

# 1.6GHz Low Noise, Low Distortion Differential ADC Driver for DC-140MHz

## FEATURES

- 1.6GHz –3dB Bandwidth
- Fixed Gain of 20V/V (26dB)
- –85dBc IMD3 at 70MHz (Equivalent OIP3 = 46.5dBm)
- –72dBc IMD3 at 140MHz (Equivalent OIP3 = 40dBm)
- 1nV/√Hz Internal Op Amp Noise
- 1.5nV/√Hz Total Input Referred Noise
- 6.8dB Noise Figure
- Differential Inputs and Outputs
- 50Ω Input Impedance
- 2.85V to 3.5V Supply Voltage
- 45mA Supply Current (135mW)
- 1V to 1.6V Output Common Mode, Adjustable
- DC- or AC-Coupled Operation
- Max Differential Output Swing 4.7V<sub>P-P</sub>
- Small 16-Lead 3mm × 3mm × 0.75mm QFN Package

## APPLICATIONS

- Differential ADC Driver
- Differential Driver/Receiver
- Single Ended to Differential Conversion
- IF Sampling Receivers
- SAW Filter Interfacing

## DESCRIPTION

The LTC<sup>®</sup>6401-26 is a high-speed differential amplifier targeted at processing signals from DC to 140MHz. The part has been specifically designed to drive 12-, 14- and 16-bit ADCs with low noise and low distortion, but can also be used as a general-purpose broadband gain block.

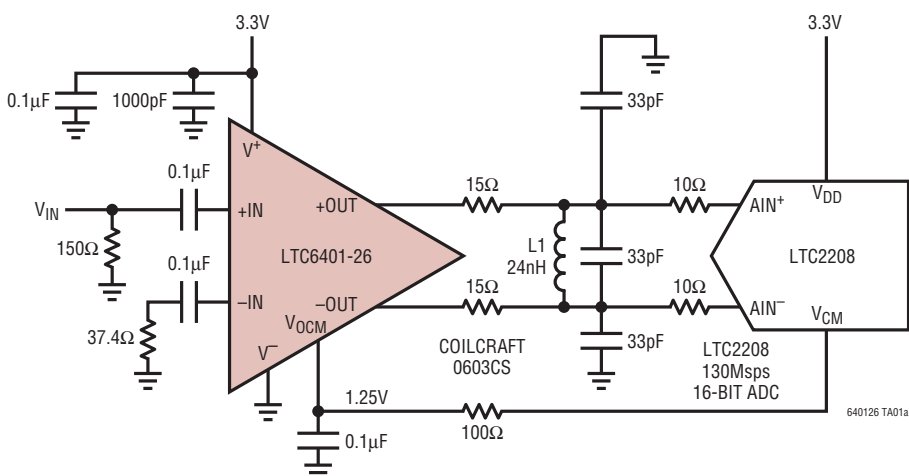
The LTC6401-26 is easy to use, with minimal support circuitry required. The output common mode voltage is set using an external pin, independent of the inputs, which eliminates the need of transformers or AC-coupling capacitors in many applications. The gain is internally fixed at 26dB (20V/V).

The LTC6401-26 saves space and power compared to alternative solutions using IF gain blocks and transformers. The LTC6401-26 is packaged in a compact 16-lead 3mm × 3mm QFN package and operates over the –40°C to 85°C temperature range.

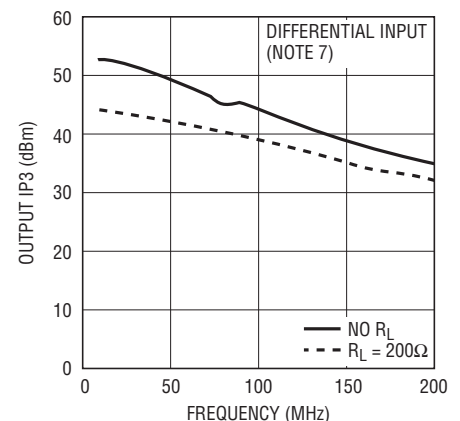
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## TYPICAL APPLICATION

Single-Ended to Differential ADC Driver at 140MHz IF



Equivalent OIP3 vs Frequency



640126 TA01b

640126f

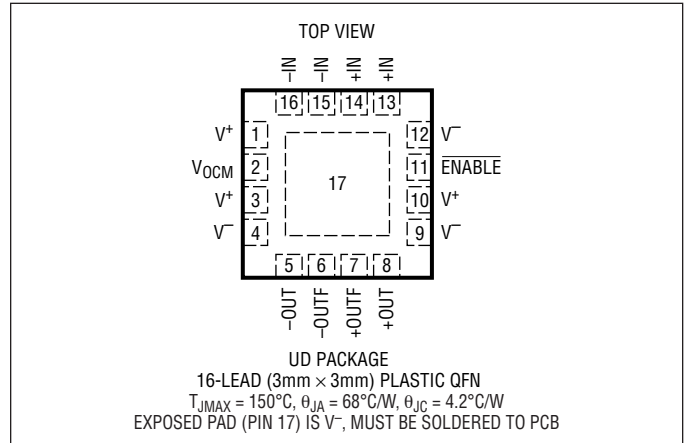
# LTC6401-26

## ABSOLUTE MAXIMUM RATINGS

(Note 1)

|                                     |  |
|-------------------------------------|--|
| Supply Voltage ( $V^+ - V^-$ )..... | 3.6V                                       |
| Input Current (Note 2).....         | $\pm 10\text{mA}$                          |
| Operating Temperature Range         |  |
| (Note 3) .....                      | $-40^\circ\text{C}$ to $85^\circ\text{C}$  |
| Specified Temperature Range         |  |
| (Note 4) .....                      | $-40^\circ\text{C}$ to $85^\circ\text{C}$  |
| Storage Temperature Range.....      | $-65^\circ\text{C}$ to $150^\circ\text{C}$ |
| Maximum Junction Temperature .....  | $150^\circ\text{C}$                        |

## PIN CONFIGURATION



## ORDER INFORMATION

| LEAD FREE FINISH  | TAPE AND REEL       | PART MARKING* | PACKAGE DESCRIPTION             | SPECIFIED TEMPERATURE RANGE               |
|-------------------|---------------------|---------------|---------------------------------|---|
| LTC6401CUD-26#PBF | LTC6401CUD-26#TRPBF | LCDG          | 16-Lead (3mm x 3mm) Plastic QFN | $0^\circ\text{C}$ to $70^\circ\text{C}$   |
| LTC6401IUD-26#PBF | LTC6401IUD-26#TRPBF | LCDG          | 16-Lead (3mm x 3mm) Plastic QFN | $-40^\circ\text{C}$ to $85^\circ\text{C}$ |

Consult LTC Marketing for parts specified with wider operating temperature ranges. \*The temperature grade is identified by a label on the shipping container. Consult LTC Marketing for information on non-standard lead based finish parts.

For more information on lead free part marking, go to: <http://www.linear.com/leadfree/>

For more information on tape and reel specifications, go to: <http://www.linear.com/tapeandreeel/>

## LTC6400 AND LTC6401 SELECTOR GUIDE Please check each datasheet for complete details.

| PART NUMBER | GAIN (dB) | GAIN (V/V) | $Z_{IN}$ (DIFFERENTIAL) ( $\Omega$ ) | $I_{CC}$ (mA) |
|-------------|-----------|------------|--------------------------------------|---------------|
| LTC6401-8   | 8         | 2.5        | 400                                  | 45            |
| LTC6401-20  | 20        | 10         | 200                                  | 50            |
| LTC6401-26  | 26        | 20         | 50                                   | 45            |
| LTC6400-20  | 20        | 10         | 200                                  | 90            |
| LTC6400-26  | 26        | 20         | 50                                   | 85            |

In addition to the LTC6401 family of amplifiers, a lower distortion LTC6400 family is available. The LTC6400 is pin compatible to the LTC6401, and has the same low noise performance. The low distortion of the LTC6400 comes at the expense of higher power consumption. Please refer to the separate LTC6400 data sheets for complete details. Other gain versions from 8dB to 14dB will follow.

**DC ELECTRICAL CHARACTERISTICS** The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V^+ = 3\text{V}$ ,  $V^- = 0\text{V}$ ,  $+IN = -IN = V_{OCM} = 1.25\text{V}$ ,  $ENABLE = 0\text{V}$ , No  $R_L$  unless otherwise noted.

| SYMBOL  | PARAMETER  | CONDITIONS   | MIN    | TYP        | MAX      | UNITS                        |    |
|---|--|--|--------|------------|----------|------------------------------|----|
| <b>Input/Output Characteristic (+IN, -IN, +OUT, -OUT, +OUTF, -OUTF)</b> |  |  |        |            |          |                              |    |
| $G_{DIFF}$  | Gain   | $V_{IN} = \pm 50\text{mV}$ Differential                            | ● 25   | 26         | 27       | dB                           |    |
| $TC_{GAIN}$   | Gain Temperature Drift                                 | $V_{IN} = \pm 50\text{mV}$ Differential                            | ●      | 0.003      |          | dB/°C                        |    |
| $V_{SWINGMIN}$  | Output Swing Low                                       | Each Output, $V_{IN} = \pm 200\text{mV}$ Differential              | ●      | 0.09       | 0.15     | V                            |    |
| $V_{SWINGMAX}$  | Output Swing High                                      | Each Output, $V_{IN} = \pm 200\text{mV}$ Differential              | ●      | 2.3        | 2.43     | V                            |    |
| $V_{OUTDIFFMAX}$  | Maximum Differential Output Swing                      | 1dB Compressed   | ●      | 4.3        | 4.7      | $V_{P-P}$                    |    |
| $I_{OUT}$   | Output Current Drive                                   | Each Output, $V_{IN} = \pm 200\text{mV}$ ,<br>$V_{OUT} > 2V_{P-P}$ | ●      | 10         |          | mA                           |    |
| $V_{OS}$  | Input Offset Voltage                                   | Differential   | ● -2.5 |            | 2.5      | mV                           |    |
| $TCV_{OS}$  | Input Offset Voltage Drift                             | Differential   | ●      | 1          |          | $\mu\text{V}/^\circ\text{C}$ |    |
| $I_{VRMIN}$   | Input Common Mode Voltage Range, MIN                   |  |        |            | 1        | V                            |    |
| $I_{VRMAX}$   | Input Common Mode Voltage Range, MAX                   |  | 1.6    |            |          | V                            |    |
| $R_{INDIFF}$  | Input Resistance (+IN, -IN)                            | Differential   | ● 42.5 | 50         | 57.5     | $\Omega$                     |    |
| $C_{INDIFF}$  | Input Capacitance (+IN, -IN)                           | Differential, Includes Parasitic                                   |        | 1          |          | pF                           |    |
| $R_{OUTDIFF}$   | Output Resistance (+OUT, -OUT)                         | Differential   | ● 18   | 25         | 32       | $\Omega$                     |    |
| $R_{OUTFDIFF}$  | Filtered Output Resistance (+OUTF, -OUTF)              | Differential   | ● 85   | 100        | 115      | $\Omega$                     |    |
| $C_{OUTFDIFF}$  | Filtered Output Capacitance (+OUTF, -OUTF)             | Differential, Includes Parasitic                                   |        | 2.7        |          | pF                           |    |
| CMRR  | Common Mode Rejection Ratio                            | Input Common Mode Voltage<br>1.1V to 1.4V                          | ●      | 50         | 75       | dB                           |    |
| <b>Output Common Mode Control</b>                                       |  |  |        |            |          |                              |    |
| $G_{CM}$  | Common Mode Gain                                       | $V_{OCM} = 1\text{V}$ to 1.6V                                      |        | 1          |          | V/V                          |    |
| $V_{OCMMIN}$  | Output Common Mode Range, MIN                          |  | ●      |            | 1<br>1.1 | V<br>V                       |    |
| $V_{OCMMAX}$  | Output Common Mode Range, MAX                          |  | ●      | 1.6<br>1.5 |          | V<br>V                       |    |
| $V_{OSCM}$  | Common Mode Offset Voltage                             | $V_{OCM} = 1.1\text{V}$ to 1.5V                                    | ● -15  |            | 15       | mV                           |    |
| $TCV_{OSCM}$  | Common Mode Offset Voltage Drift                       |  | ●      | 3          |          | $\mu\text{V}/^\circ\text{C}$ |    |
| $I_{V_{OCM}}$   | $V_{OCM}$ Input Current                                |  | ●      | 5          | 15       | $\mu\text{A}$                |    |
| <b>ENABLE Pin</b>   |  |  |        |            |          |                              |    |
| $V_{IL}$  | ENABLE Input Low Voltage                               |  | ●      |            | 0.8      | V                            |    |
| $V_{IH}$  | ENABLE Input High Voltage                              |  | ●      | 2.4        |          | V                            |    |
| $I_{IL}$  | ENABLE Input Low Current                               | ENABLE = 0.8V  | ●      |            | 0.5      | $\mu\text{A}$                |    |
| $I_{IH}$  | ENABLE Input High Current                              | ENABLE = 2.4V  | ●      | 1.4        | 3        | $\mu\text{A}$                |    |
| <b>Power Supply</b>   |  |  |        |            |          |                              |    |
| $V_S$   | Operating Supply Range                                 |  | ●      | 2.85       | 3        | 3.5                          | V  |
| $I_S$   | Supply Current   | ENABLE = 0V, Both Inputs and<br>Outputs Floating                   | ●      | 35         | 45       | 60                           | mA |
| $I_{SHDN}$  | Shutdown Supply Current                                | ENABLE = 3V, Both Inputs and<br>Outputs Floating                   | ●      |            | 0.8      | 3                            | mA |
| PSRR  | Power Supply Rejection Ratio (Differential<br>Outputs) | 2.85V to 3.5V  | ●      | 60         | 95.5     | dB                           |    |

**AC ELECTRICAL CHARACTERISTICS**

Specifications are at  $T_A = 25^\circ\text{C}$ .  $V^+ = 3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{OCM}} = 1.25\text{V}$ ,  
**ENABLE = 0V**, No  $R_L$  unless otherwise noted.

| SYMBOL                            | PARAMETER                                 | CONDITIONS   | MIN | TYP  | MAX | UNITS            |
|-----------------------------------|---|--|-----|------|-----|------------------|
| -3dBBW                            | -3dB Bandwidth                            | 200mV <sub>P-P,OUT</sub> (Note 6)  | 1.2 | 1.6  |     | GHz              |
| 0.5dBBW                           | Bandwidth for 0.5dB Flatness              | 200mV <sub>P-P,OUT</sub> (Note 6)  |     | 0.5  |     | GHz              |
| 0.1dBBW                           | Bandwidth for 0.1dB Flatness              | 200mV <sub>P-P,OUT</sub> (Note 6)  |     | 0.22 |     | GHz              |
| 1/f                               | 1/f Noise Corner                          |  |     | 16   |     | kHz              |
| SR                                | Slew Rate                                 | Differential $V_{\text{OUT}} = 2\text{V}$ Step (Note 6)                            |     | 3300 |     | V/ $\mu\text{s}$ |
| $t_{S1\%}$                        | 1% Settling Time                          | $V_{\text{OUT}} = 2V_{P-P}$ (Note 6)   |     | 3    |     | ns               |
| $t_{\text{OVR}}$                  | Overdrive Recovery Time                   | $V_{\text{OUT}} = 1.9V_{P-P}$ (Note 6)   |     | 19   |     | ns               |
| $t_{\text{ON}}$                   | Turn-On Time                              | +OUT, -OUT Within 10% of Final Values  |     | 93   |     | ns               |
| $t_{\text{OFF}}$                  | Turn-Off Time                             | $I_{\text{CC}}$ Falls to 10% of Nominal  |     | 140  |     | ns               |
| -3dBBW <sub>V<sub>OCM</sub></sub> | $V_{\text{OCM}}$ Pin Small Signal -3dB BW | 0.1V <sub>P-P</sub> at $V_{\text{OCM}}$ , Measured Single-Ended at Output (Note 6) |     | 14.7 |     | MHz              |

**10MHz Input Signal**

|                             |  |  |         |                        |
|-----------------------------|--|--|---------|------------------------|
| HD2,10M/HD3,10M             | Second/Third Order Harmonic Distortion   | $V_{\text{OUT}} = 2V_{P-P}$ , $R_L = 200\Omega$          | -95/-81 | dBc                    |
|                             |  | $V_{\text{OUT}} = 2V_{P-P}$ , No $R_L$                   | -93/-96 | dBc                    |
| IMD3,10M                    | Third-Order Intermodulation<br>( $f_1 = 9.5\text{MHz}$ $f_2 = 10.5\text{MHz}$ )                | $V_{\text{OUT}} = 2V_{P-P}$ Composite, $R_L = 200\Omega$ | -80     | dBc                    |
|                             |  | $V_{\text{OUT}} = 2V_{P-P}$ Composite, No $R_L$          | -97     | dBc                    |
| OIP3,10M                    | Equivalent Third-Order Output Intercept Point ( $f_1 = 9.5\text{MHz}$ $f_2 = 10.5\text{MHz}$ ) | $V_{\text{OUT}} = 2V_{P-P}$ Composite, No $R_L$ (Note 7) | 52.5    | dBm                    |
| $P_{1\text{dB},10\text{M}}$ | 1dB Compression Point  | $R_L = 375\Omega$ (Notes 5, 7)                           | 17.3    | dBm                    |
| $NF_{10\text{M}}$           | Noise Figure   | $R_L = 375\Omega$ (Note 5)                               | 6.8     | dB                     |
| $e_{\text{IN},10\text{M}}$  | Input Referred Voltage Noise Density   | Includes Resistors (Short Inputs)                        | 1.5     | nV/ $\sqrt{\text{Hz}}$ |
| $e_{\text{ON},10\text{M}}$  | Output Referred Voltage Noise Density  | Includes Resistors (Short Inputs)                        | 30      | nV/ $\sqrt{\text{Hz}}$ |

**70MHz Input Signal**

|                             |   |  |         |                        |
|-----------------------------|---|--|---------|------------------------|
| HD2,70M/HD3,70M             | Second/Third Order Harmonic Distortion  | $V_{\text{OUT}} = 2V_{P-P}$ , $R_L = 200\Omega$          | -83/-66 | dBc                    |
|                             |   | $V_{\text{OUT}} = 2V_{P-P}$ , No $R_L$                   | -86/-81 | dBc                    |
| IMD3,70M                    | Third-Order Intermodulation<br>( $f_1 = 69.5\text{MHz}$ $f_2 = 70.5\text{MHz}$ )                | $V_{\text{OUT}} = 2V_{P-P}$ Composite, $R_L = 200\Omega$ | -74     | dBc                    |
|                             |   | $V_{\text{OUT}} = 2V_{P-P}$ Composite, No $R_L$          | -85     | dBc                    |
| OIP3,70M                    | Equivalent Third-Order Output Intercept Point ( $f_1 = 69.5\text{MHz}$ $f_2 = 70.5\text{MHz}$ ) | $V_{\text{OUT}} = 2V_{P-P}$ Composite, No $R_L$ (Note 7) | 46.5    | dBm                    |
| $P_{1\text{dB},70\text{M}}$ | 1dB Compression Point   | $R_L = 375\Omega$ (Notes 5, 7)                           | 17.2    | dBm                    |
| $NF_{70\text{M}}$           | Noise Figure  | $R_L = 375\Omega$ (Note 5)                               | 6.7     | dB                     |
| $e_{\text{IN},70\text{M}}$  | Input Referred Voltage Noise Density  | Includes Resistors (Short Inputs)                        | 1.44    | nV/ $\sqrt{\text{Hz}}$ |
| $e_{\text{ON},70\text{M}}$  | Output Referred Voltage Noise Density   | Includes Resistors (Short Inputs)                        | 28.8    | nV/ $\sqrt{\text{Hz}}$ |

**AC ELECTRICAL CHARACTERISTICS**

Specifications are at  $T_A = 25^\circ\text{C}$ .  $V^+ = 3\text{V}$ ,  $V^- = 0\text{V}$ ,  $V_{\text{OCM}} = 1.25\text{V}$ ,  
**ENABLE = 0V, No  $R_L$  unless otherwise noted.**

| SYMBOL                     | PARAMETER   | CONDITIONS  | MIN | TYP     | MAX | UNITS                        |
|----------------------------|---|---|-----|---------|-----|------------------------------|
| <b>140MHz Input Signal</b> |   |   |     |         |     |                              |
| HD2,140M/<br>HD3,140M      | Second/Third Order Harmonic Distortion  | $V_{\text{OUT}} = 2V_{\text{P-P}}$ , $R_L = 200\Omega$          |     | -81/-54 |     | dBc                          |
|                            |   | $V_{\text{OUT}} = 2V_{\text{P-P}}$ , No $R_L$                   |     | -85/-69 |     | dBc                          |
| IMD3,140M                  | Third-Order Intermodulation<br>( $f_1 = 139.5\text{MHz}$ $f_2 = 140.5\text{MHz}$ )                  | $V_{\text{OUT}} = 2V_{\text{P-P}}$ Composite, $R_L = 200\Omega$ |     | -64     |     | dBc                          |
|                            |   | $V_{\text{OUT}} = 2V_{\text{P-P}}$ Composite, No $R_L$          |     | -72     |     | dBc                          |
| OIP3,140M                  | Equivalent Third-Order Output Intercept Point( $f_1 = 139.5\text{MHz}$ $f_2 = 140.5\text{MHz}$ )    | $V_{\text{OUT}} = 2V_{\text{P-P}}$ Composite, No $R_L$ (Note 7) |     | 40      |     | dBm                          |
| $P_{1\text{dB}}$ ,140M     | 1dB Compression Point   | $R_L = 375\Omega$ (Notes 5, 7)                                  |     | 17.4    |     | dBm                          |
| $NF_{140\text{M}}$         | Noise Figure  | $R_L = 375\Omega$ (Note 5)                                      |     | 6.5     |     | dB                           |
| $e_{\text{N}}$ ,140M       | Input Referred Voltage Noise Density  | Includes Resistors (Short Inputs)                               |     | 1.43    |     | $\text{nV}/\sqrt{\text{Hz}}$ |
| $e_{\text{ON}}$ ,140M      | Output Referred Voltage Noise Density   | Includes Resistors (Short Inputs)                               |     | 28.6    |     | $\text{nV}/\sqrt{\text{Hz}}$ |
| IMD <sub>3,130M/150M</sub> | Third-Order Intermodulation<br>( $f_1 = 130\text{MHz}$ $f_2 = 150\text{MHz}$ )<br>Measure at 170MHz | $V_{\text{OUT}} = 2V_{\text{P-P}}$ Composite, $R_L = 375\Omega$ |     | -70     | -62 | dBc                          |

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** Input pins (+IN, -IN) are protected by steering diodes to either supply. If the inputs go beyond either supply rail, the input current should be limited to less than 10mA.

**Note 3:** The LTC6401C and LTC6401I are guaranteed functional over the operating temperature range of  $-40^\circ\text{C}$  to  $85^\circ\text{C}$

**Note 4:** The LTC6401C is guaranteed to meet specified performance from  $0^\circ\text{C}$  to  $70^\circ\text{C}$ . It is designed, characterized and expected to meet specified performance from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$  but is not tested or QA sampled at these

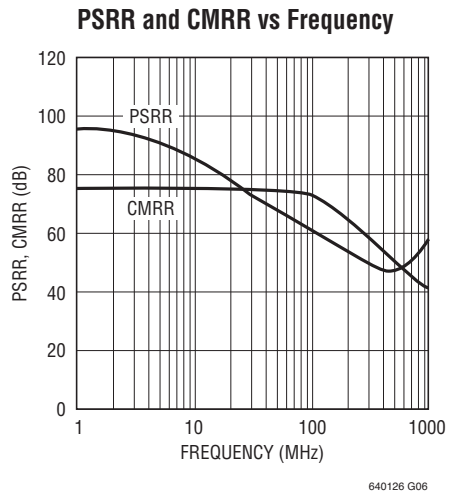
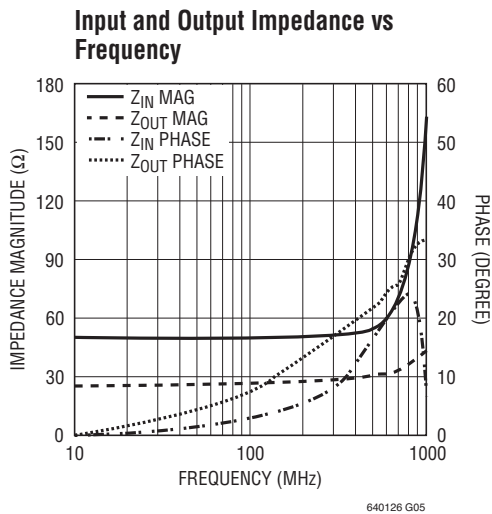
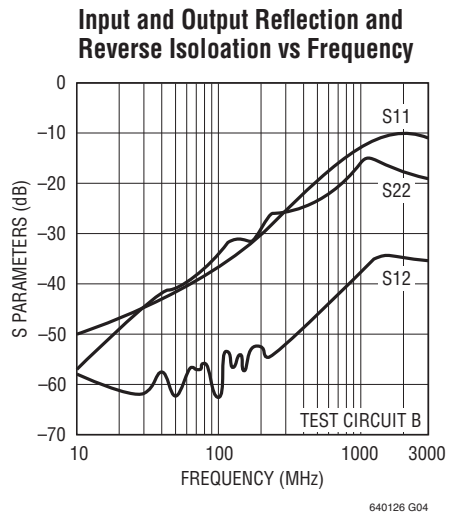
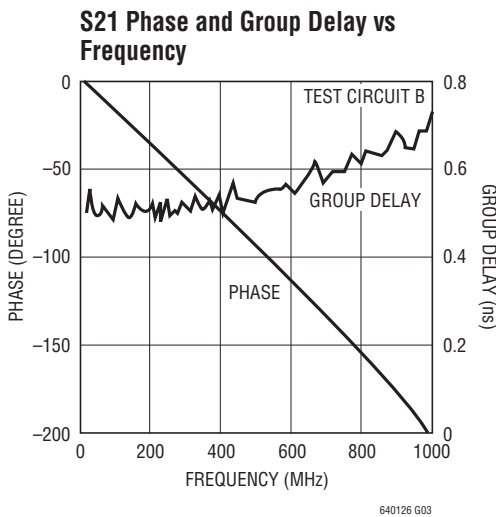
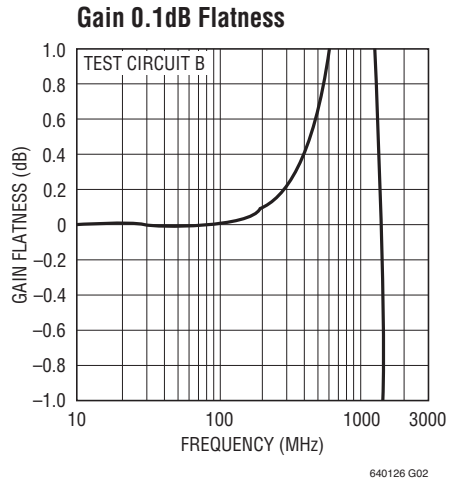
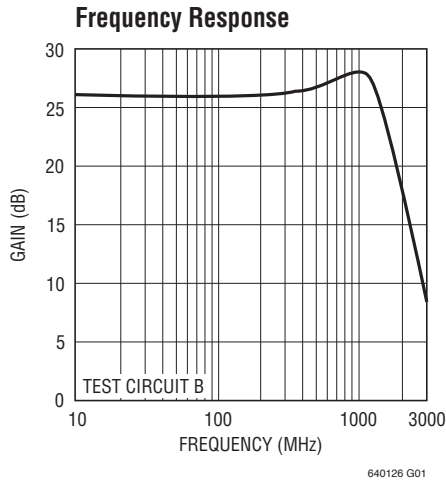
temperatures. The LTC6401I is guaranteed to meet specified performance from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ .

**Note 5:** Input and output baluns used. See Test Circuit A.

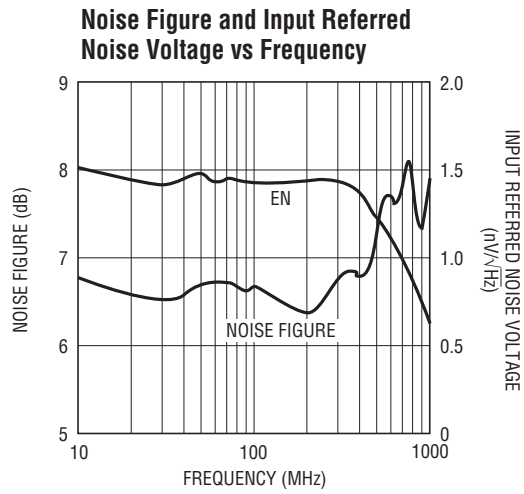
**Note 6:** Measured using Test Circuit B.  $R_L = 87.5\Omega$  per output.

**Note 7:** Since the LTC6401-26 is a feedback amplifier with low output impedance, a resistive load is not required when driving an AD converter. Therefore, typical output power is very small. In order to compare the LTC6401-26 with amplifiers that require  $50\Omega$  output load, the output voltage swing driving a given  $R_L$  is converted to OIP<sub>3</sub> and  $P_{1\text{dB}}$  as if it were driving a  $50\Omega$  load. Using this modified convention,  $2V_{\text{P-P}}$  is by definition equal to 10dBm, regardless of actual  $R_L$ .

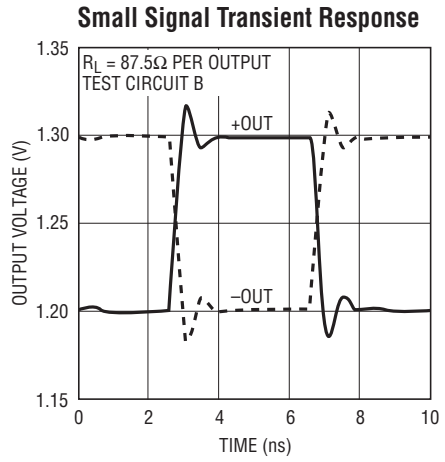
TYPICAL PERFORMANCE CHARACTERISTICS



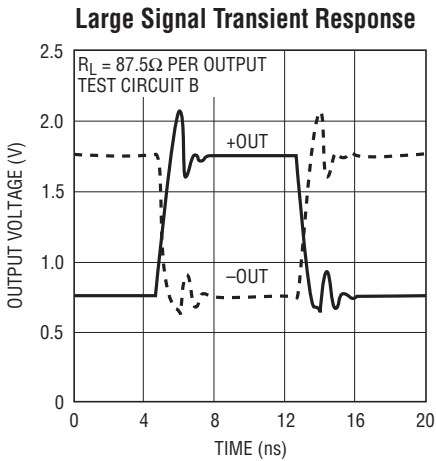
# TYPICAL PERFORMANCE CHARACTERISTICS



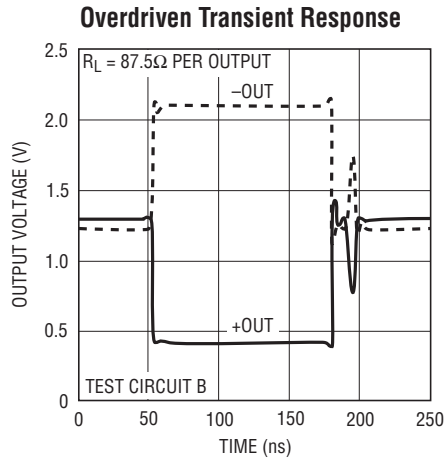
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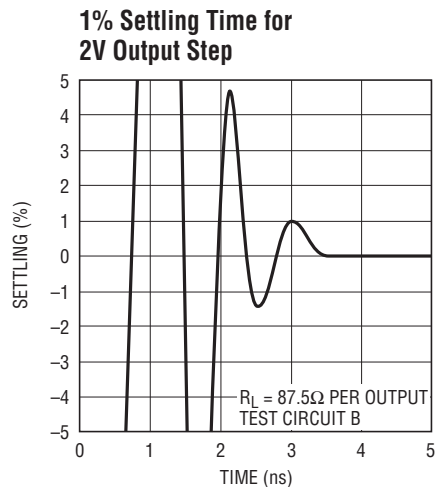
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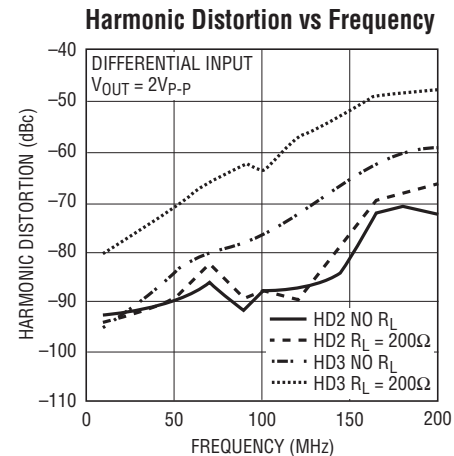
640126 G09



640126 G10



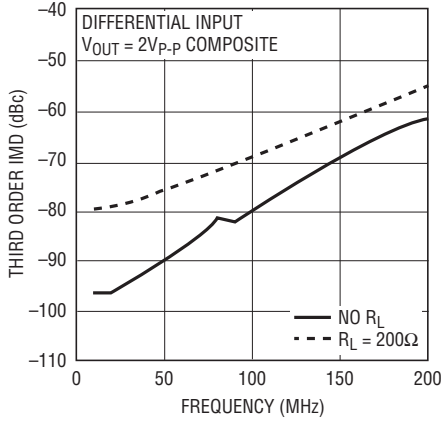
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640126 G12

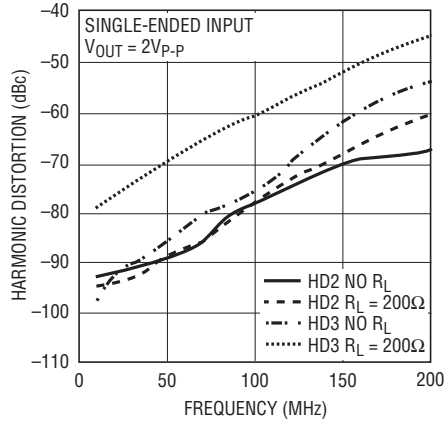
## TYPICAL PERFORMANCE CHARACTERISTICS

**Third Order Intermodulation Distortion vs Frequency**



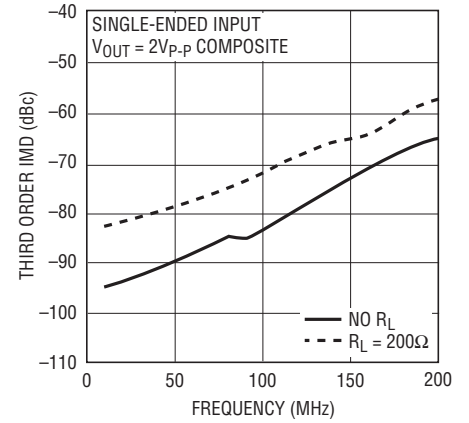
640126 G13

**Harmonic Distortion vs Frequency**



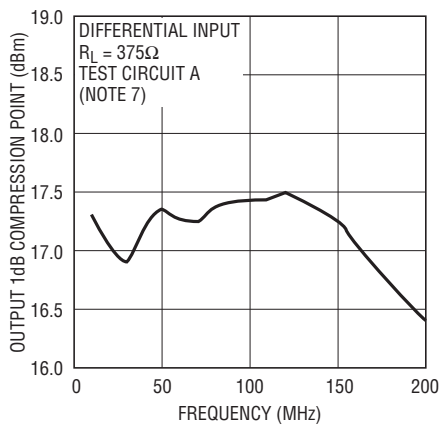
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**Third Order Intermodulation Distortion vs Frequency**



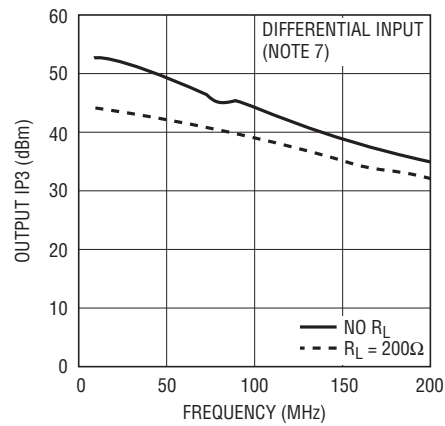
640126 G15

**Output 1dB Compression Point vs Frequency**



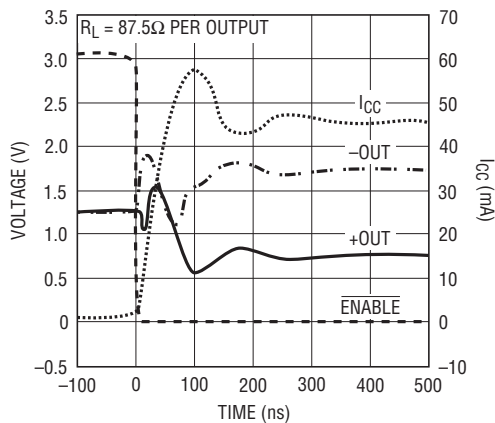
640126 G16

**Equivalent Output Third Order Intercept Point vs Frequency**



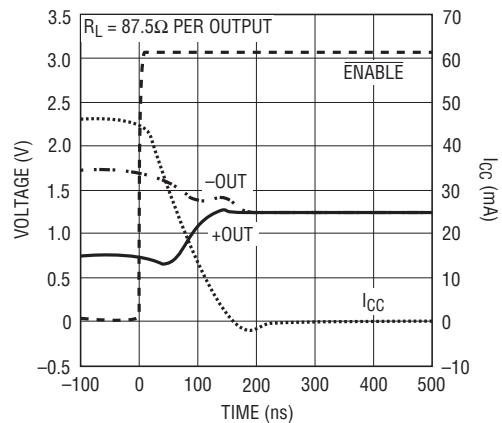
640126 G17

**Turn-On Time**



640126 G18

**Turn-Off Time**



640126 G19



## PIN FUNCTIONS

**V<sup>+</sup> (Pins 1, 3, 10):** Positive Power Supply (Normally tied to 3V or 3.3V). All three pins must be tied to the same voltage. Bypass each pin with 1000pF and 0.1μF capacitors as close to the pins as possible.

**V<sub>OCM</sub> (Pin 2):** This pin sets the output common mode voltage. An 0.1μF external bypass capacitor is recommended.

**V<sup>-</sup> (Pins 4, 9, 12, 17):** Negative Power Supply. All four pins must be connected to same voltage/ground.

**-OUT, +OUT (Pins 5, 8):** Unfiltered Outputs. These pins have series 12.5Ω resistors R<sub>OUT</sub>.

**-OUTF, +OUTF (Pins 6, 7):** Filtered Outputs. These pins have 50Ω series resistors and a 2.7pF shunt capacitor.

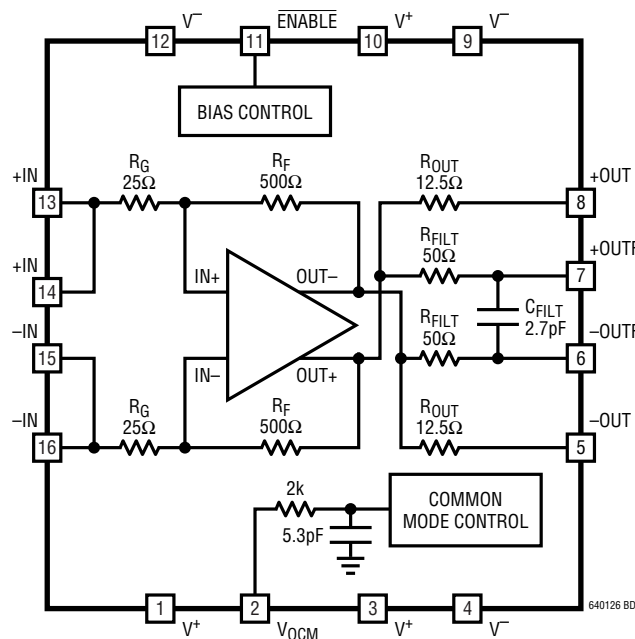
**ENABLE (Pin 11):** This pin is a logic input referenced to V<sub>EE</sub>. If low, the part is enabled. If high, the part is disabled and draws very low standby current while the internal op amp has high output impedance.

**+IN (Pins 13, 14):** Positive Input. Pins 13 and 14 are internally shorted together.

**-IN (Pins 15, 16):** Negative Input. Pins 15 and 16 are internally shorted together.

**Exposed Pad (Pin 17):** V<sup>-</sup>. The Exposed Pad must be connected to same voltage/ground as pins 4, 9, 12.

## BLOCK DIAGRAM



## APPLICATIONS INFORMATION

### Circuit Operation

The LTC6401-26 is a low noise and low distortion fully differential op amp/ADC driver with:

- Operation from DC to 1.6GHz –3dB bandwidth
- Fixed gain of 20V/V (26dB)
- Differential input impedance 50Ω
- Differential output impedance 25Ω
- Differential impedance of output filter 100Ω

The LTC6401-26 is composed of a fully differential amplifier with on chip feedback and output common mode voltage control circuitry. Differential gain and input impedance are set by 25Ω/500Ω resistors in the feedback network. Small output resistors of 12.5Ω improve the circuit stability over various load conditions. They also provide a possible external filtering option, which is often desirable when the load is an ADC.

Filter resistors of 50Ω are available for additional filtering. Lowpass/bandpass filters are easily implemented with just a couple of external components. Moreover, they offer single-ended 50Ω matching in wideband applications and no external resistor is needed.

The LTC6401-26 is very flexible in terms of I/O coupling. It can be AC- or DC-coupled at the inputs, the outputs or both. Due to the internal connection between input and output, users are advised to keep input common mode voltage between 1V and 1.6V for proper operation. If the inputs are AC-coupled, the input common mode voltage is automatically biased close to  $V_{OCM}$  and thus no external circuitry is needed for bias. The LTC6401-26 provides an output common mode voltage set by  $V_{OCM}$ , which allows driving ADC directly without external components such as transformer or AC coupling capacitors. The input signal can be either single-ended or differential with only minor difference in distortion performance.

### Input Impedance and Matching

The differential input impedance of the LTC6401-26 is 50Ω. The interface between the input of LTC6401-26 and 50Ω source is straightforward. One way is to directly connect

them if the source is differential (Figure 1). Another approach is to employ a wideband transformer if the source is single ended (Figure 2). Both methods provide a wideband match. Alternatively, one could apply a narrowband impedance match at the inputs of the LTC6401-26 for frequency selection and/or noise reduction.

Referring to Figure 3, LTC6401-26 can be easily configured for single-ended input and differential output without a balun. The signal is fed to one of the inputs through a matching network while the other input is connected to the same matching network and a source resistor. Because the return ratios of the two feedback paths are equal, the two outputs have the same gain and thus symmetrical swing. In general, the single-ended input impedance and termination resistor  $R_T$  are determined by the combination of  $R_S$ ,  $R_G$  and  $R_F$ . For example, when  $R_S$  is 50Ω, it is found that the single-ended input impedance is 75Ω and  $R_T$  is 150Ω in order to match to a 50Ω source impedance.

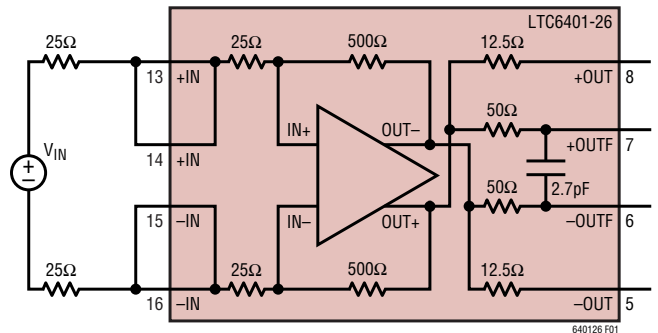


Figure 1. Input Termination for Differential 50Ω Input Impedance

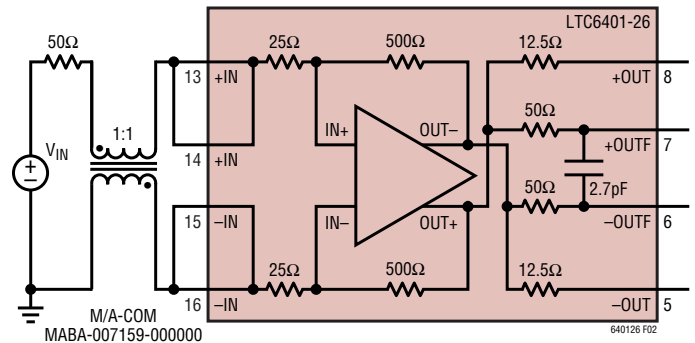


Figure 2. Input Termination for Differential 50Ω Input Impedance Using a Balun

## APPLICATIONS INFORMATION

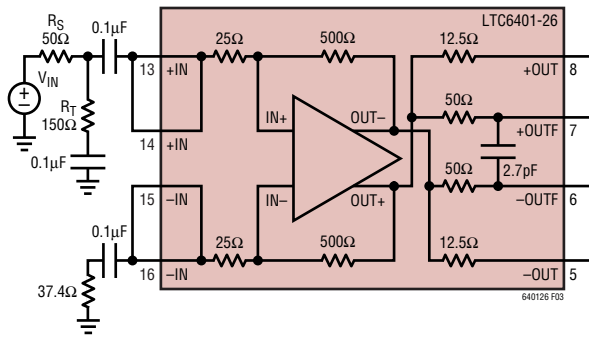


Figure 3. Input Termination for Single-Ended 50Ω Input Impedance

The LTC6401-26 is unconditionally stable, i.e. differential stability factor  $K_f > 1$  and stability measure  $B1 > 0$ . However, the overall differential gain is affected by both source impedance and load impedance as shown in Figure 4:

$$A_V = \left| \frac{V_{OUT}}{V_{IN}} \right| = \frac{1000}{R_S + 50} \cdot \frac{R_L}{25 + R_L}$$

The noise performance of the LTC6401-26 also depends upon the source impedance and termination. A trade-off between gain and noise is obvious when constant noise figure circle and constant gain circle are plotted within the same input Smith Chart, based on which users can choose the optimal source impedance for a given gain and noise requirement.

### Output Impedance Match and Filter

The LTC6401-26 can drive an ADC directly without external output impedance matching. Alternatively, the differential output impedance of 25Ω can be made larger, e.g. 50Ω, by series resistors or LC network.

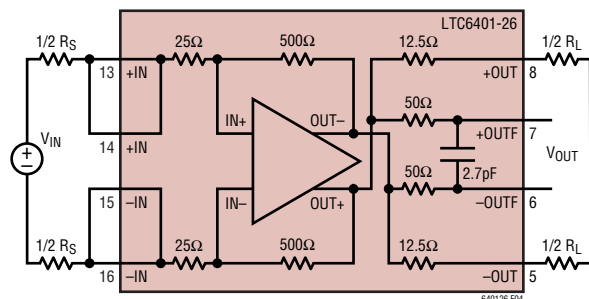


Figure 4. Calculate Differential Gain

The internal low pass filter outputs at +OUTF/-OUTF have a  $-3\text{dB}$  bandwidth of 590MHz. External capacitors can reduce the low pass filter bandwidth as shown in Figure 5. A bandpass filter is easily implemented with only a few components as shown in Figure 6. Three 39pF capacitors and 16nH inductor create a bandpass filter with 165MHz center frequency,  $-3\text{dB}$  frequencies at 138MHz and 200MHz.

### Output Common Mode Adjustment

The LTC6401-26's output common mode voltage is set by the  $V_{OCM}$  pin, which is a high impedance input. The output common mode voltage is capable of tracking  $V_{OCM}$  in a range from 1V to 1.6V. Bandwidth of  $V_{OCM}$  control is typically 15MHz, which is dominated by a low pass filter connected to the  $V_{OCM}$  pin and is aimed to reduce common mode noise generation at the outputs. The internal common mode feedback loop has a  $-3\text{dB}$  bandwidth of 400MHz, allowing fast rejection of any common mode output voltage disturbance. The  $V_{OCM}$  pin should be tied to a DC bias voltage with a 0.1μF bypass capacitor. When interfacing with 3V A/D converters such as the LTC22xx families, the  $V_{OCM}$  pin can be connected to the  $V_{CM}$  pin of the ADC.

### Driving A/D Converters

The LTC6401-26 has been specifically designed to interface directly with high speed A/D converters. Figure 7 shows the LTC6401-26 with single-ended input driving the LTC2208, which is a 16-bit, 130Msps ADC. Two external 5Ω resistors help eliminate potential resonance associated with bond wires of either the ADC input or the driver output.  $V_{OCM}$

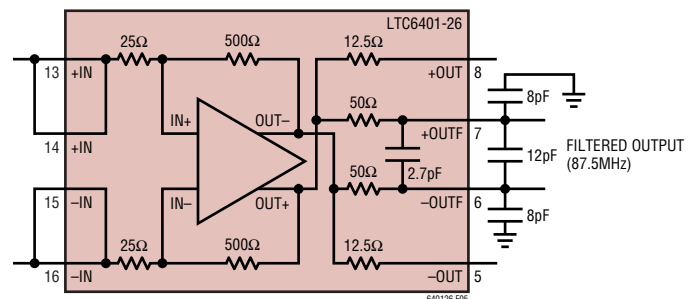


Figure 5. LTC6401-26 Internal Filter Topology Modified for Low Filter Bandwidth (Three External Capacitors)

## APPLICATIONS INFORMATION

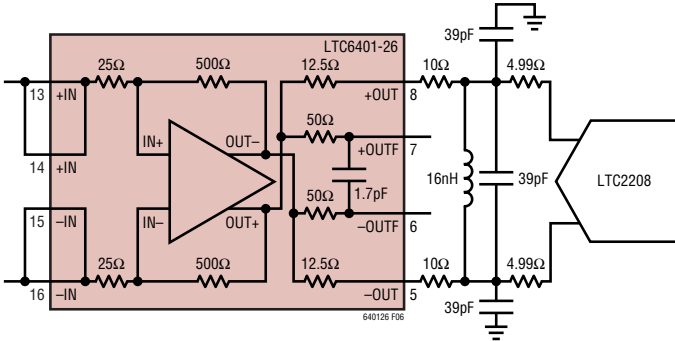


Figure 6. LTC6401-26 with 165MHz Output Bandpass Filter

of the LTC6401-26 is connected to  $V_{CM}$  of the LTC2208 at 1.25V. Alternatively, a single-ended input signal can be converted to a differential signal via a balun and fed to the input of the LTC6401-26. Figure 8 summarizes the IMD3 performance of the whole system as shown in Figure 7.

### Test Circuits

Due to the fully-differential design of the LTC6401 and its usefulness in applications with differing characteristic specifications, two test circuits are used to generate the information in this datasheet. Test Circuit A is DC987B, a two-port demonstration circuit for the LTC6401 family. The silkscreen is shown in Figure 9. This circuit includes input and output transformers (baluns) for single-ended-to-differential conversion and impedance transformation, allowing direct hook-up to a 2-port network analyzer. There are also series resistors at the output to present the LTC6401 with a 375Ω differential load, optimizing distortion performance. Due to the input and output transformers, the -3dB bandwidth is reduced from 1.6GHz to 1.37GHz.

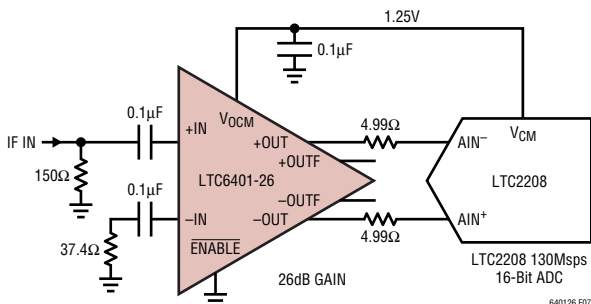


Figure 7. Single-Ended Input to LTC6401-26 and LTC2208

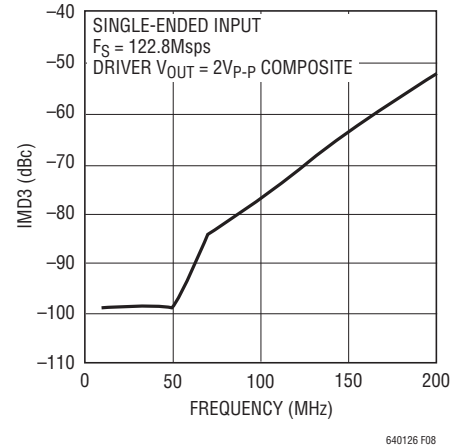


Figure 8. IMD<sub>3</sub> for the Combination of LTC6401-26 and LTC2208

Test Circuit B uses a 4-port network analyzer to measure S-parameters and gain/phase response. This removes the effects of the wideband baluns and associated circuitry, for a true picture of the >1GHz S-parameters and AC characteristics.

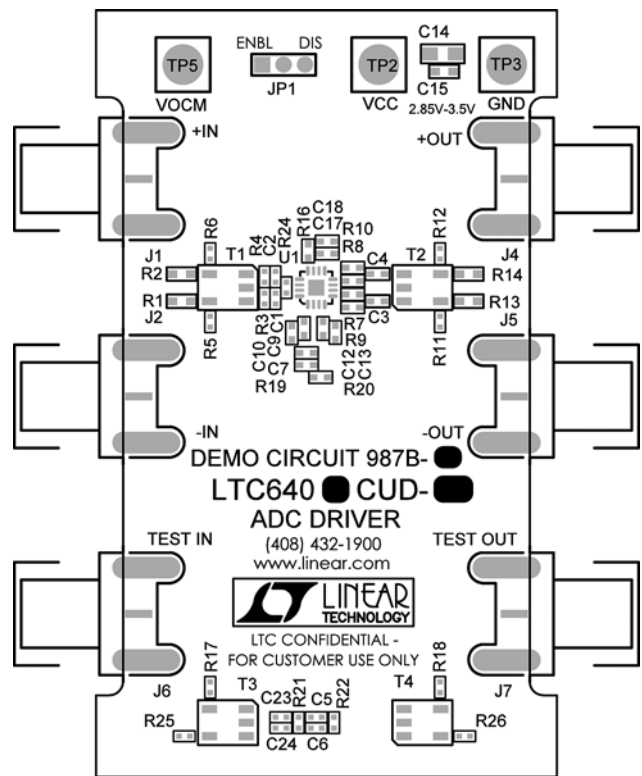
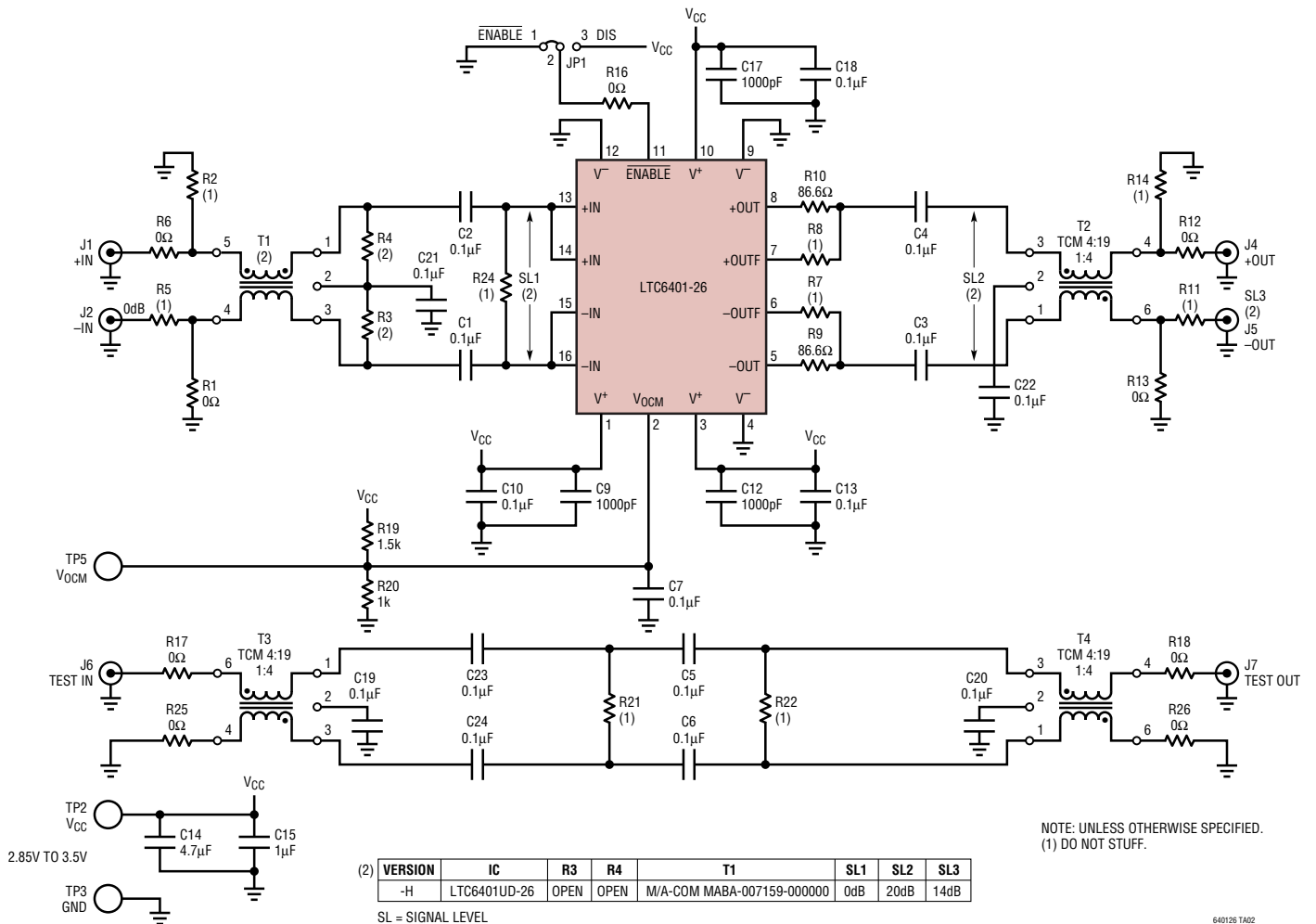


Figure 9. Top Silkscreen for DC987B, Test Circuit A

# TYPICAL APPLICATION

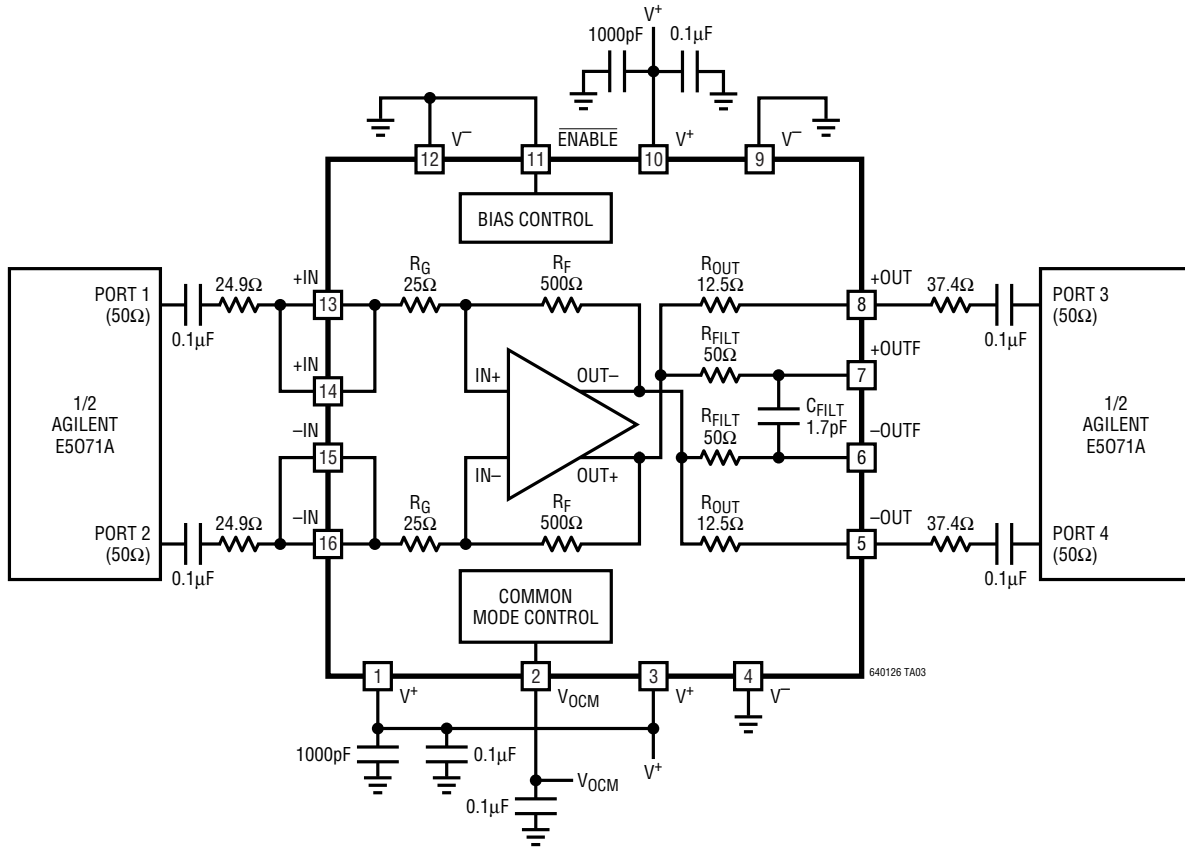
Demo Circuit 987B Schematic (Test Circuit A)



640126 TA02

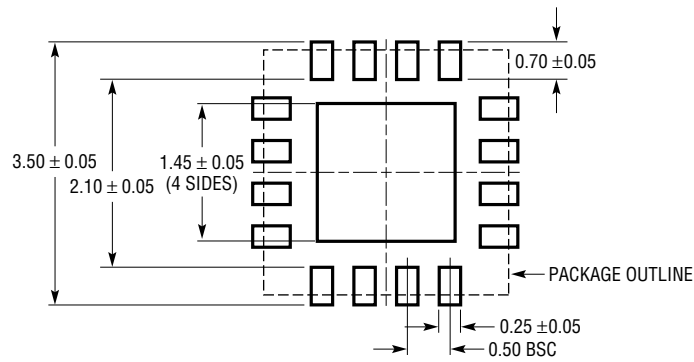
TYPICAL APPLICATION

Test Circuit B, 4-Port Analysis

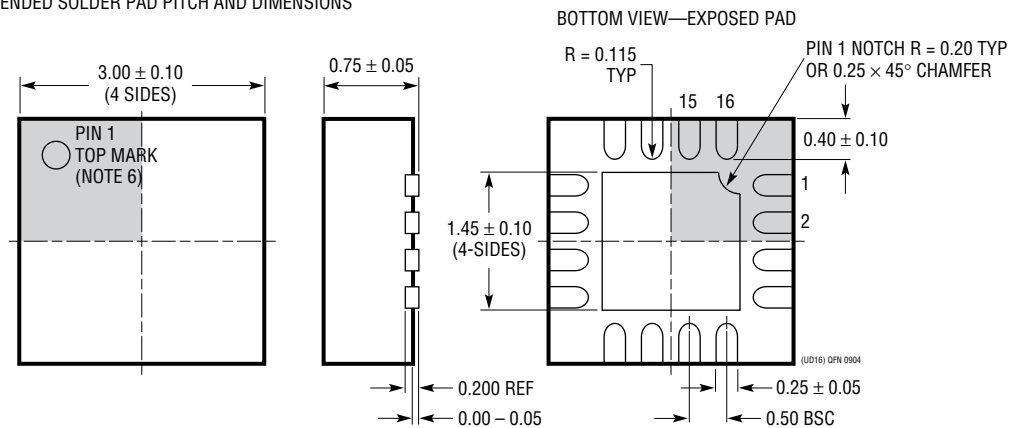


## PACKAGE DESCRIPTION

### UD Package 16-Lead Plastic QFN (3mm × 3mm) (Reference LTC DWG # 05-08-1691)



RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS



**NOTE:**

1. DRAWING CONFORMS TO JEDEC PACKAGE OUTLINE MO-220 VARIATION (WEED-2)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE SOLDER PLATED
6. SHADED AREA IS ONLY A REFERENCE FOR PIN 1 LOCATION ON THE TOP AND BOTTOM OF PACKAGE