NEC NE34018 2.4GHz LNA

1. Purpose

These low-noise amplifier prototypes were designed and tested for application in the receiver tuners in Logitech's 2.4GHz wireless video camera project. This is the second revision of the 113012 LNA multiple prototype PCB. This second revision is used to optimize the PCB layout of the microstrip transmission line elements.

A secondary purpose of these LNA prototype circuits is to correct for modeling errors in the circuit simulation tool in order to support a better understanding of component and PCB layout issues. This information will be vital during manufacturing if component vendor or PCB changes become necessary.

2. Measurement condition

Ambient temperature T_A: 25 °C
Nominal impedance 50 Ω

3. Characteristics

Data	typ. value		tolerance / limit	
Supply Voltage	3.3	V	±.066	V
Note: The schematic and photos indicated 3.6V but these test were conducted at 3.3V in order to be compatible with the tuner regulated supply.				
Supply Current	tbd	mA	<10	mA
Tuning Range	-	MHz	2400-2485	MHz
Gain	14	dB	±1	dB
Noise Figure	1.5	dB	<2.5	dB
Input Return Loss	-	dB	>14	dB
VSWR	<1.50:1			
Output Return Loss	-		>10	dB
VSWR	<1.95:1			
Output P1dB	+3	dBm		
Output IP3	+15	dBm		

4. Circuit Topology

The input and output bias and matching circuit topology chosen for these HJ-FET LNA is a high pass network. The high pass network offers better control of the impedances presented to the transistor at out of band frequencies. Further, the high pass network on the input and output improve stability at low frequencies by reducing gain and buffering the device from other system impedances.

The three LNAs are all part of the 113012 rev. 2.0 PCB fabrication. The three LNAs are distinguished by the differences in gate input transmission line length, **tl1** of 0.100", 0.115", and 0125". This is the only difference between them and the only parameter that needed further optimization.

The goal of these LNA designs is not to provide the lowest possible noise figure, which is around 0.7dB for the NE34018 at 2.4GHz. Instead the goal is to provide a low cost, reproducible design that presents a consistent <2.0:1 mismatch to the input and output ports while providing high, stable gain over a broad range of frequencies.

5. PCB Layout and Components

In addition to the type and manufacture of the inductors and capacitors used, the exact location of the matching and bypass elements is critical. These boards are designed on FR-4 material with the er=4.5 assumed at 2.4GHz. The microstrip substrate height for the first dielectric layer is 0.016". The number and location of via holes is also critical to the performance of these circuits. When reproducing these designs in the tuner LNA all dimensions should be carefully checked and followed. Some further optimization of the final design may be required. In these prototypes, the thermal relief usually associated with SMT has been eliminated in order to maintain low impedance connections to the ground plane. This layout method needs to be addressed by manufacturing.

Its important to also note that 100pF capacitors are used to bypass the source pins and the output bias/matching network. These are muRata GRM 0603 series capacitors and are being intentionally operated above the series resonant frequency which is around 1000MHz. This is important because its desirable for stability consideration and optimum noise figure to have the source bypass slightly inductive. Do not substitute capacitor type or value for these bypass applications.

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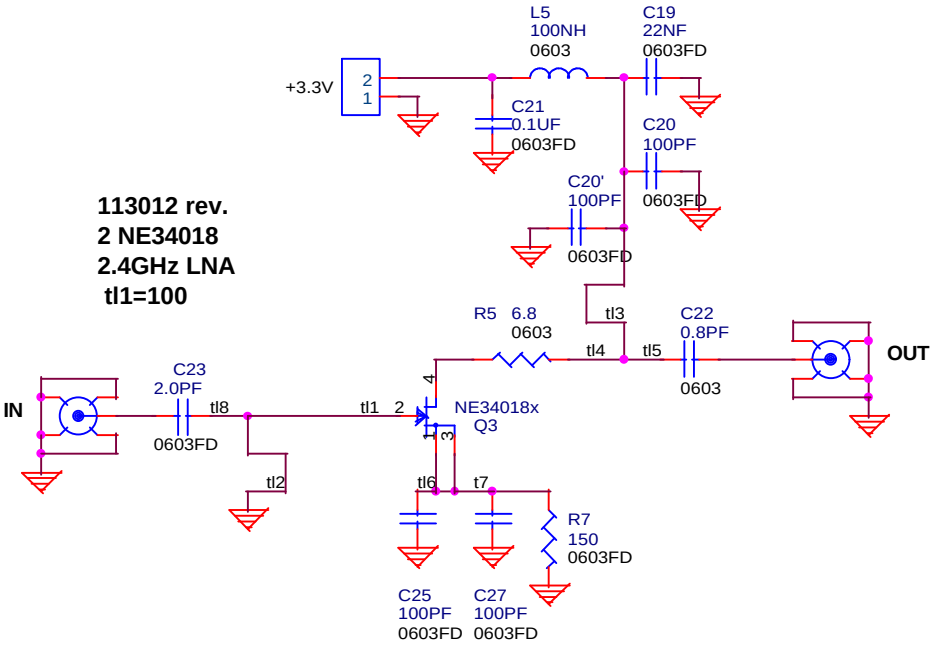

Schematic diagram of the LNA tl=100, tl=100 refers to transmission line tl1 on the gate of Q1

Previous revisions used a total of four bypass capacitors on the two source leads of the transistor. This was found to be unnecessary or desirable with the highpass input network.

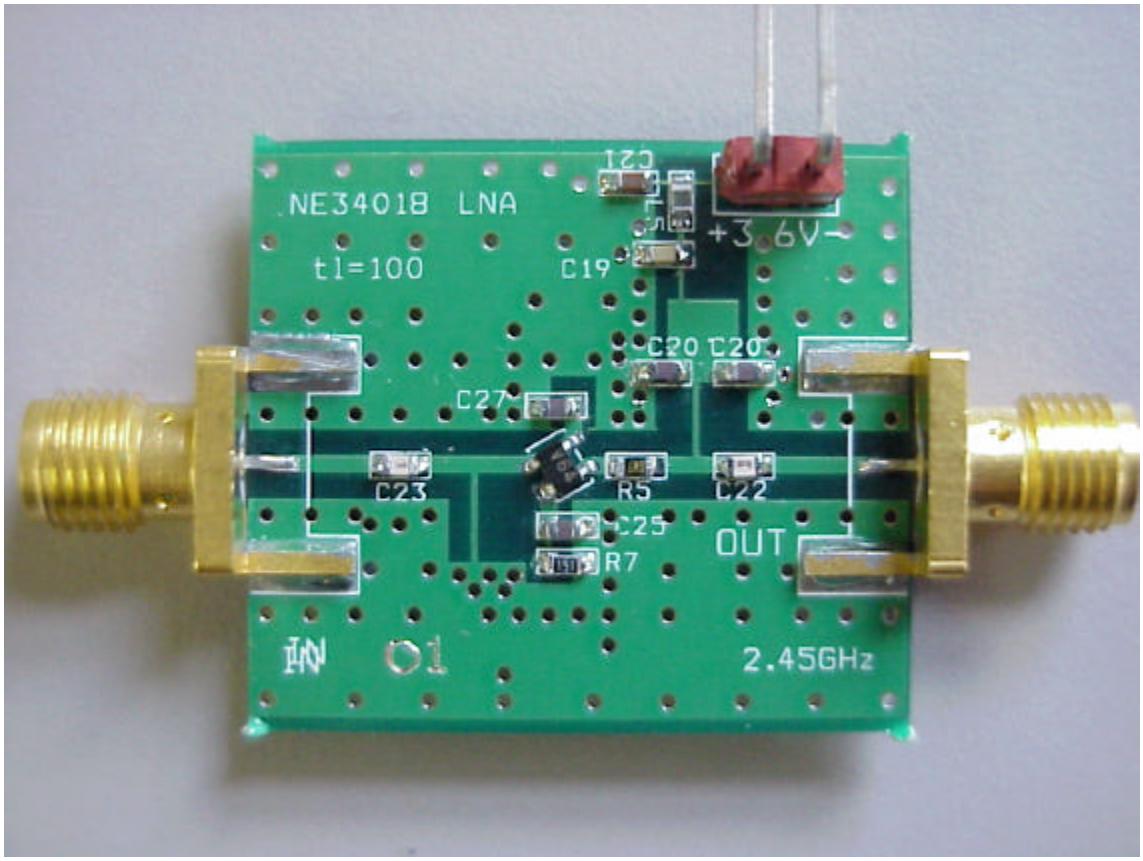

Figure 1—LNA tl=100 .

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LNA tl=100 Component Values

113012 rev. 2 #01 LNA tl=100 Component values											
C23	C11	C14	R7	R5	C22	C20	C20'	L1	C19	C21	Q1
2.0pF ATC 600S	100pF muRata	100pF muRata	150 Ω	6.8 Ω	0.8pF ATC 600S	100pF muRata	100pF muRata	100uH Toko	22nF muRata	0.1uf muRata	NE34018 NEC

LNA tl=100 Transmission Line Dimensions

113012 rev. 2 #01 LNA tl=100 transmission lines (dimensions are inch mils							
t1l	tl2	tl3	tl4	tl5	tl6	tl7	tl8
30x100	12x145	12x125	30x75	30x60	30x50	30x50	30x75

Transmission line dimensions are taken from end of an element to the end or corner of adjoining element with the following exceptions:

- Transmission line tl1 dimension is taken from the edge of tl2 to the center of the gate pad.
- Transmission lines tl6 and tl7 dimensions are taken from the center of the source pads to the center of the bypass capacitor pads.

LNA tl=100 Measured Performance

113012 rev. 2 tl=100	**2400MHz**	**2450MHz**	**2500MHz**	**Goal**	**Units**
Gain	14.14	14.07	13.95	14±1	dB
Input Return Loss	-9.01	-10.11	-11.2	<-14	dB
Input VSWR	2.1	1.91	1.76	<1.5:1	-
Output Return Loss	-13.85	-19.12	-23.89	<-10	dB
Output VSWR	1.51	1.25	1.14	<2.0:1	-
Noise Figure	0.7	0.7	0.7	<1.5	dB
Output P1dB	5.2	5,5	5.8	>0	dBm
Output IP3	16	17	17	>15	dBm
Current at 3.3Vdc	5.12	5.12	5.12	<6.0	mA

- Gain and return losses are measured using an Agilent 8714C network analyzer. Measurement power to the LNA is set to –16dBm with a 6dB input pad. The LNA output (network analyzer input) also has a 10dB pad in order to minimize measurement error due to port reflections.
- The output IP3 intermodulation distortion is measured using an Agilent 8595E spectrum analyzer. The LNA is driven with two tones each at –20dBm separated by 2MHz supplied by Agilent E4432B signal generator with 1MHz I/Q modulation supplied by a second Agilent E4432B signal generator. The input level is adjusted to –20dBm using an Agilent 8494B and 8496B step attenuator set.
- OutputP1dB is measured with the Agilent 8714C network analyzer using the swept power function. A 6dB pad is used on the LNA input port and a 10dB pad is used on the LNA output port.
- Noise figure is measured using the Noise Com Inc. NC346B noise source in a Y-Factor measurement. The system noise figure is 1.5dB established by an AML Corp. balance amplifier with 1.3dB noise figure, 14dB gain, 1.05:1 input VSWR, followed by Down East Microwave 13LNA20WP amplifier with 1.5dB noise figure, 22dB gain, 1.5:1 input VSWR. The Agilent 8595E was used to measure the Y-Factor.

LNA tl=100 Input match is not quite adequate however all other parameters exceed the desired specifications for the LNA.

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LNA tl=100 Performance Plots

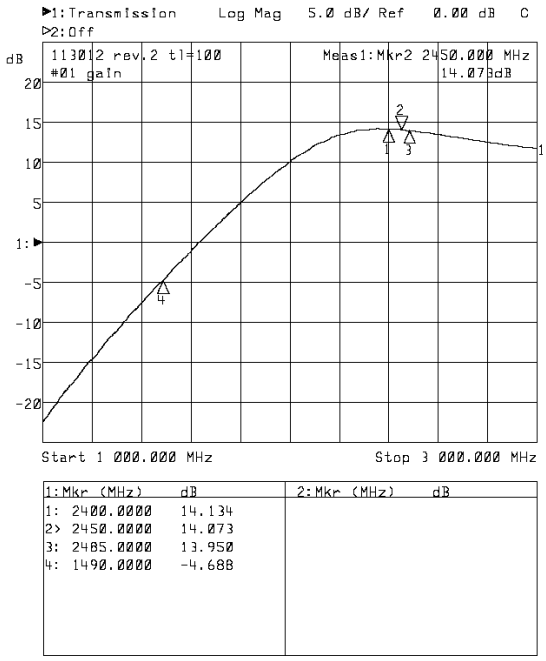

Figure 2- LNA tl=100 Gain

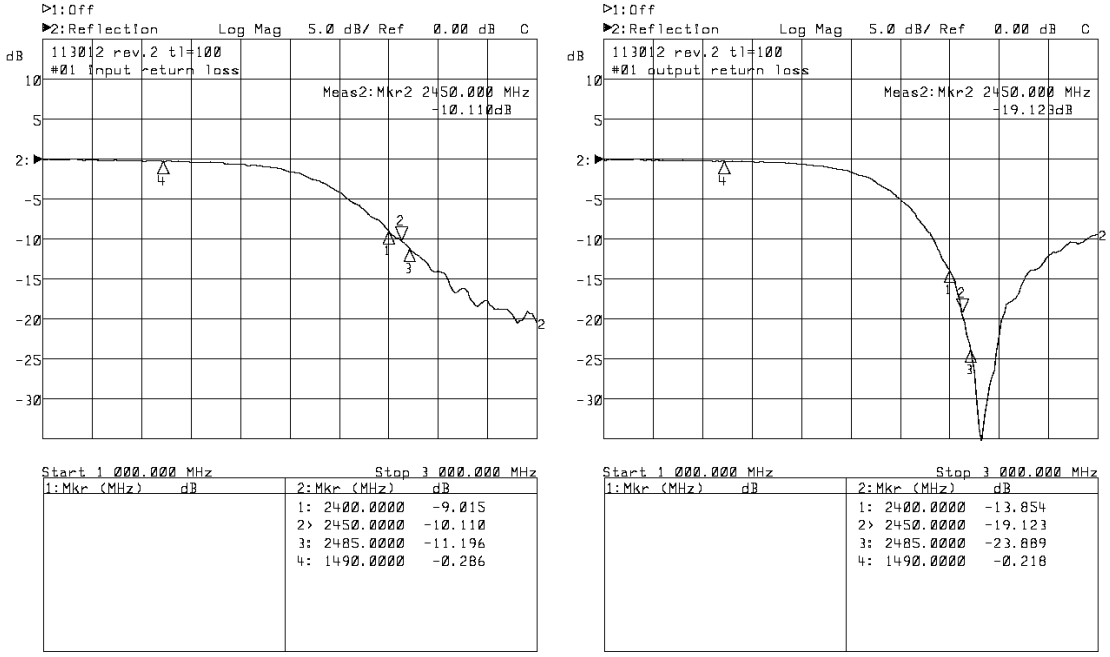

Figure 3--LNA tl=100 Input and Output return loss

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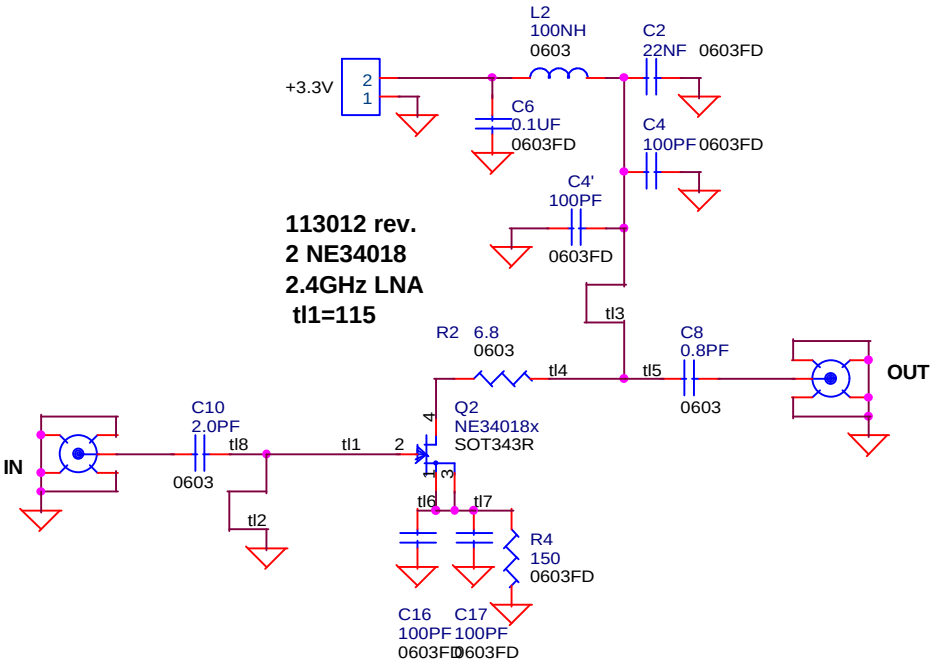

Figure 4— Schematic of LNA tl=115

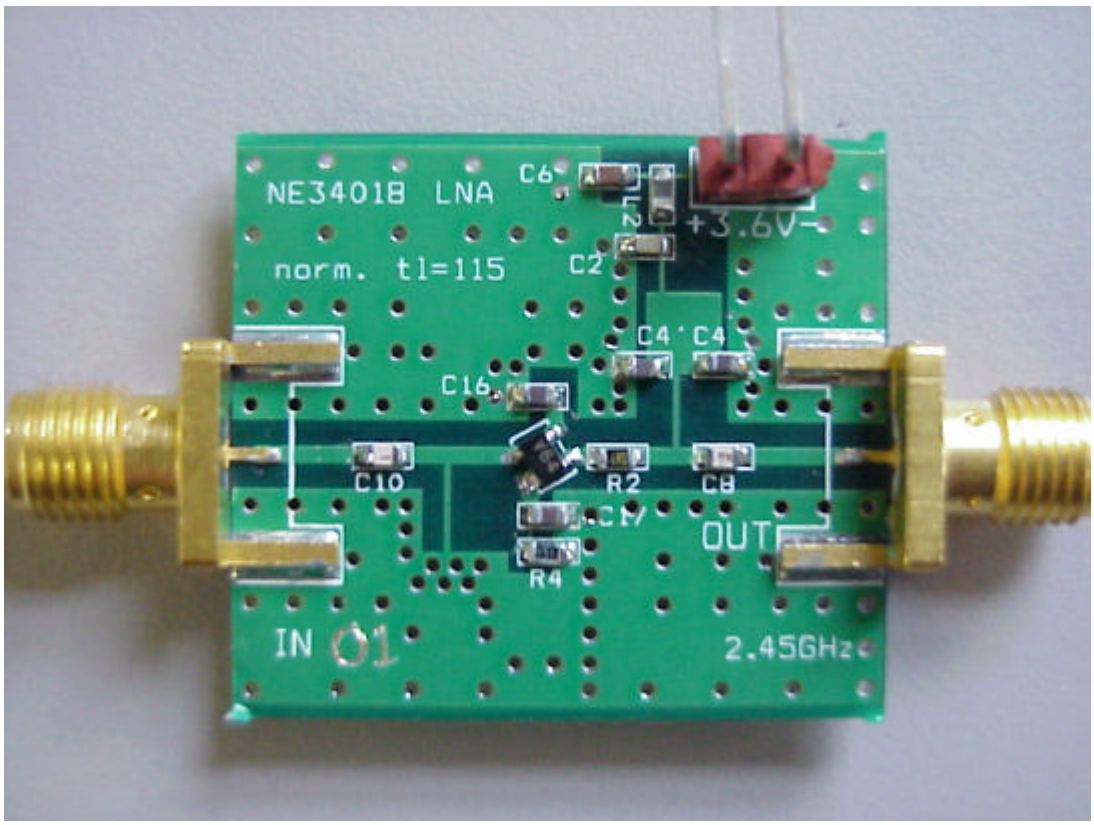

Figure 5— LNA tl=115

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LNA tl=115 Component Values

113012 rev. 2 #01 LNA tl=115 Component values											
C10	C16	C17	R4	R2	C8	C4	C4'	L2	C2	C6	Q2
2.0pF ATC 600S	100pF muRata	100pF muRata	150 Ω	6.8 Ω	0.8pF ATC 600S	100pF muRata	100pF muRata	100uH Toko	22nF muRata	0.1uf muRata	NE34018 NEC

LNA tl=115 Transmission Line Dimensions

113012 rev. 2 #01 LNA tl=115 transmission lines (dimensions are inch mils							
t1l	tl2	tl3	tl4	tl5	tl6	tl7	tl8
30x115	12x145	12x125	30x75	30x60	30x50	30x50	30x75

Transmission line dimensions are taken from end of an element to the end or corner of adjoining element with the following exceptions:

- Transmission line tl1 dimension is taken from the edge of tl2 to the center of the gate pad.
- Transmission lines tl6 and tl7 dimensions are taken from the center of the source pads to the center of the bypass capacitor pads.

LNA tl=115 Measured Performance

113012 rev. 2 tl=115	**2400MHz**	**2450MHz**	**2500MHz**	**Goal**	**Units**
Gain	14.19	14.11	14.00	14±1	dB
Input Return Loss	-9.66	-10.85	-12.22	<-14	dB
Input VSWR	1.98	1.80	1.65	<1.5:1	-
Output Return Loss	-13.95	-18.60	-22.55	<-10	dB
Output VSWR	1.50	1.27	1.16	<2.0:1	-
Noise Figure	0.7	0.7	0.7	<1.5	dB
Output P1dB	5.2	5,5	5.8	>0	dBm
Output IP3	16	17	17	>15	dBm
Current at 3.3Vdc	5.07	5.07	5.07	<6.0	mA

- Gain and return losses are measured using an Agilent 8714C network analyzer. Measurement power to the LNA is set to –16dBm with a 6dB input pad. The LNA output (network analyzer input) also has a 10dB pad in order to minimize measurement error due to port reflections.
- The output IP3 intermodulation distortion is measured using an Agilent 8595E spectrum analyzer. The LNA is driven with two tones each at –20dBm separated by 2MHz supplied by Agilent E4432B signal generator with 1MHz I/Q modulation supplied by a second Agilent E4432B signal generator. The input level is adjusted to –20dBm using an Agilent 8494B and 8496B step attenuator set.
- OutputP1dB is measured with the Agilent 8714C network analyzer using the swept power function. A 6dB pad is used on the LNA input port and a 10dB pad is used on the LNA output port.
- Noise figure is measured using the Noise Com Inc. NC346B noise source in a Y-Factor measurement. The system noise figure is 1.5dB established by an AML Corp. balance amplifier with 1.3dB noise figure, 14dB gain, 1.05:1 input VSWR, followed by Down East Microwave 13LNA20WP amplifier with 1.5dB noise figure, 22dB gain, 1.5:1 input VSWR. The Agilent 8595E was used to measure the Y-Factor.

LNA tl=115 Input VSWR is less than 1.98:1 at the low end of the band and drops to 1.65:1 at the high end of the band.

LNA tl=115 Performance Plots

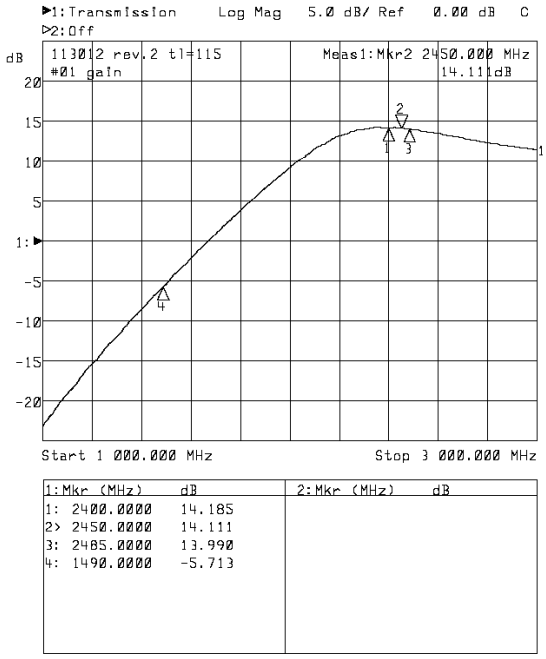

Figure 6-- LNA tl=115 Gain

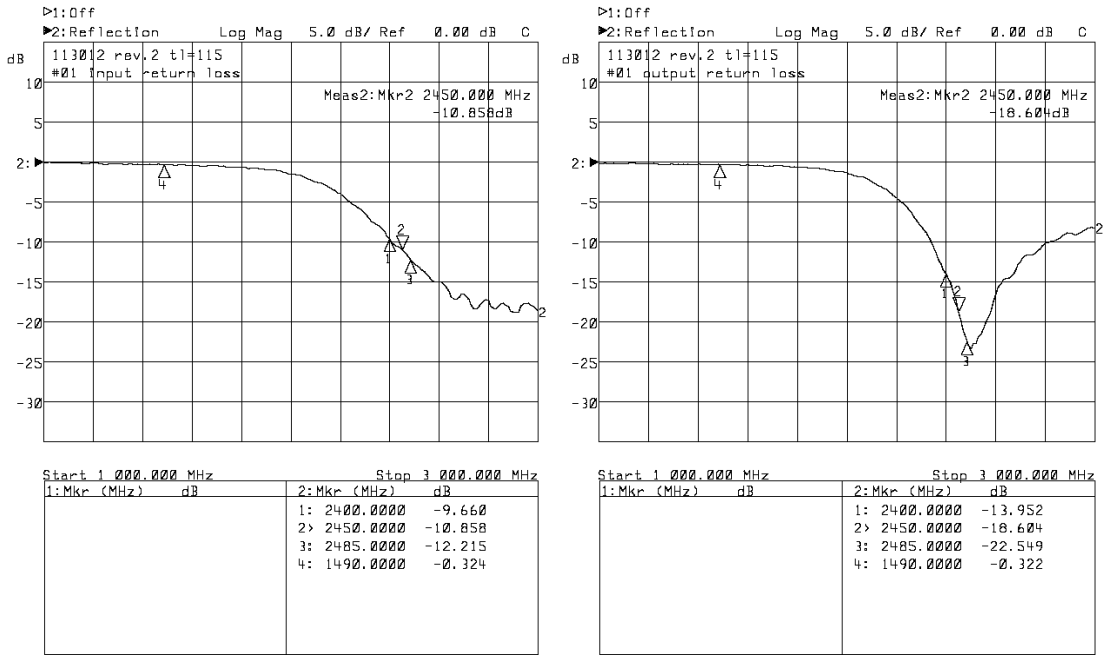

Figure 7-- LNA tl=115 Input and Output Return Loss

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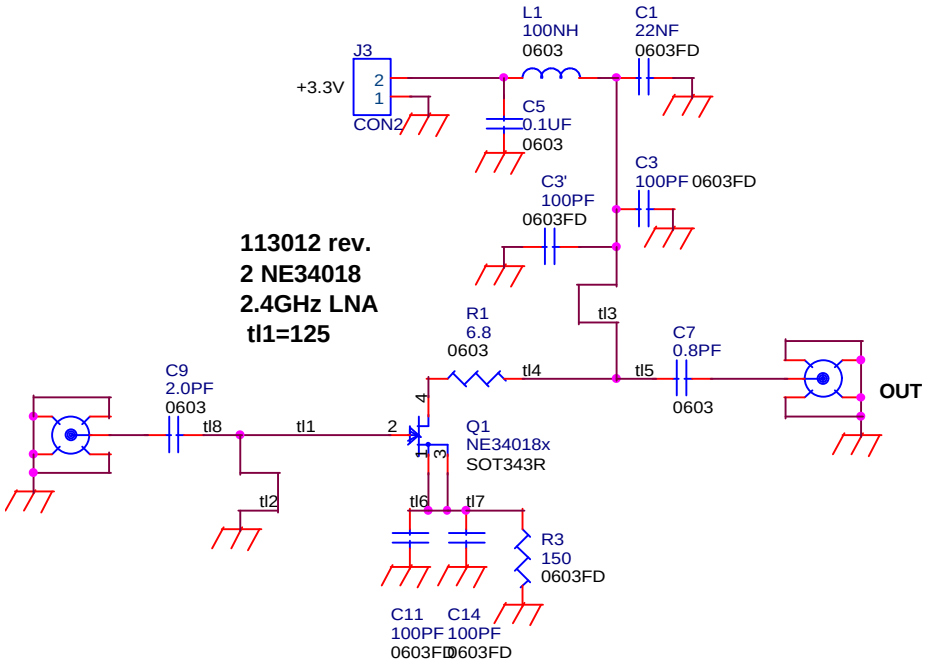

Figure 8—Schematic diagram of LNA tl=125

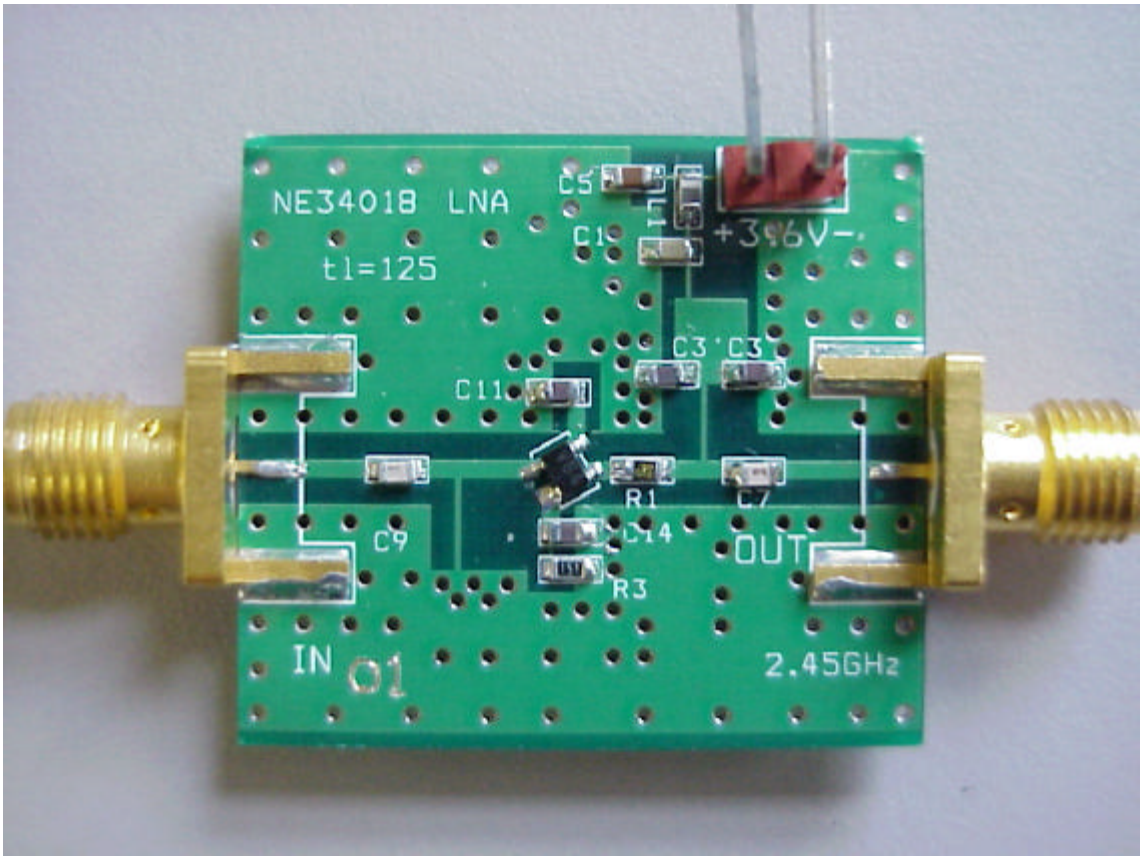

Figure 9-- LNA tl=125

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LNA tl=125 Component Values

113012 rev. 2 #01 LNA tl=125 Component values											
C9	C11	C14	R3	R1	C7	C3	C3'	L1	C1	C5	Q3
2.0pF ATC 600S	100pF muRata	100pF muRata	150 Ω	6.8 Ω	0.8pF ATC 600S	100pF muRata	100pF muRata	100uH Toko	22nF muRata	0.1uf muRata	NE34018 NEC

LNA tl=125 Transmission Line Dimensions

113012 rev. 2 #01 LNA tl=215 transmission lines (dimensions are inch mils							
t1l	tl2	tl3	tl4	tl5	tl6	tl7	tl8
30x125	12x145	12x125	30x75	30x60	30x50	30x50	30x75

Transmission line dimensions are taken from end of an element to the end or corner of adjoining element with the following exceptions:

- Transmission line tl1 dimension is taken from the edge of tl2 to the center of the gate pad.
- Transmission lines tl6 and tl7 dimensions are taken from the center of the source pads to the center of the bypass capacitor pads.

LNA tl=125 Measured Performance

113012 rev. 2 tl=125	**2400MHz**	**2450MHz**	**2500MHz**	**Goal**	**Units**
Gain	14.16	14.04	13.90	14±1	dB
Input Return Loss	-11.97	-13.18	-14.49	<-14	dB
Input VSWR	1.67	1.52	1.46	<1.5:1	-
Output Return Loss	-15.66	-23.12	-32.66	<-10	dB
Output VSWR	1.39	1.15	1.05	<2.0:1	-
Noise Figure	0.7	0.7	0.7	<1.5	dB
Output P1dB	5.2	5,5	5.8	>0	dBm
Output IP3	16	17	17	>15	dBm
Current at 3.3Vdc	5.11	5.11	5.11	<6.0	mA

- Gain and return losses are measured using an Agilent 8714C network analyzer. Measurement power to the LNA is set to –16dBm with a 6dB input pad. The LNA output (network analyzer input) also has a 10dB pad in order to minimize measurement error due to port reflections.
- The output IP3 intermodulation distortion is measured using an Agilent 8595E spectrum analyzer. The LNA is driven with two tones each at –20dBm separated by 2MHz supplied by Agilent E4432B signal generator with 1MHz I/Q modulation supplied by a second Agilent E4432B signal generator. The input level is adjusted to –20dBm using an Agilent 8494B and 8496B step attenuator set.
- OutputP1dB is measured with the Agilent 8714C network analyzer using the swept power function. A 6dB pad is used on the LNA input port and a 10dB pad is used on the LNA output port.
- Noise figure is measured using the Noise Com Inc. NC346B noise source in a Y-Factor measurement. The system noise figure is 1.5dB established by an AML Corp. balance amplifier with 1.3dB noise figure, 14dB gain, 1.05:1 input VSWR, followed by Down East Microwave 13LNA20WP amplifier with 1.5dB noise figure, 22dB gain, 1.5:1 input VSWR. The Agilent 8595E was used to measure the Y-Factor.

LNA tl=125 Input VSWR is less that 1.67:1, just slightly above the desired 1.5:1. This amplifier topology and layout dimensions are adequate for the LNA application.

LNA tl=125 Performance Plots

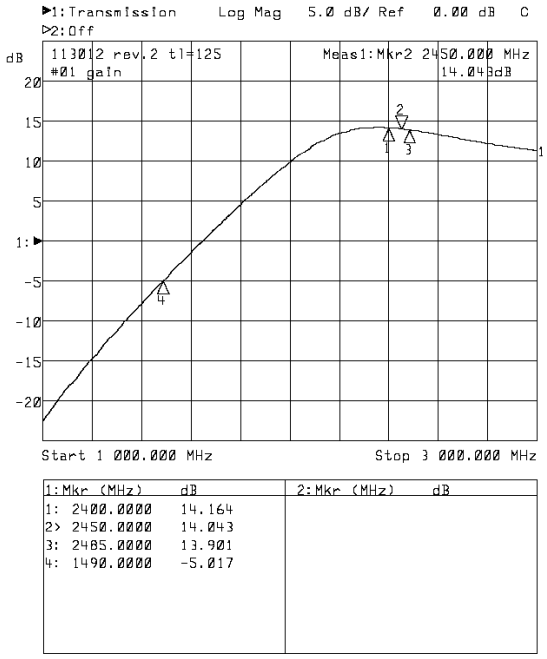

Figure 10-- LNA tl=125 Gain

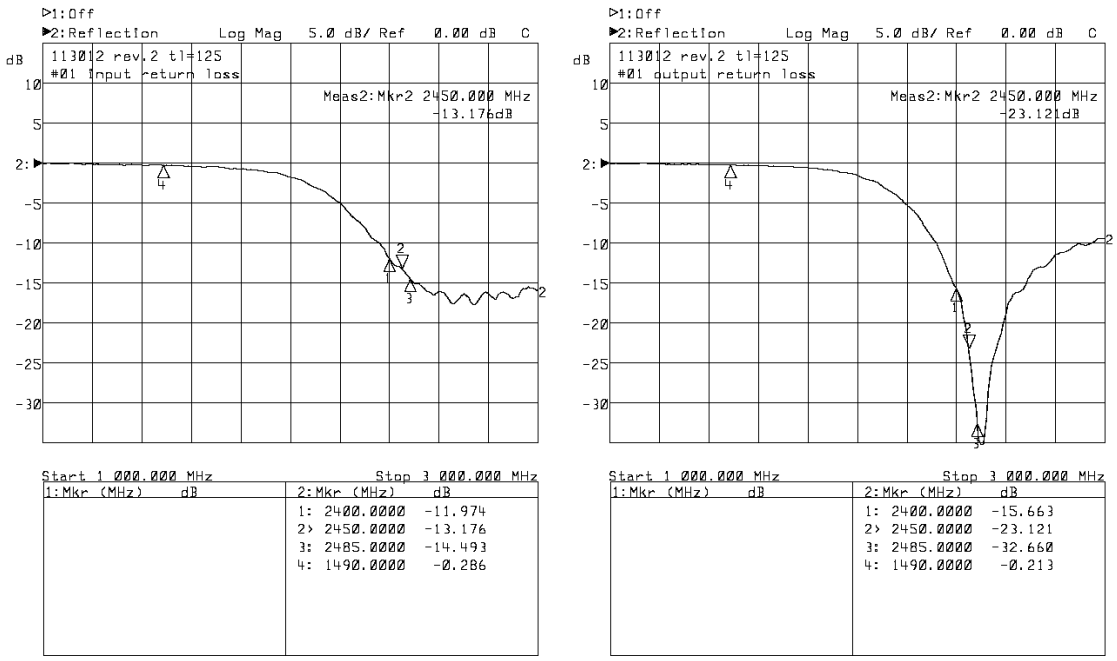

Figure 11-- LNA tl=125 Input and Output return loss