 0x3F. The improved IMD performance comes with a reduction in gain of approximately 0.5dB.

At minimum frequency (circa 100MHz) the IM bits should be set to minimum i.e. 0x00.

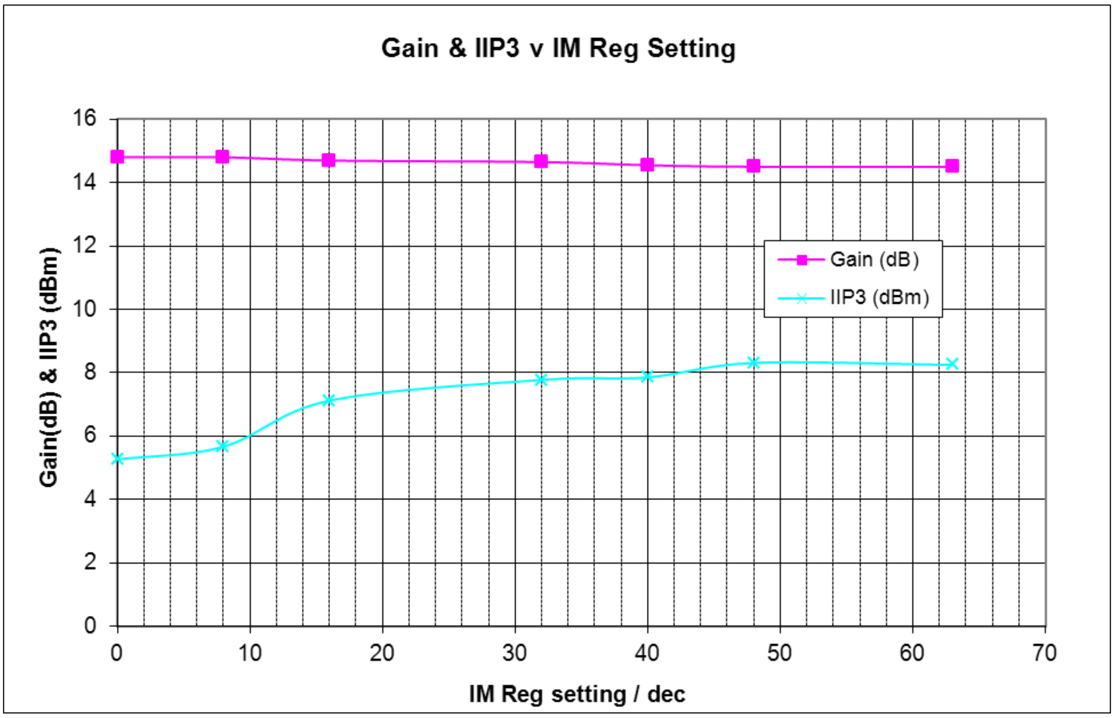


Figure 6 – IIP3 & Gain Response with varying IM Reg setting at 450MHz

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