

# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### General Description

The MAX2686L/MAX2693L low-noise amplifiers (LNAs) are designed for GPS L1, Galileo, and GLONASS applications. Designed in Maxim's advanced SiGe process, the devices achieve high gain and low noise figure while maximizing the input-referred 1dB compression point and the 3rd-order intercept point. Both devices include an internal LDO ideal for battery-powered applications. For current-sensitive applications, the MAX2693L achieves excellent performance while consuming only 1.8mA current.

The devices operate from a +1.6V to +4.2V single supply. The shutdown feature reduces the supply current to less than 20μA. The devices are available in a very small, lead-free, RoHS-compliant, 0.86mm x 0.86mm x 0.65mm wafer-level package (WLP).

### Applications

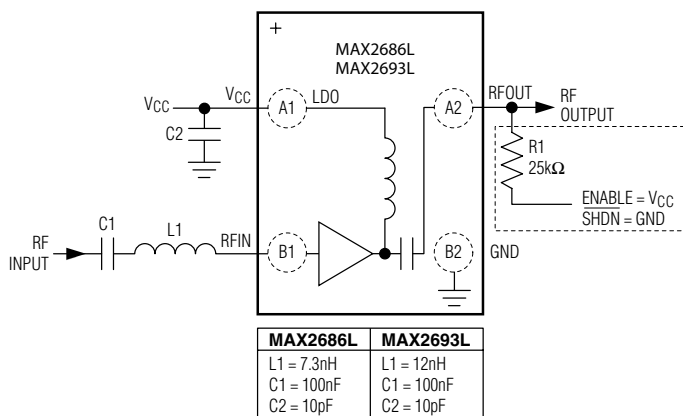
Telematics (Asset Tracking and Management)  
Cellular Phones with GPS  
Notebook PCs/Ultra-Mobile PCs  
Recreational, Marine Navigation  
Watches  
Digital Cameras

### Features

- ◆ High Power Gain: 19dB (MAX2686L)
- ◆ Low Noise Figure: 0.88dB (MAX2686L)
- ◆ Integrated 50Ω Output Matching Circuit
- ◆ Low Supply Current: 1.8mA (MAX2693L)
- ◆ Wide Supply Voltage Range: 1.6V to 4.2V
- ◆ Low Bill of Materials: One Inductor, Two Capacitors
- ◆ Small Footprint: 0.86mm x 0.86mm
- ◆ 0.4mm Pitch WLP

[Ordering Information](#) appears at end of data sheet.

### Typical Operating Circuit



# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### ABSOLUTE MAXIMUM RATINGS

V<sub>CC</sub> to GND ..... -0.3V to +4.2V  
 Other Pins to GND ..... -0.3V to (+ Operating V<sub>CC</sub> + 0.3V)  
 Maximum RF Input Power ..... +5dBm  
 Continuous Power Dissipation (T<sub>A</sub> = +70°C)  
     WLP (derates 9.7mW/°C above +70°C) ..... 776mW

Maximum Current into RF Input ..... 10mA  
 Operating Temperature Range ..... -40°C to +85°C  
 Junction Temperature ..... +150°C  
 Storage Temperature Range ..... -65°C to +160°C  
 Soldering Temperature (reflow) (Note 1) ..... +260°C

**Note 1:** Refer to Application Note 1891: *Wafer-Level Packaging (WLP) and Its Applications*.



**CAUTION!** ESD SENSITIVE DEVICE

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.

### DC ELECTRICAL CHARACTERISTICS

(MAX2686L/MAX2693L EV kit, V<sub>CC</sub> = 1.6V to 4.2V, T<sub>A</sub> = -40°C to +85°C, no RF signals are applied. Typical values are at V<sub>CC</sub> = 3.3V and T<sub>A</sub> = +25°C, unless otherwise noted.) (Note 2)

| PARAMETER                | CONDITIONS                                              |          | MIN  | TYP | MAX | UNITS         |
|--------------------------|---------------------------------------------------------|----------|------|-----|-----|---------------|
| Supply Voltage           |                                                         |          | 1.6  | 3.3 | 4.2 | V             |
| Supply Current           | $\overline{\text{SHDN}}$ = high                         | MAX2686L | 5    |     |     | mA            |
|                          |                                                         | MAX2693L | 1.8  |     |     |               |
|                          | Shutdown mode, $V_{\overline{\text{SHDN}}} = 0\text{V}$ |          | 20   |     |     | $\mu\text{A}$ |
| Digital Input Logic-High | (Note 3)                                                |          | 1.2  |     |     | V             |
| Digital Input Logic-Low  | (Note 3)                                                |          | 0.45 |     |     | V             |

### AC ELECTRICAL CHARACTERISTICS

(MAX2686L/MAX2693L EV kit, V<sub>CC</sub> = 1.6V to 4.2V, T<sub>A</sub> = -40°C to +85°C, f<sub>RFIN</sub> = 1575.42MHz. Typical values are at V<sub>CC</sub> = 3.3V and T<sub>A</sub> = +25°C, unless otherwise noted.) (Note 2)

| PARAMETER                                   | CONDITIONS                      |          | MIN     | TYP  | MAX | UNITS |
|---------------------------------------------|---------------------------------|----------|---------|------|-----|-------|
| RF Frequency                                | L1 band                         |          | 1575.42 |      |     | MHz   |
| Power Gain                                  | V <sub>CC</sub> = 4.2V (Note 4) | MAX2686L | 14.65   | 19.0 |     | dB    |
|                                             |                                 | MAX2693L | 11.6    | 18.4 |     |       |
|                                             | V <sub>CC</sub> = 1.6V          | MAX2686L | 14.85   | 19.1 |     |       |
|                                             |                                 | MAX2693L | 11.6    | 18.7 |     |       |
| Noise Figure                                | V <sub>CC</sub> = 1.6V to 4.2V  | MAX2686L | 0.88    |      |     | dB    |
|                                             |                                 | MAX2693L | 1.05    |      |     |       |
| In-Band 3rd-Order Input Intercept Point     | (Note 5)                        | MAX2686L | -4.1    |      |     | dBm   |
|                                             |                                 | MAX2693L | -14.3   |      |     |       |
| Out-of-Band 3rd-Order Input Intercept Point | (Note 6)                        | MAX2686L | -0.1    |      |     | dBm   |
|                                             |                                 | MAX2693L | -13.9   |      |     |       |
| Input 1dB Compression Point                 | (Note 7)                        | MAX2686L | -12.1   |      |     | dBm   |
|                                             |                                 | MAX2693L | -11.0   |      |     |       |
| Input Return Loss                           | MAX2686L                        |          | 11.2    |      |     | dB    |
|                                             | MAX2693L                        |          | 10.7    |      |     |       |

# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### AC ELECTRICAL CHARACTERISTICS (continued)

(MAX2686L/MAX2693L EV kit,  $V_{CC} = 1.6V$  to  $4.2V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ ,  $f_{RFIN} = 1575.42MHz$ . Typical values are at  $V_{CC} = 3.3V$  and  $T_A = +25^{\circ}C$ , unless otherwise noted.) (Note 2)

| PARAMETER          | CONDITIONS | MIN | TYP  | MAX | UNITS |
|--------------------|------------|-----|------|-----|-------|
| Output Return Loss | MAX2686L   |     | 22.0 |     | dB    |
|                    | MAX2693L   |     | 14.3 |     |       |
| Reverse Isolation  | MAX2686L   |     | 41.0 |     | dB    |
|                    | MAX2693L   |     | 40.0 |     |       |

**Note 2:** Min and max limits guaranteed by test at  $T_A = +25^{\circ}C$  and guaranteed by design and characterization at  $T_A = -40^{\circ}C$  and  $T_A = +85^{\circ}C$ , unless otherwise noted.

**Note 3:** Min and max limits guaranteed by test at  $T_A = +25^{\circ}C$ .

**Note 4:** Min limit guaranteed by design and characterization.

**Note 5:** Measured with the two tones located at 1MHz and 2MHz offset from the center of the GPS band with -30dBm/tone.

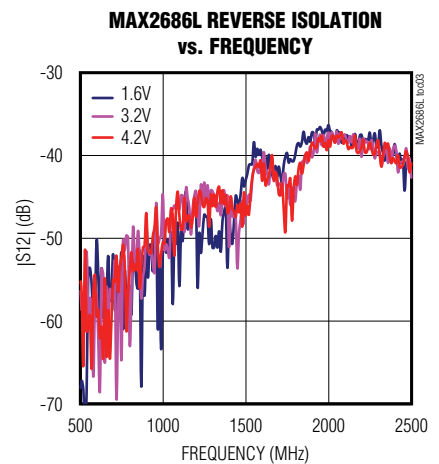
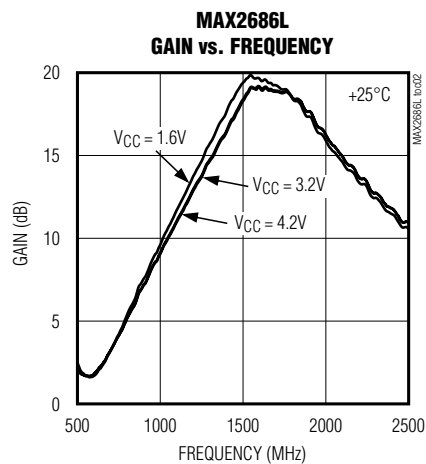
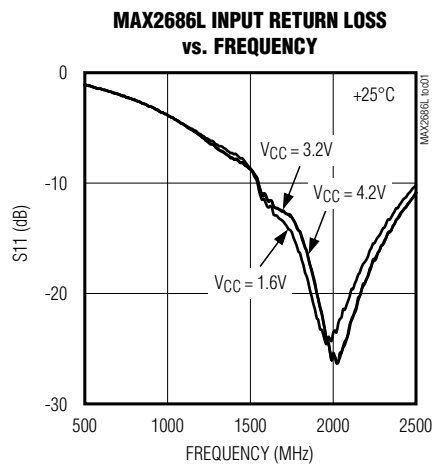
**Note 6:** Measured with input tones at 1713MHz (-27dBm) and 1851MHz (-39dBm).

**Note 7:** Measured with a tone located at the center of the GPS band.

### Typical Operating Characteristics

(MAX2686L/MAX2693L EV kit. Typical values are at  $V_{CC} = 3.3V$ ,  $T_A = +25^{\circ}C$ , and  $f_{RFIN} = 1575.42MHz$ , unless otherwise noted.)

#### MAX2686L



# MAX2686L/MAX2693L

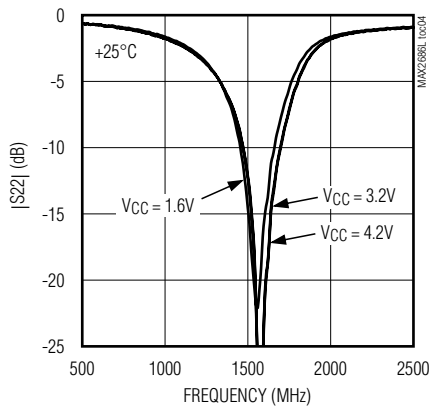
## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### Typical Operating Characteristics (continued)

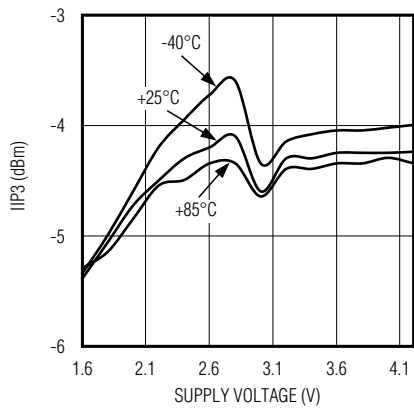
(MAX2686L/MAX2693L EV kit. Typical values are at  $V_{CC} = 2.85V$ ,  $T_A = +25^\circ C$ , and  $f_{RFIN} = 1575.42MHz$ , unless otherwise noted.)

#### MAX2686L

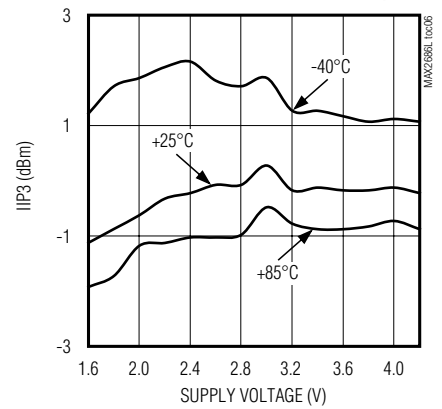
**MAX2686L OUTPUT RETURN LOSS vs. FREQUENCY**



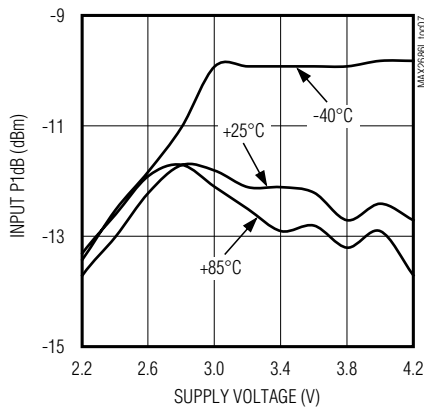
**MAX2686L IN-BAND IIP3 vs. SUPPLY VOLTAGE AND TEMPERATURE (TWO TONES LOCATED AT 1MHz AND 2MHz OFFSET WITH -30dBm/TONE)**



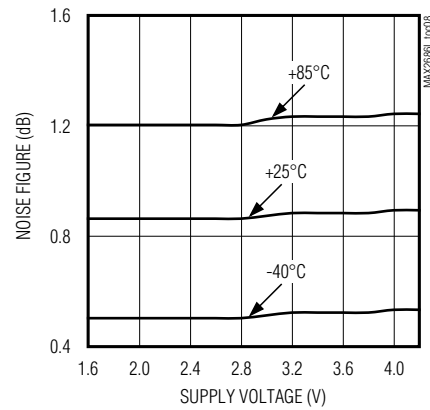
**MAX2686L OUT-OF-BAND IIP3 vs. SUPPLY VOLTAGE AND TEMPERATURE (TONE 1 AT 1713MHz, -27dBm; TONE 2 AT 1851MHz, -39dBm)**



**MAX2686L INPUT P1dB COMPRESSION vs. SUPPLY VOLTAGE AND TEMPERATURE**



**MAX2686L NOISE FIGURE vs. SUPPLY VOLTAGE AND TEMPERATURE**



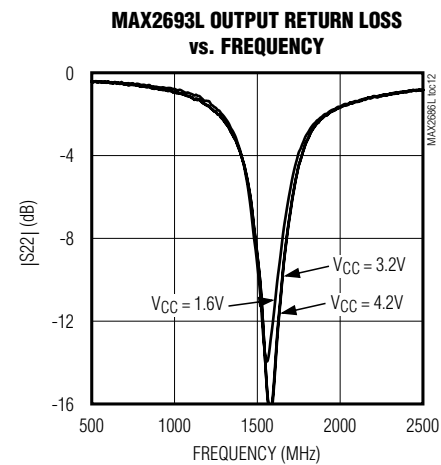
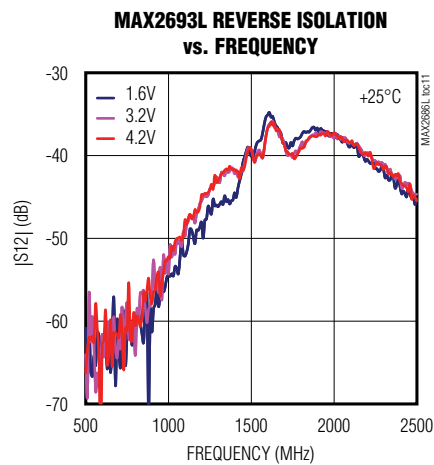
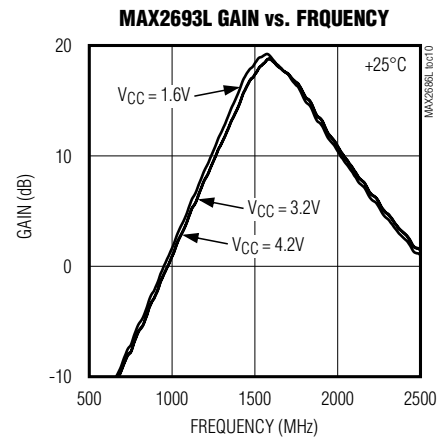
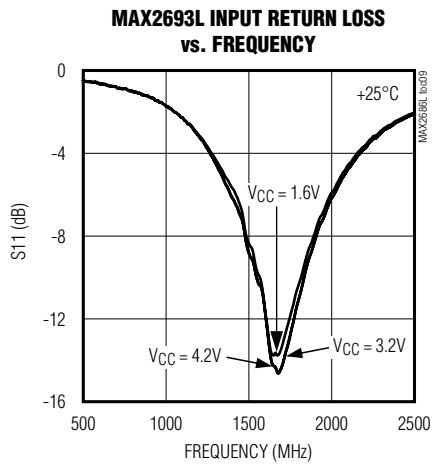
# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### Typical Operating Characteristics (continued)

(MAX2686L/MAX2693L EV kit. Typical values are at  $V_{CC} = 2.85V$ ,  $T_A = +25^\circ C$ , and  $f_{RFIN} = 1575.42MHz$ , unless otherwise noted.)

#### MAX2693L



# MAX2686L/MAX2693L

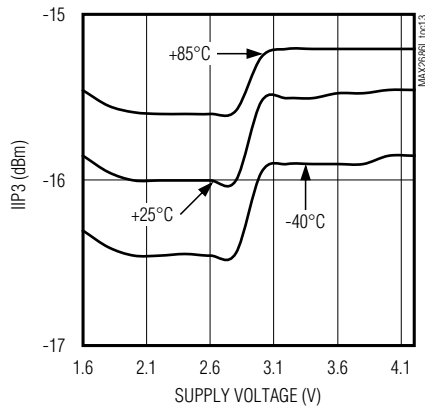
## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### Typical Operating Characteristics (continued)

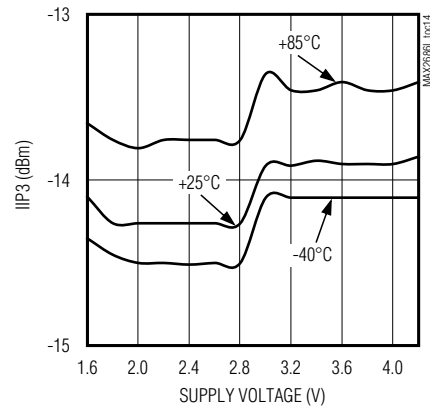
(MAX2686L/MAX2693L EV kit. Typical values are at  $V_{CC} = 2.85V$ ,  $T_A = +25^\circ C$ , and  $f_{RFIN} = 1575.42MHz$ , unless otherwise noted.)

#### MAX2693L

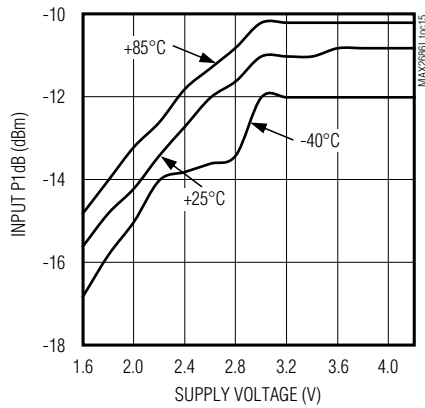
**MAX2693L IN-BAND IIP3 vs. SUPPLY VOLTAGE AND TEMPERATURE**  
(TWO TONES LOCATED AT 1MHz AND 2MHz OFFSET WITH -30dBm/TONE)



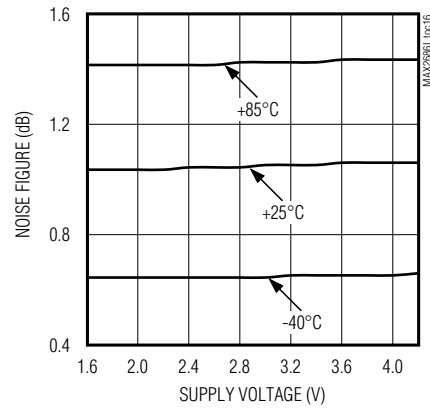
**MAX2693L OUT-OF-BAND IIP3 vs. SUPPLY VOLTAGE AND TEMPERATURE**  
(TONE 1 AT 1713MHz, -27dBm; TONE 2 AT 1851MHz, -39dBm)



**MAX2693L INPUT P1dB COMPRESSION vs. SUPPLY VOLTAGE AND TEMPERATURE**



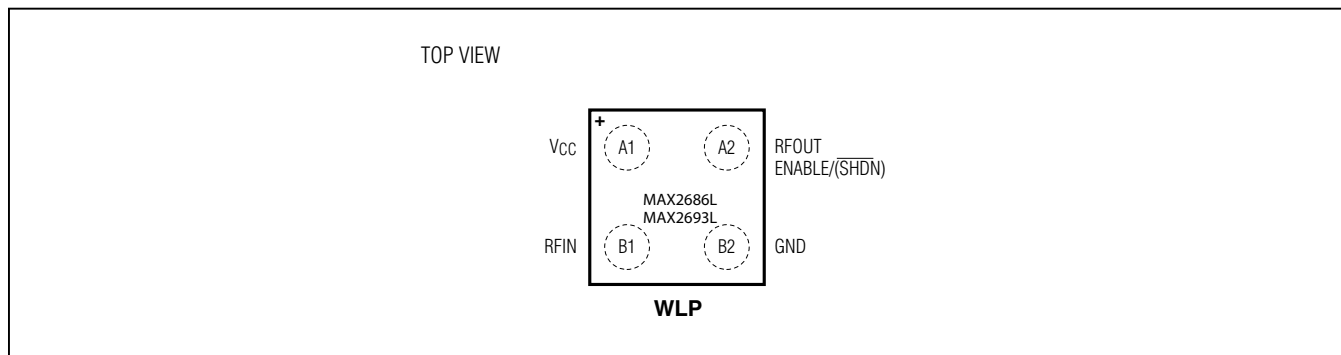
**MAX2693L NOISE FIGURE vs. SUPPLY VOLTAGE AND TEMPERATURE**



# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### Bump Configuration



### Bump Description

| BUMP | NAME                   | FUNCTION                                                                                                                                                                                        |
|------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A1   | VCC                    | Supply Voltage. Bypass to ground with a 10pF capacitor as close as possible to the IC.                                                                                                          |
| A2   | RFOUT<br>ENABLE/(SHDN) | RF Output. RFOUT is internally matched to 50Ω. Pulling the DC high through the 25kΩ resistor enables the IC. RFOUT(SHDN) can be pulled to a DC low through a 25kΩ resistor to shut down the IC. |
| B1   | RFIN                   | RF Input. Requires a DC-blocking capacitor and external matching components.                                                                                                                    |
| B2   | GND                    | Ground. Connect to the PCB ground plane.                                                                                                                                                        |

### Detailed Description

The MAX2686L/MAX2693L are LNAs designed for GPS L1, Galileo, and GLONASS applications. The devices feature an optional power-shutdown control mode to eliminate the need for an external supply switch. The devices achieve high gain and low noise figure in an ultra-small package ideal for space-sensitive applications. These integrated ICs eliminate the need for an external LDO.

#### Input and Output Matching

The devices require an off-chip input matching. Only an inductor in series with a DC-blocking capacitor is needed to form the input matching circuit. The [Typical Operating Circuit](#) shows the recommended input-matching network. These values are optimized for the best simultaneous gain, noise figure, and return loss performance. The value of the input coupling capacitor affects IIP3. A smaller coupling capacitor results in lower IIP3. The

devices integrate an on-chip output matching to 50Ω at the output, eliminating the need for external matching components. [Table 1](#) and [Table 2](#) list typical device S parameters and K<sub>f</sub> values. Typical noise parameters are shown in [Table 3](#) and [Table 4](#).

#### ENABLE/(SHDN)

The devices include a shutdown feature to turn off the entire chip. The devices are placed in active mode by default once VCC is applied, due to the off-chip pullup resistor to VCC at the RFOUT bump. To shut down the part, apply a logic-low to the RFOUT bump through an external resistor with an adequate value, e.g., 25kΩ, in order not to load the RF output signal during active operation.

To enable the part, apply a logic-high to the RFOUT bump through the external 25kΩ resistor.

# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

**Table 1. MAX2686L Typical S Parameter Values and K-Factor**

| FREQ (MHz) | S11 MAG (dB) | S11 PHASE (DEGREES) | S21 MAG (dB) | S21 PHASE (DEGREES) | S12 MAG (dB) | S12 PHASE (DEGREES) | S22 MAG (dB) | S22 PHASE (DEGREES) | K <sub>f</sub> |
|------------|--------------|---------------------|--------------|---------------------|--------------|---------------------|--------------|---------------------|----------------|
| 1000       | -2.7         | -88.3               | 7.9          | 162.0               | -56.7        | 101.9               | -1.9         | -153.8              | 16.1           |
| 1100       | -2.9         | -95.0               | 9.6          | 150.5               | -48.5        | 57.5                | -2.4         | -169.9              | 9.8            |
| 1200       | -3.2         | -101.7              | 11.2         | 136.9               | -45.5        | 64.8                | -3.1         | 172.8               | 7.4            |
| 1300       | -3.4         | -107.4              | 12.8         | 122.2               | -49.2        | 51.0                | -4.4         | 153.8               | 6.6            |
| 1400       | -3.5         | -113.3              | 14.4         | 104.8               | -47.4        | 1.8                 | -6.8         | 132.5               | 6.9            |
| 1500       | -3.3         | -120.2              | 16.0         | 85.4                | -50.7        | 19.3                | -11.9        | 102.3               | 7.8            |
| 1575       | -3.5         | -125.7              | 16.8         | 66.9                | -44.6        | 29.9                | -26.0        | 46.7                | 5.9            |
| 1600       | -3.7         | -126.8              | 16.8         | 58.4                | -43.4        | 15.5                | -24.3        | -79.5               | 5.1            |
| 1700       | -3.6         | -131.1              | 16.5         | 34.7                | -49.8        | -7.5                | -10.1        | -125.4              | 6.5            |
| 1800       | -3.5         | -139.0              | 16.1         | 12.9                | -51.0        | 39.5                | -5.4         | -148.1              | 4.0            |
| 1900       | -3.7         | -146.3              | 15.2         | -7.7                | -41.9        | 7.5                 | -3.0         | -169.7              | 2.2            |
| 2000       | -4.0         | -152.0              | 13.8         | -24.4               | -41.8        | -10.7               | -1.9         | 170.5               | 2.0            |

**Table 2. MAX2693L Typical S Parameter Values and K-Factor**

| FREQ (MHz) | S11 MAG (dB) | S11 PHASE (DEGREES) | S21 MAG (dB) | S21 PHASE (DEGREES) | S12 MAG (dB) | S12 PHASE (DEGREES) | S22 MAG (dB) | S22 PHASE (DEGREES) | K <sub>f</sub> |
|------------|--------------|---------------------|--------------|---------------------|--------------|---------------------|--------------|---------------------|----------------|
| 1000       | -1.0         | -77.4               | -2.5         | -148.6              | -55.5        | 78.6                | -0.9         | -138.2              | 16.1           |
| 1100       | -1.1         | -84.8               | 0.1          | -159.7              | -51.0        | 85.5                | -1.2         | -154.2              | 9.8            |
| 1200       | -1.2         | -92.5               | 2.7          | -172.2              | -48.0        | 70.0                | -1.6         | -172.0              | 7.4            |
| 1300       | -1.3         | -99.4               | 5.6          | 171.7               | -46.4        | 56.0                | -2.3         | 167.2               | 6.6            |
| 1400       | -1.5         | -106.5              | 8.4          | 152.1               | -45.9        | 35.6                | -3.8         | 140.1               | 6.9            |
| 1500       | -1.6         | -113.2              | 11.0         | 124.7               | -46.3        | 22.2                | -8.0         | 96.8                | 7.8            |
| 1575       | -1.6         | -118.5              | 12.2         | 99.5                | -44.0        | 38.3                | -14.8        | 23.5                | 5.9            |
| 1600       | -1.7         | -120.6              | 12.3         | 88.4                | -42.4        | 22.2                | -14.9        | -33.4               | 5.1            |
| 1700       | -1.9         | -126.6              | 11.5         | 55.8                | -45.3        | -9.5                | -6.5         | -117.5              | 6.5            |
| 1800       | -1.8         | -133.6              | 10.0         | 30.2                | -43.6        | 12.4                | -3.3         | -152.3              | 4.0            |
| 1900       | -2.0         | -140.7              | 8.4          | 10.0                | -40.1        | -8.1                | -2.0         | -176.5              | 2.2            |
| 2000       | -2.1         | -146.9              | 6.9          | -4.9                | -39.6        | -29.9               | -1.5         | 164.9               | 2.0            |

**Table 3. MAX2686L Simulated Typical Noise Parameters (V<sub>CC</sub> = 3.3V, T<sub>A</sub> = +25°C)**

| FREQUENCY (MHz) | F <sub>MIN</sub> (dB) | Γ <sub>OPT</sub> | Γ <sub>OPT</sub>   ANGLE | R <sub>N</sub> (Ω) |
|-----------------|-----------------------|------------------|--------------------------|--------------------|
| 1550            | 0.70                  | 0.43             | 45                       | 8.45               |
| 1560            | 0.70                  | 0.43             | 45                       | 8.43               |
| 1570            | 0.70                  | 0.42             | 45                       | 8.42               |
| 1580            | 0.70                  | 0.42             | 45                       | 8.41               |
| 1590            | 0.70                  | 0.42             | 46                       | 8.39               |
| 1600            | 0.71                  | 0.42             | 46                       | 8.38               |

# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

**Table 4. MAX2693L Simulated Typical Noise Parameters ( $V_{CC} = 3.3V$ ,  $T_A = +25^\circ C$ )**

| FREQUENCY (MHz) | FMIN (dB) | $  \Gamma_{OPT}  $ | $  \Gamma_{OPT}  $ ANGLE | $R_N (\Omega)$ |
|-----------------|-----------|--------------------|--------------------------|----------------|
| 1550            | 0.88      | 0.69               | 32                       | 24.27          |
| 1560            | 0.88      | 0.69               | 32                       | 24.22          |
| 1570            | 0.88      | 0.68               | 32                       | 24.17          |
| 1580            | 0.88      | 0.68               | 32                       | 24.12          |
| 1590            | 0.88      | 0.68               | 32                       | 24.07          |
| 1600            | 0.88      | 0.68               | 33                       | 24.03          |

### Applications Information

A properly designed PCB is essential to any RF micro-wave circuit. Use controlled-impedance lines on all high-frequency inputs and outputs. Bypass  $V_{CC}$  with decoupling capacitors located close to the device. For long  $V_{CC}$  lines, it may be necessary to add decoupling capacitors. Locate these additional capacitors further away from the device package. Proper grounding of the GND bump is essential. If the PCB uses a topside RF ground, connect it directly to the GND bump. For a board where the ground is not on the component layer, connect the GND bump to the board with multiple vias close to the package. For general layout guidelines, refer to [www.maximintegrated.com/app-notes/index.mvp/id/5100](http://www.maximintegrated.com/app-notes/index.mvp/id/5100).

Refer to [www.maximintegrated.com/datasheet/index.mvp/id/6934/t/do](http://www.maximintegrated.com/datasheet/index.mvp/id/6934/t/do) for the MAX2686L/MAX2693L EV kit schematic, Gerber data, PADS layout file, and BOM information.

### Ordering Information

| PART          | TEMP RANGE     | PIN-PACKAGE |
|---------------|----------------|-------------|
| MAX2686LEWS+T | -40°C to +85°C | 4 WLP       |
| MAX2693LEWS+T | -40°C to +85°C | 4 WLP       |

+ Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel

### Chip Information

PROCESS: SiGe BiCMOS

### Package Information

For the latest package outline information and land patterns (foot-prints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

| PACKAGE TYPE | PACKAGE CODE | OUTLINE NO.             | LAND PATTERN NO.                               |
|--------------|--------------|-------------------------|------------------------------------------------|
| 4 WLP        | W40A0+1      | <a href="#">21-0480</a> | Refer to <a href="#">Application Note 1891</a> |

# MAX2686L/MAX2693L

## GPS/GNSS Low-Noise Amplifiers with Integrated LDO

### Revision History

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION                                                                                                                                                              | PAGES<br>CHANGED |
|--------------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| 0                  | 3/12             | Initial release                                                                                                                                                          | —                |
| 1                  | 2/15             | Updated <i>Typical Operating Circuit</i> , <i>Bump Description</i> , and <i>Detailed Description</i> to show that the external resistor is now required and not optional | 1, 7             |



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