



# Low-Noise, High-Linearity Broadband Amplifier

MAX3524

## General Description

The MAX3524 broadband amplifier is designed specifically for cable television receiver and cable modem applications. The MAX3524 is a single-ended input, differential-output low-noise amplifier (LNA) that offers 15dB of gain. It operates from a +4.75V to +5.25V single supply from 44MHz to 880MHz. The MAX3524 includes an operational amplifier that is used to control an off-chip PIN attenuator circuit at the input of the LNA. The attenuator is typically used to regulate the input signal to a value that maintains high linearity for large signals. The MAX3524 is available in a 10-pin  $\mu$ MAX<sup>®</sup> package with an exposed paddle (EP) and operates in the extended temperature range (-40°C to +85°C).

## Features

- ◆ Single-Ended Input, Differential Output
- ◆ +4.75V to +5.25V Single-Supply Operation
- ◆ Broadband Operation: 44MHz to 880MHz
- ◆ Low Noise Figure: 4.2dB
- ◆ High Linearity: IIP2 (42dBm), IIP3(14dBm)
- ◆ Voltage Gain: 15dB
- ◆ Independent On-Chip Op Amp

## Applications

Cable Modems  
Cable Set-Top Boxes  
Broadband Amplifiers  
CATV Infrastructures

## Ordering Information

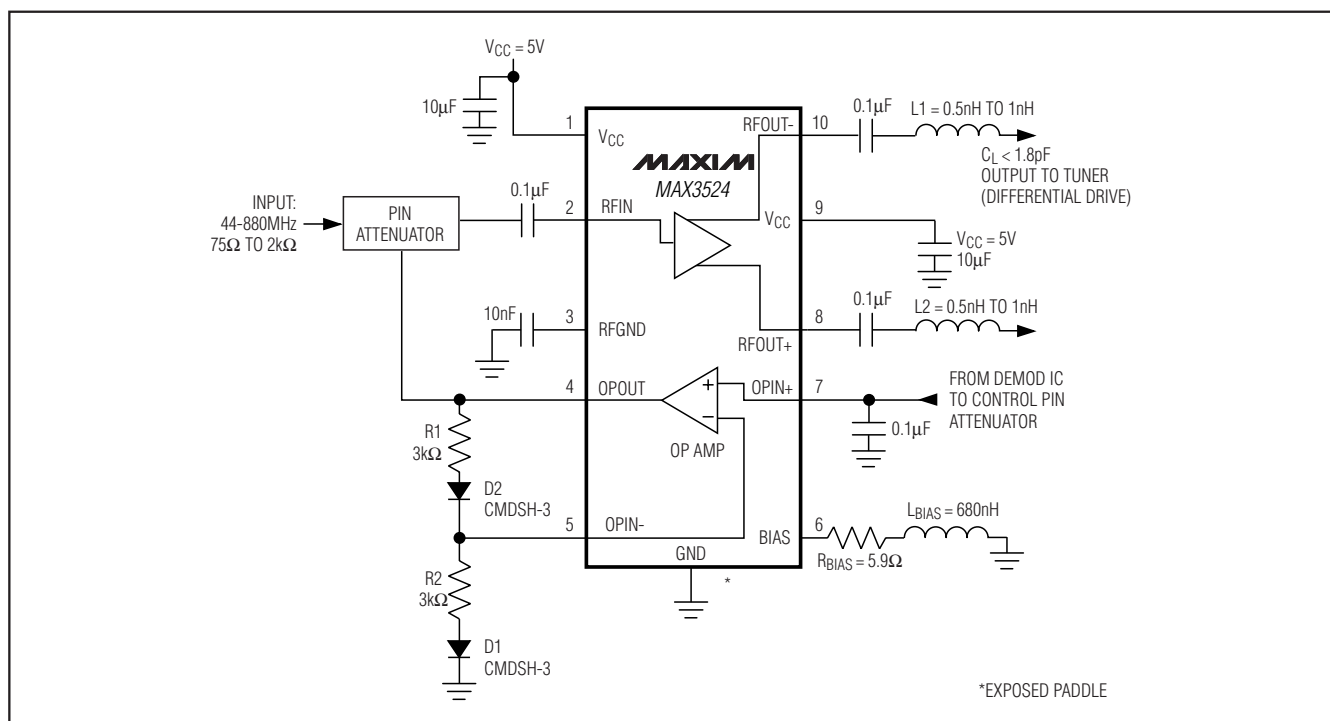
| PART        | TEMP RANGE     | PIN-PACKAGE      |
|-------------|----------------|------------------|
| MAX3524EVB  | -40°C to +85°C | 10 $\mu$ MAX-EP* |
| MAX3524EVB+ | -40°C to +85°C | 10 $\mu$ MAX-EP* |

\*EP = Exposed paddle.

+Denotes lead-free package.

$\mu$ MAX is a registered trademark of Maxim Integrated Products, Inc.

## Typical Application Circuit



Pin Configuration appears at end of data sheet.



Maxim Integrated Products 1

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at [www.maxim-ic.com](http://www.maxim-ic.com).

# Low-Noise, High-Linearity Broadband Amplifier

## ABSOLUTE MAXIMUM RATINGS

V<sub>CC</sub> to GND .....-0.3V to +7.0V  
 RFIN .....+2.0V  
 PRFIN .....0dBm  
 R<sub>BIAS</sub> (MINIMUM).....5Ω  
 RFOUT+, RFOUT-, OPIN-, OPIN+, OPOUT...-0.3V to (V<sub>CC</sub> + 0.3V)  
 RFOUT+, RFOUT- Short-Circuit Duration ..... 10s

Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
 10-Pin μMAX (derate 10.3mW/°C above +70°C) .....825mW  
 Operating Temperature Range .....-40°C to +85°C  
 Storage Temperature Range .....-65°C to +150°C  
 Junction Temperature .....+150°C  
 Lead Temperature (soldering, 10s) .....+300°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.



**CAUTION!** ESD SENSITIVE DEVICE

## DC ELECTRICAL CHARACTERISTICS

(Typical Application Circuit, V<sub>CC</sub> = +4.75V to +5.25V, R<sub>BIAS</sub> = 5.9Ω, L<sub>BIAS</sub> = 680nH, T<sub>A</sub> = -40°C to +85°C, unless otherwise indicated. Typical values measured at V<sub>CC</sub> = +5.0V, T<sub>A</sub> = +25°C.) (Notes 1, 2)

| PARAMETERS                   | CONDITIONS            | MIN                   | TYP | MAX  | UNITS |
|------------------------------|-----------------------|-----------------------|-----|------|-------|
| <b>SUPPLY</b>                |                       |                       |     |      |       |
| Supply Voltage               |                       | 4.75                  |     | 5.25 | V     |
| Supply Current               |                       |                       | 85  | 95   | mA    |
| <b>OPERATIONAL AMPLIFIER</b> |                       |                       |     |      |       |
| Common-Mode Input Range      |                       | 0.5                   |     | 3.0  | V     |
| Maximum Output Voltage       | I <sub>O</sub> = 20mA | V <sub>CC</sub> - 0.5 |     |      | V     |
| Minimum Output Voltage       | I <sub>O</sub> = 20mA |                       |     | 0.5  | V     |

## AC ELECTRICAL CHARACTERISTICS

(MAX3524 EV kit as shown in Figure 1, V<sub>CC</sub> = +4.75V to +5.25V, PRFIN = -20dBm, Z<sub>S</sub> = 75Ω, R<sub>BIAS</sub> = 5.9Ω, L<sub>BIAS</sub> = 680nH, f<sub>IN</sub> = 44MHz, Z<sub>L</sub> = 50Ω || 2pF, T<sub>A</sub> = +25°C. Typical values are at V<sub>CC</sub> = +5V, unless otherwise indicated.) (Notes 2, 3)

| PARAMETERS                | CONDITIONS                      | MIN | TYP | MAX  | UNITS |
|---------------------------|---------------------------------|-----|-----|------|-------|
| Operating Frequency Range |                                 | 44  |     | 880  | MHz   |
| Power Gain (Note 4)       | T <sub>A</sub> = +25°C          | 8.0 | 9.8 | 11   | dB    |
|                           | T <sub>A</sub> = -40°C to +85°C | 7.6 |     | 11.5 |       |
| Voltage Gain (Note 5)     | R <sub>L</sub> = 3kΩ            |     | 15  |      | dB    |
| Noise Figure (Note 3)     | f <sub>RFIN</sub> = 300MHz      |     | 4.2 | 4.9  | dB    |
| IIP3 (Notes 3, 6)         |                                 | 12  | 14  |      | dBm   |
| IIP2 (Notes 3, 6)         |                                 | 40  | 42  |      | dBm   |
| Output-to-Input Isolation | f <sub>RFIN</sub> = 300MHz      | 40  | 60  |      | dB    |

**Note 1:** Parameters are production tested at T<sub>A</sub> = +25°C and T<sub>A</sub> = +85°C. Limits are guaranteed by design and characterization for T<sub>A</sub> = -40°C to +25°C.

**Note 2:** For optimum linearity, the DC resistance of L<sub>BIAS</sub> in series with R<sub>BIAS</sub> must be approximately 7.3Ω.

**Note 3:** Guaranteed by design and characterization.

**Note 4:** Gain is guaranteed over the operating frequency range, by design and characterization. Insertion loss of balun is subtracted. Production tested at 44MHz and 880MHz.

**Note 5:** Corresponding voltage gain at R<sub>L</sub> = 3kΩ, calculated as in Figure 2.

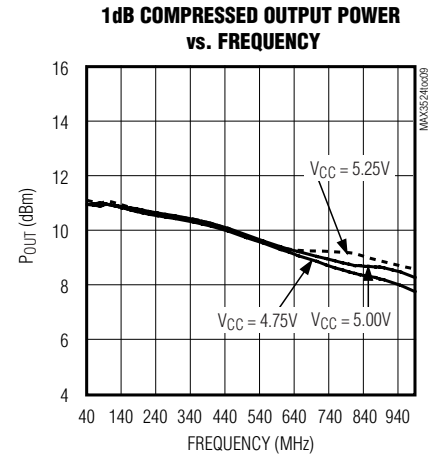
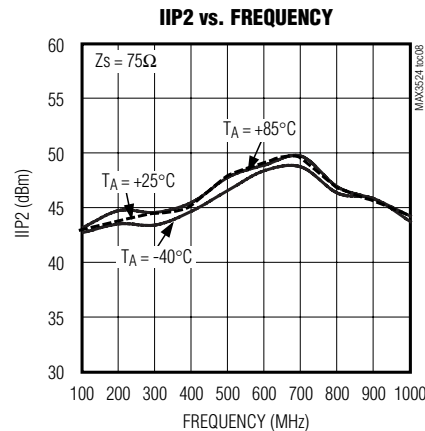
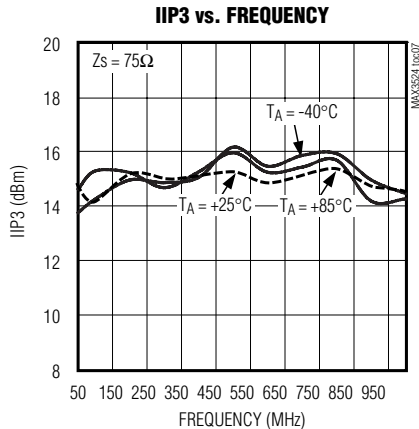
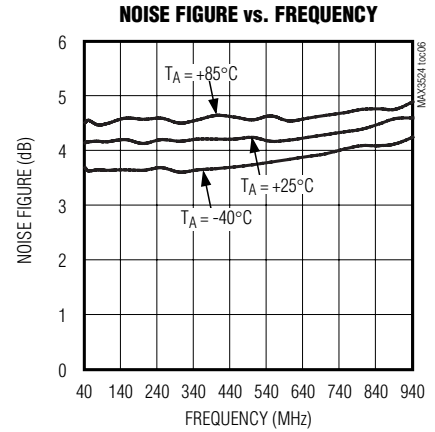
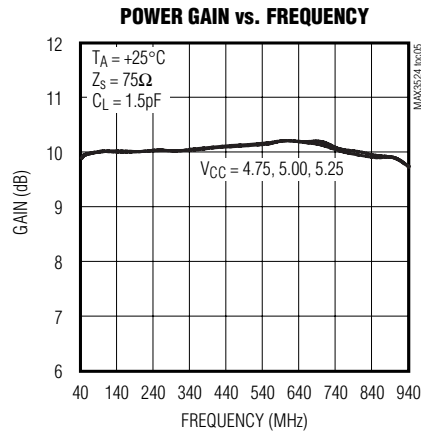
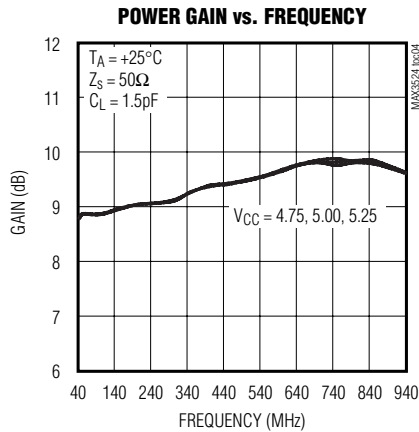
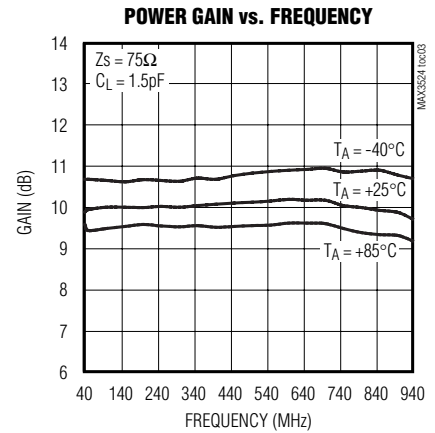
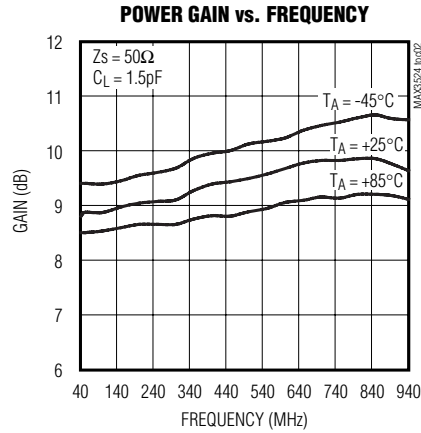
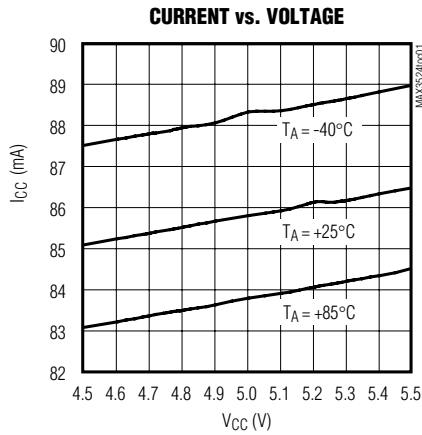
**Note 6:** Frequencies and input power levels: 275MHz, 325MHz, and -20dBm per tone.

# Low-Noise, High-Linearity Broadband Amplifier

## Typical Operating Characteristics

(MAX3524 EV kit as shown in Figure 1,  $V_{CC} = +5V$ ,  $P_{RFIN} = -20dBm$ ,  $Z_L = 50\Omega \parallel 2pF$ ,  $R_{BIAS} = 5.9\Omega$ ,  $L_{BIAS} = 680nH$ , insertion loss of balun subtracted,  $T_A = +25^\circ C$ .)

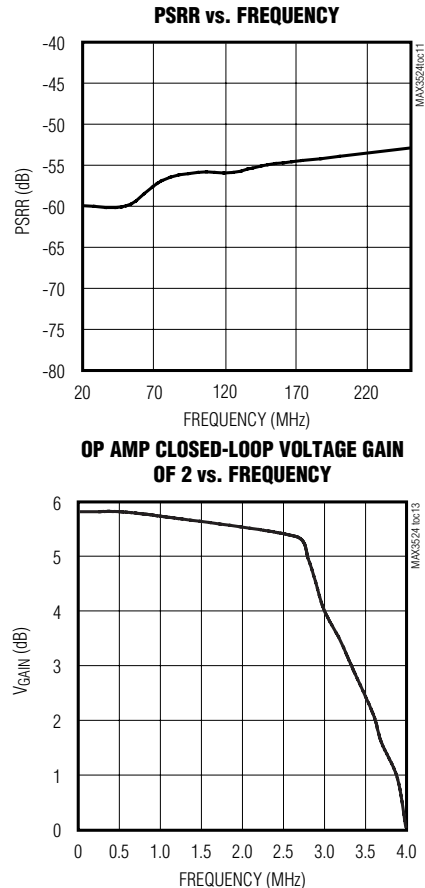
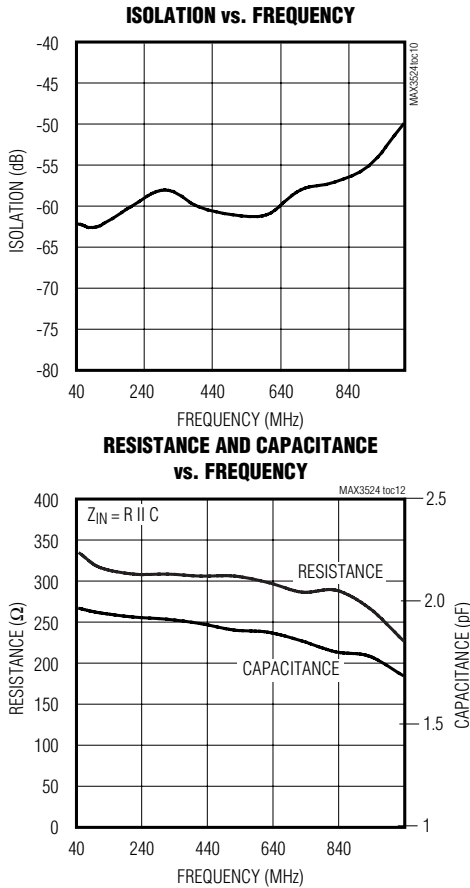
MAX3524



# Low-Noise, High-Linearity Broadband Amplifier

## Typical Operating Characteristics (continued)

(MAX3524 EV kit as shown in Figure 1,  $V_{CC} = +5V$ ,  $P_{RFIN} = -20dBm$ ,  $Z_L = 50\Omega \parallel 2pF$ ,  $R_{BIAS} = 5.9\Omega$ ,  $L_{BIAS} = 680nH$ , insertion loss of balun subtracted,  $T_A = +25^{\circ}C$ .)



## Pin Description

| PIN  | NAME     | FUNCTION                                                                                                                                                                                                                                                                                           |
|------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1, 9 | $V_{CC}$ | Supply Voltage Input. Connect both pins together. Bypass with a $10\mu F$ and $47pF$ capacitor to GND.                                                                                                                                                                                             |
| 2    | RFIN     | RF Input of LNA. Requires DC blocking capacitor.                                                                                                                                                                                                                                                   |
| 3    | RFGND    | Bypass to GND through $10nF$ capacitor.                                                                                                                                                                                                                                                            |
| 4    | OPOUT    | Operational Amplifier Output                                                                                                                                                                                                                                                                       |
| 5    | OPIN-    | Inverting Input of Operational Amplifier                                                                                                                                                                                                                                                           |
| 6    | BIAS     | LNA Bias Setting Pin. For nominal bias, connect $5.9\Omega$ resistor in series with $680nH$ to GND (total DC resistance = resistance of $R_{BIAS}$ + DC resistance of the inductor = $7.3\Omega$ ). The value of the resistor is adjusted to alter the current and therefore linearity of the LNA. |
| 7    | OPIN+    | Noninverting Input of Operational Amplifier                                                                                                                                                                                                                                                        |
| 8    | RFOUT-   | Inverting Output of LNA                                                                                                                                                                                                                                                                            |
| 10   | RFOUT+   | Noninverting Output of LNA                                                                                                                                                                                                                                                                         |
| Slug | GND      | Ground                                                                                                                                                                                                                                                                                             |

# Low-Noise, High-Linearity Broadband Amplifier

## Detailed Description

The MAX3524 is a broadband amplifier with a single-ended input and differential outputs, including an operational amplifier that can be used to control an external attenuator circuit. Figure 1 is the MAX3524 EV kit schematic.

## Low-Noise Amplifier

The low-noise amplifier operates from 44MHz to 880MHz and is designed specifically for cable TV and cable modem applications. The LNA provides 15dB of insertion voltage gain (see Figure 2) when driving a

3k $\Omega$  load. At 300MHz, the noise figure is 4.2dB, IIP2 and IIP3 are 42dBm and 14dBm, respectively.

## Operational Amplifier

The operational amplifier is suitable for interfacing to a PIN attenuator circuit which is typically employed at the input of the LNA. The common-mode input range is 0.5V to 3V and the output voltage swing is 0.5V to  $V_{CC} - 0.5V$  while sinking or sourcing 20mA. Input bias current and input offset voltage are 1 $\mu$ A and 1mV, respectively. The open-loop voltage gain is greater than 10,000. The gain bandwidth product is greater than 1MHz for a closed-loop voltage gain of one.

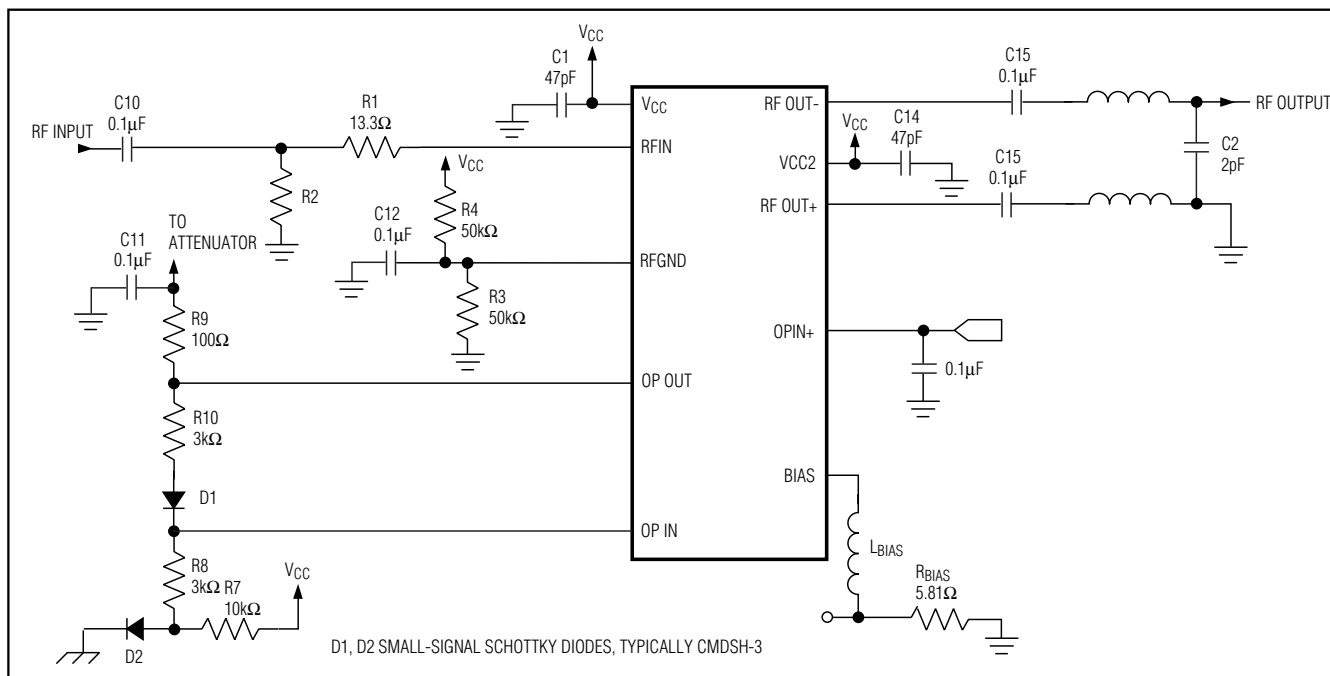


Figure 1. MAX3524 EV Kit Schematic

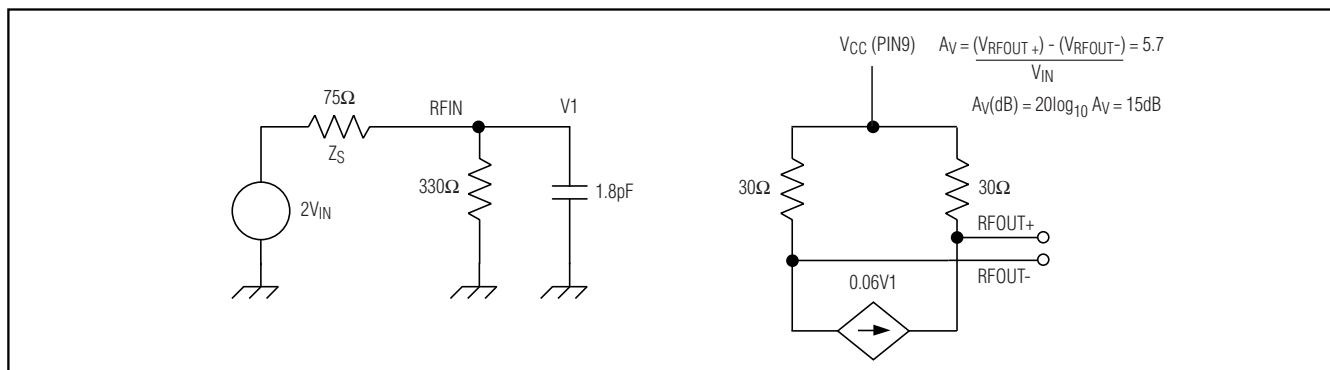


Figure 2. LNA Equivalent Circuit and Open-Circuit Voltage Gain Calculation

# Low-Noise, High-Linearity Broadband Amplifier

**Table 1. Shunt-Resistor Noise-Figure Values**

| R <sub>SHUNT</sub> (Ω) | S <sub>11</sub>   (LNA) (dB) | NOISE FIGURE (dB) |
|------------------------|------------------------------|-------------------|
| 450                    | -6                           | 5 to 5.5          |
| 250                    | -8                           | 5.5 to 6          |
| 125                    | -10                          | 6 to 6.5          |

## Applications Information

### Bias Current

The resistor, R<sub>BIAS</sub>, connected between BIAS and GND controls the LNA current. To make the current insensitive to temperature fluctuations, select a 1%, low temperature coefficient resistor for R<sub>BIAS</sub>. The current drawn by the LNA is calculated using the following formula:

$$I_{BIAS} \approx 0.58V / (R_{BIAS} + \text{DC resistance of } L_{BIAS})$$

It is important to include the inductor resistance in the above equation as it is typically 1Ω to 2Ω. The MAX3524 EV kit uses a nominal inductor with DC resistance of 1.4Ω. Higher values of R<sub>BIAS</sub> may be used to reduce supply current predominantly at the expense of linearity. Circuit board layout and source impedance may require the value of I<sub>BIAS</sub> to be optimized for best linearity.

### Input and Output

The LNA input is single-ended. The RF input signal is coupled to RFIN through a DC blocking capacitor. The LNA outputs drive a differential load, such as a mixer, through DC blocking capacitors. The equivalent input LNA impedance is 330Ω resistive in parallel with 1.8pf, as shown in Figure 2. The approximate equivalent differential output impedance of the LNA is 60Ω. To achieve S<sub>11</sub> less than -6dB, an insertion loss of greater than 1dB must exist between the cable input and MAX3524. This loss typically comes from a diplexer and PIN attenuator in a cable modem application. A shunt resistor may be added at the input of the LNA to improve the return loss (S<sub>11</sub>). Typically the return loss of the system is 2dB better, as explained above. The S<sub>11</sub> and noise-figure values for different shunt resistors are given in Table 1.

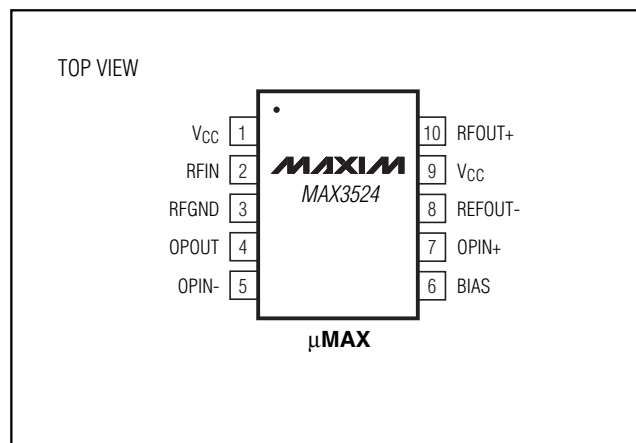
### RF Input Power Control Using the Operational Amplifier

In a cable system, the power level at the LNA input is typically restricted to a maximum value to maintain linearity. This is accomplished by connecting a variable attenuator at the input of the LNA and varying the attenuation with the operational amplifier output. The operational amplifier receives a DC control input that is proportional to LNA output power. See *Typical Application Circuit*.

### Layout Issues

A properly designed PC board is essential to any RF/microwave circuit. Use short interconnect and controlled impedance lines on all high-frequency inputs and outputs. Use low inductance connections to ground on all GND nodes and place decoupling capacitors close to all V<sub>CC</sub> connections. The EP is the ground for the MAX3524 and must be soldered to ground for proper operation.

## Pin Configuration



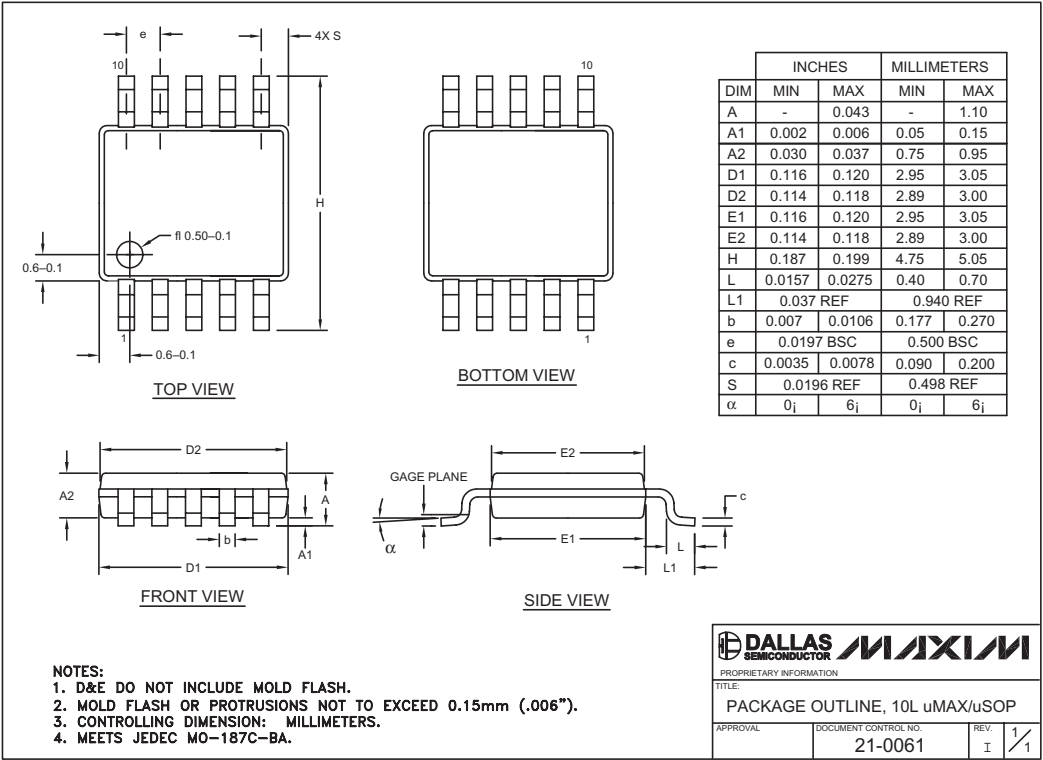
## Chip Information

TRANSISTOR COUNT: 550

# Low-Noise, High-Linearity Broadband Amplifier

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600 7