# LTC6401-8

# 2.2GHz Low Noise, Low Distortion Differential ADC Driver for DC-140MHz

## FEATURES

- 2.2GHz –3dB Bandwidth
- Fixed Gain of 2.5V/V (8dB)
- –92dBc IMD3 at 70MHz (Equivalent OIP3 = 50dBm)
- –80.5dBc IMD3 at 140MHz (Equivalent OIP3 = 44dBm)
- $1nV/\sqrt{Hz}$ Internal Op Amp Noise
- 12.1dB Noise Figure
- Differential Inputs and Outputs
- 400Ω 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 4.6V$_{P-P}$
- 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®6401-8 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 LTC6401-8 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 for transformers or AC-coupling capacitors in many applications. The gain is internally fixed at 8dB (2.5V/V).

The LTC6401-8 saves space and power compared to alternative solutions using IF gain blocks and transformers. The LTC6401-8 is packaged in a compact 16-lead 3mm × 3mm QFN package and operates over the –40°C to 85°C temperature range.

## TYPICAL APPLICATION



Equivalent Output IP3 vs Frequency
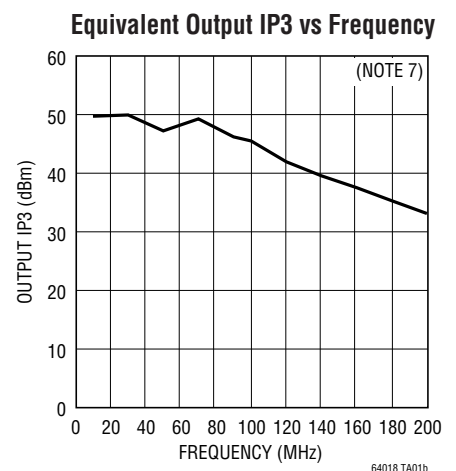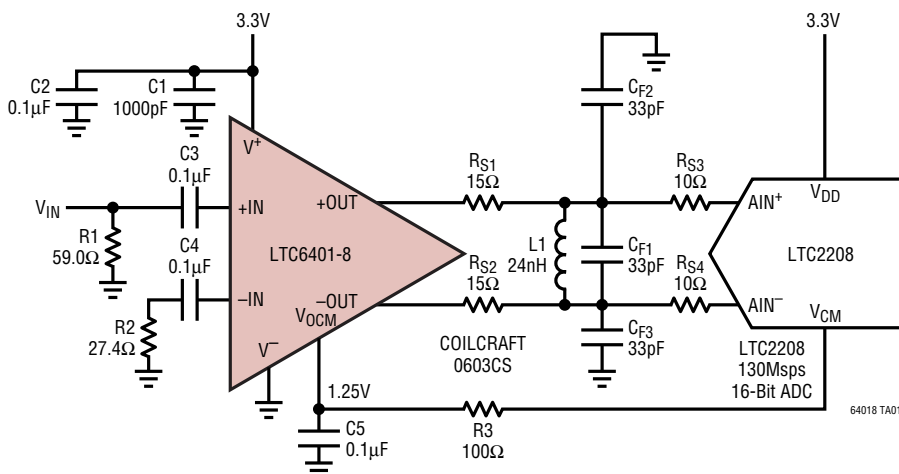
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# ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltage ($V_{CC} - V_{EE}$) ..................................... 3.6V
Input Current (Note 2) .......................................... ±10mA
Operating Temperature Range
    (Note 3) ............................................... –40°C to 85°C
Specified Temperature Range
    (Note 4) ............................................... –40°C to 85°C
Storage Temperature Range ................. –65°C to 150°C
Maximum Junction Temperature .......................... 150°C

# PIN CONFIGURATION

TOP VIEW

```
         V⁻   V⁻   V⁻   V⁺
        ┌───┬───┬───┬───┐
        │16 │15 │14 │13 │
     ┌──┴───┴───┴───┴───┴──┐
 V⁺  │ 1 ┌ ─ ─ ─ ─ ─ ┐  12│ V⁻
     │   ┆             ┆   │
V_OCM│ 2 ┆             ┆  11│ ENABLE
     │   ┆     17      ┆   │
 V⁺  │ 3 ┆             ┆  10│ V⁺
     │   ┆             ┆   │
 V⁻  │ 4 └ ─ ─ ─ ─ ─ ┘   9│ V⁻
     └──┬───┬───┬───┬──┘
        │ 5 │ 6 │ 7 │ 8 │
        └───┴───┴───┴───┘
         –OUT –OUTF +OUTF +OUT
```

UD PACKAGE
16-LEAD (3mm × 3mm) PLASTIC QFN
$T_{JMAX} = 150°C$, $\theta_{JA} = 68°C/W$, $\theta_{JC} = 4.2°C/W$
EXPOSED PAD (PIN 17) IS V⁻, MUST BE SOLDERED TO PCB
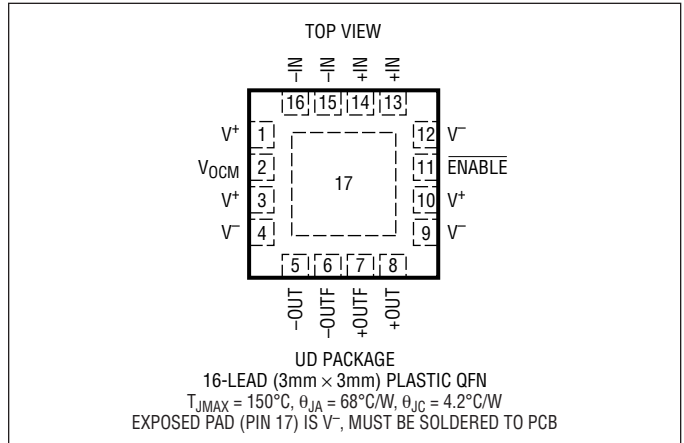
# ORDER INFORMATION

| LEAD FREE FINISH | TAPE AND REEL | PART MARKING* | PACKAGE DESCRIPTION | SPECIFIED TEMPERATURE RANGE |
|---|---|---|---|---|
| LTC6401CUD-8#PBF | LTC6401CUD-8#TRPBF | LCCY | 16-Lead (3mm × 3mm) Plastic QFN | 0°C to 70°C |
| LTC6401IUD-8#PBF | LTC6401IUD-8#TRPBF | LCCY | 16-Lead (3mm × 3mm) Plastic QFN | –40°C to 85°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/tapeandreel/

# 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 LTC6400 shows higher linearity especially at input frequency above 140MHz at the expense of higher supply current. Please refer to the separate LTC6400 data sheets for complete details. Other gain versions from 8dB to 14dB will follow.

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LINEAR
TECHNOLOGY

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

| SYMBOL | PARAMETER | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **Input/Output Characteristic** | | | | | | | |
| $G_{DIFF}$ | Gain | $V_{IN}$ = ±400mV Differential | ● | 7.5 | 8 | 8.5 | dB |
| $TC_{GAIN}$ | Gain Temperature Drift | $V_{IN}$ = ±400mV Differential | ● | | −0.5 | | mdB/°C |
| $V_{SWINGMIN}$ | Output Swing Low | Each Output, $V_{IN}$ = ±1.6V Differential | ● | | 89 | 170 | mV |
| $V_{SWINGMAX}$ | Output Swing High | Each Output, $V_{IN}$ = ±1.6V Differential | ● | 2.3 | 2.42 | | V |
| $V_{OUTDIFFMAX}$ | Maximum Differential Output Swing | 1dB Compressed | ● | | 4.6 | | $V_{P-P}$ |
| $I_{OUT}$ | Output Current Drive | $V_{OUT}$ > 2$V_{P-P,DIFF}$ | ● | 10 | | | mA |
| $V_{OS}$ | Input Offset Voltage | Differential | ● | −4 | | 4 | mV |
| $TCV_{OS}$ | Input Offset Voltage Drift | Differential | ● | | 3 | | μV/°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 | ● | 340 | 400 | 460 | Ω |
| $C_{INDIFF}$ | Input Capacitance (+IN, −IN) | Differential, Includes Parasitic | | | 1 | | pF |
| $R_{OUTDIFF}$ | Output Resistance (+OUT, −OUT) | Differential | ● | 18 | 25 | 32 | Ω |
| $R_{OUTFDIFF}$ | Filtered Output Resistance (+OUTF, −OUTF) | Differential | ● | 85 | 100 | 115 | Ω |
| $C_{OUTFDIFF}$ | Filtered Output Capacitance (+OUTF, −OUTF) | Differential, Includes Parasitic | | | 2.7 | | pF |
| CMRR | Common Mode Rejection Ratio | Input Common Mode Voltage 1.1V~1.4V | ● | 36 | 55 | | dB |
| **Output Common Mode Voltage Control** | | | | | | | |
| $G_{CM}$ | Common Mode Gain | $V_{OCM}$ = 1V to 1.6V | | | 1 | | V/V |
| $V_{OCMMIN}$ | Output Common Mode Range, MIN | | | | | 1 | V |
| | | | ● | | | 1.1 | V |
| $V_{OCMMAX}$ | Output Common Mode Range, MAX | | | 1.6 | | | V |
| | | | ● | 1.5 | | | V |
| $V_{OSCM}$ | Common Mode Offset Voltage | $V_{OCM}$ = 1.1V to 1.5V | ● | −15 | | 15 | mV |
| $TCV_{OSCM}$ | Common Mode Offset Voltage Drift | | ● | | 5 | | μV/°C |
| $IV_{OCM}$ | $V_{OCM}$ Input Current | | ● | | 3.6 | 15 | μA |
| **$\overline{ENABLE}$ Pin** | | | | | | | |
| $V_{IL}$ | $\overline{ENABLE}$ Input Low Voltage | | ● | | | 0.8 | V |
| $V_{IH}$ | $\overline{ENABLE}$ Input High Voltage | | ● | 2.4 | | | V |
| $I_{IL}$ | $\overline{ENABLE}$ Input Low Current | $\overline{ENABLE}$ = 0.8V | ● | | | 0.5 | μA |
| $I_{IH}$ | $\overline{ENABLE}$ Input High Current | $\overline{ENABLE}$ = 2.4V | ● | | 1.4 | 4 | μA |
| **Power Supply** | | | | | | | |
| $V_S$ | Operating Supply Range | | ● | 2.85 | 3 | 3.5 | V |
| $I_S$ | Supply Current | $\overline{ENABLE}$ = 0.8V, Input and Output Floating | ● | 36 | 45 | 60 | mA |
| $I_{SHDN}$ | Shutdown Supply Current | $\overline{ENABLE}$ = 2.4V, Input and Output Floating | ● | | 0.8 | 3 | mA |
| PSRR | Power Supply Rejection Ratio (Differential Outputs) | $V^+$ = 2.85V to 3.5V | ● | 50 | 73.5 | | dB |

# AC ELECTRICAL CHARACTERISTICS

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

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|--------|-----------|------------|-----|-----|-----|-------|
| –3dBBW | –3dB Bandwidth | $200mV_{P-P,OUT}$ (Note 6) | 1 | 2.22 | | GHz |
| 0.5dBBW | Bandwidth for 0.5dB Flatness | $200mV_{P-P,OUT}$ (Note 6) | | 0.43 | | GHz |
| 0.1dBBW | Bandwidth for 0.1dB Flatness | $200mV_{P-P,OUT}$ (Note 6) | | 0.22 | | GHz |
| 1/f | 1/f Noise Corner | | | 12.2 | | kHz |
| SR | Slew Rate | $V_{OUT}$ = 2V Step (Note 6) | | 3400 | | V/µs |
| $t_{S1\%}$ | 1% Settling Time | $V_{OUT}$ = $2V_{P-P}$ (Note 6) | | 2.3 | | ns |
| $t_{OVDR}$ | Overdrive Recovery Time | $V_{OUT}$ = $1.9V_{P-P}$ (Note 6) | | 18 | | ns |
| $t_{ON}$ | Turn-On Time | $V_{OUT}$ Within 10% of Final Values | | 79 | | ns |
| $t_{OFF}$ | Turn-Off Time | $I_{CC}$ Falls to 10% of Nominal | | 193 | | ns |
| –3dBBW$_{VOCM}$ | $V_{OCM}$ Pin Small Signal –3dB BW | $0.1V_{P-P}$ at $V_{OCM}$, Measured Single-Ended at Output (Note 6) | | 14 | | MHz |
| **10MHz Input Signal** | | | | | | |
| HD2,10M/HD3,10M | Second/Third Order Harmonic Distortion | $V_{OUT}$ = $2V_{P-P}$, $R_L$ = 200Ω | | –109/–88 | | dBc |
| | | $V_{OUT}$ = $2V_{P-P}$, No $R_L$ | | –118/–100 | | dBc |
| IMD3,10M | Third-Order Intermodulation (f1 = 9.5MHz f2 = 10.5MHz) | $V_{OUT}$ = $2V_{P-P}$ Composite, $R_L$ = 200Ω | | –88 | | dBc |
| | | $V_{OUT}$ = $2V_{P-P}$ Composite, No $R_L$ | | –93 | | dBc |
| OIP3,10M | Equivalent Third-Order Output Intercept Point (f1 = 9.5MHz f2 = 10.5MHz) | $V_{OUT}$ = $2V_{P-P}$ Composite, No $R_L$ (Note 7) | | 50.7 | | dBm |
| P1dB,10M | 1dB Compression Point | $R_L$ = 375Ω (Notes 5, 7) | | 17.8 | | dBm |
| NF10M | Noise Figure | $R_L$ = 375Ω (Note 5) | | 12.1 | | dB |
| $e_{IN,10M}$ | Input Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 3.2 | | nV/√Hz |
| $e_{ON,10M}$ | Output Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 8 | | nV/√Hz |
| **70MHz Input Signal** | | | | | | |
| HD2,70M/HD3,70M | Second/Third Order Harmonic Distortion | $V_{OUT}$ = $2V_{P-P}$, $R_L$ = 200Ω | | –91/–72 | | dBc |
| | | $V_{OUT}$ = $2V_{P-P}$, No $R_L$ | | –100/–87 | | dBc |
| IMD3,70M | Third-Order Intermodulation (f1 = 69.5MHz f2 = 70.5MHz) | $V_{OUT}$ = $2V_{P-P}$ Composite, $R_L$ = 200Ω | | –83 | | dBc |
| | | $V_{OUT}$ = $2V_{P-P}$ Composite, No $R_L$ | | –92 | | dBc |
| OIP3,70M | Equivalent Third-Order Output Intercept Point (f1 = 69.5MHz f2 = 70.5MHz) | $V_{OUT}$ = $2V_{P-P}$ Composite, No $R_L$ (Note 7) | | 50 | | dBm |
| P1dB,70M | 1dB Compression Point | $R_L$ = 375Ω (Notes 5, 7) | | 18.3 | | dBm |
| NF70M | Noise Figure | $R_L$ = 375Ω (Note 5) | | 12.2 | | dB |
| $e_{IN,70M}$ | Input Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 3.2 | | nV/√Hz |
| $e_{ON,70M}$ | Output Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 7.9 | | nV/√Hz |

# AC ELECTRICAL CHARACTERISTICS

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

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **140MHz Input Signal** | | | | | | |
| HD2,140M/ HD3,140M | Second/Third Order Harmonic Distortion | $V_{OUT}$ = 2$V_{P-P}$, $R_L$ = 200Ω | | −78/−59 | | dBc |
| | | $V_{OUT}$ = 2$V_{P-P}$, No $R_L$ | | −87/−70 | | dBc |
| IMD3,140M | Third-Order Intermodulation (f1 = 139.5MHz f2 = 140.5MHz) | $V_{OUT}$ = 2$V_{P-P}$ Composite, $R_L$ = 200Ω | | −71 | | dBc |
| | | $V_{OUT}$ = 2$V_{P-P}$ Composite, No $R_L$ | | −80 | | dBc |
| OIP3,140M | Equivalent Third-Order Output Intercept Point (f1 = 139.5MHz f2 = 140.5MHz) | $V_{OUT}$ = 2$V_{P-P}$ Composite, No $R_L$ (Note 7) | | 44.2 | | dBm |
| P1dB,140M | 1dB Compression Point | $R_L$ = 375Ω (Notes 5, 7) | | 18.7 | | dBm |
| NF140M | Noise Figure | $R_L$ = 375Ω (Note 5) | | 12.3 | | dB |
| $e_{IN,140M}$ | Input Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 3.1 | | nV/$\sqrt{Hz}$ |
| $e_{ON,140M}$ | Output Referred Voltage Noise Density | Includes Resistors (Short Inputs) | | 7.9 | | nV/$\sqrt{Hz}$ |
| IMD3,130M/150M | Third-Order Intermodulation (f1 = 130MHz f2 = 150MHz) Measure at 170MHz | $V_{OUT}$ = 2$V_{P-P}$ Composite, $R_L$ = 375Ω | | −75 | −67 | 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°C to 85°C.
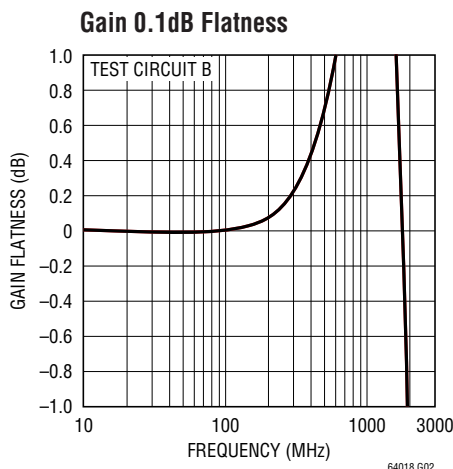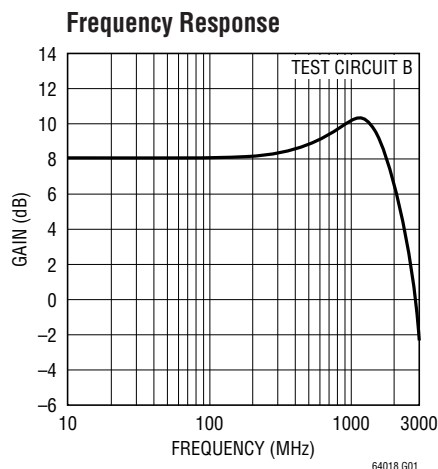
**Note 4:** The LTC6401C is guaranteed to meet specified performance from 0°C to 70°C. It is designed, characterized and expected to meet specified performance from −40°C to 85°C but is not tested or QA sampled at these temperatures. The LTC6401I is guaranteed to meet specified performance from −40°C to 85°C.

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

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

**Note 7:** Since the LTC6401-8 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 LTC6401-8 with amplifiers that require 50Ω output load, the LTC6401-8 output voltage swing driving a given $R_L$ is converted to OIP3 and P$_{1dB}$ as if it were driving a 50Ω load. Using this modified convention, 2$V_{P-P}$ is by definition equal to 10dBm, regardless of actual $R_L$.
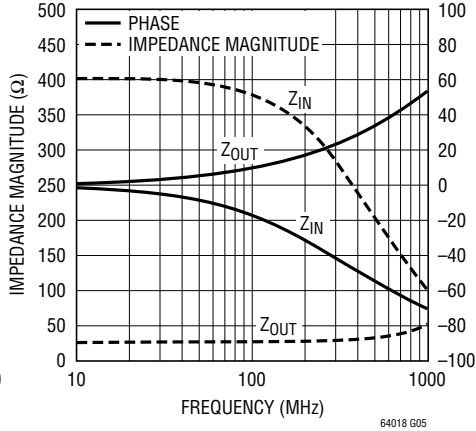
# TYPICAL PERFORMANCE CHARACTERISTICS

### Frequency Response



64018 G01

### Gain 0.1dB Flatness



64018 G02

### S21 Phase and Group Delay vs Frequency



64018 G03
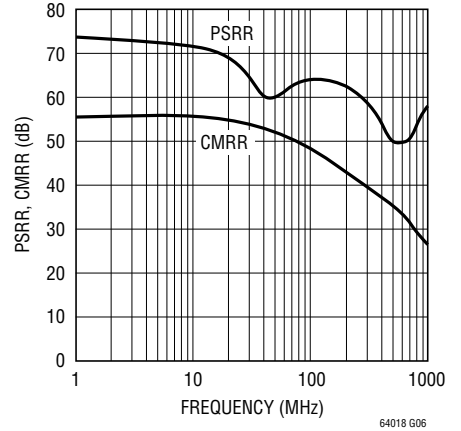
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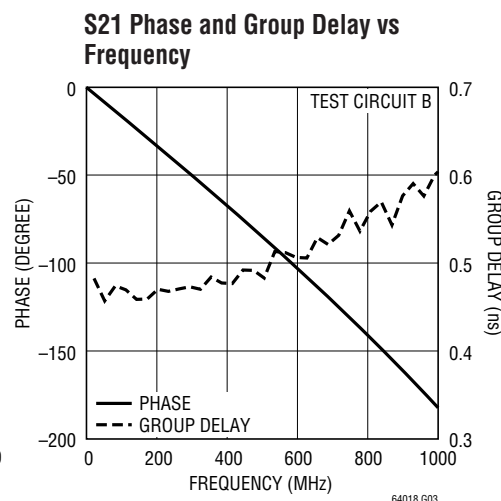
# TYPICAL PERFORMANCE CHARACTERISTICS

### Input and Output Reflection and Reverse Isolation vs Frequency
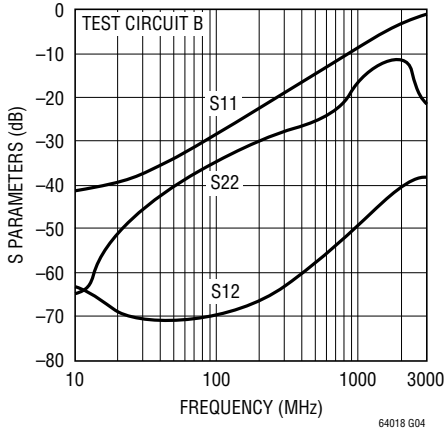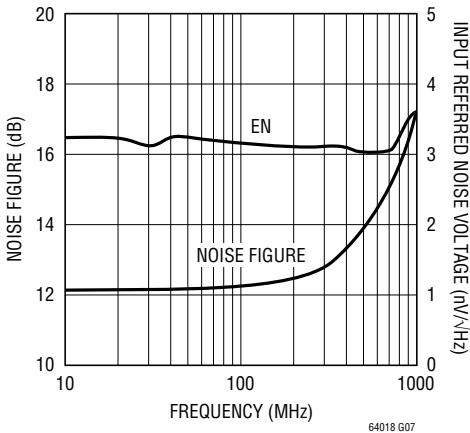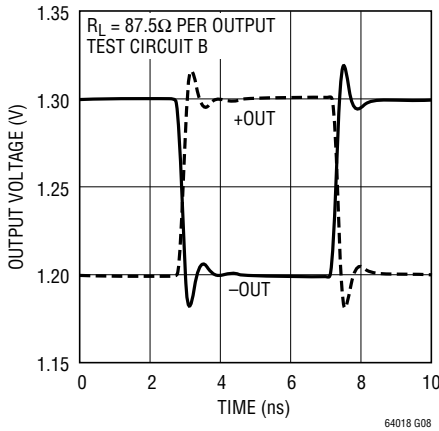
### Input and Output Impedance vs Frequency
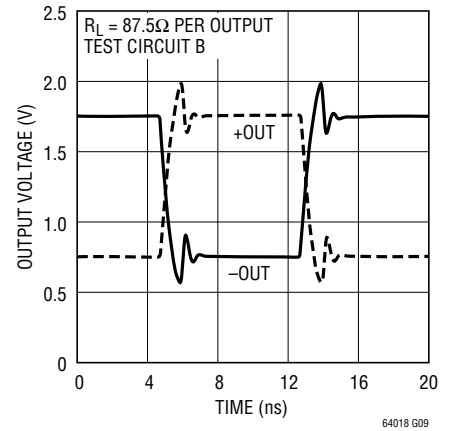
### PSRR and CMRR vs Frequency

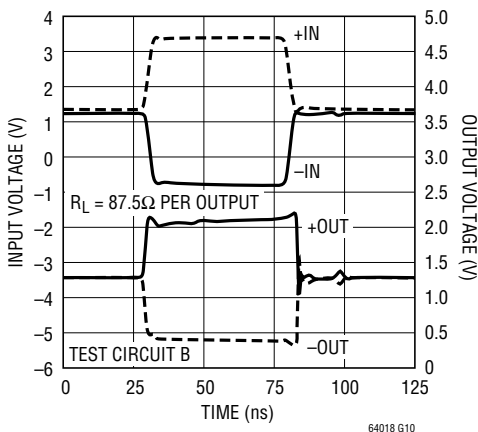### Noise Figure and Input Referred Noise Voltage vs Frequency

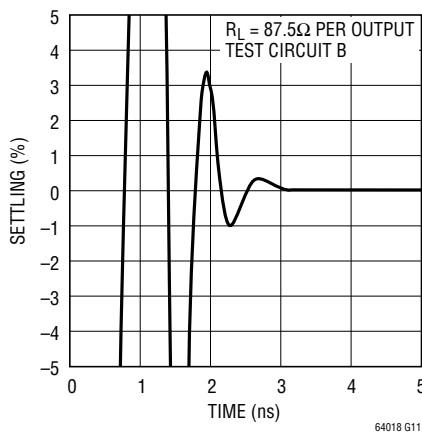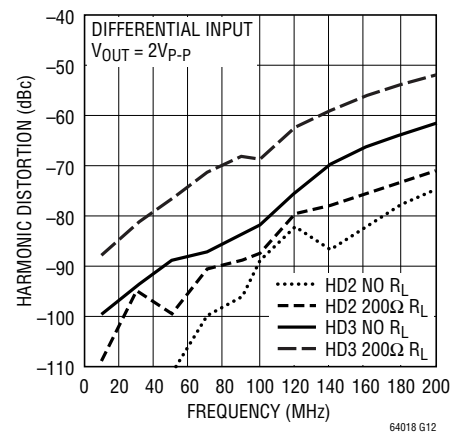### Small Signal Transient Response

### Large Signal Transient Response

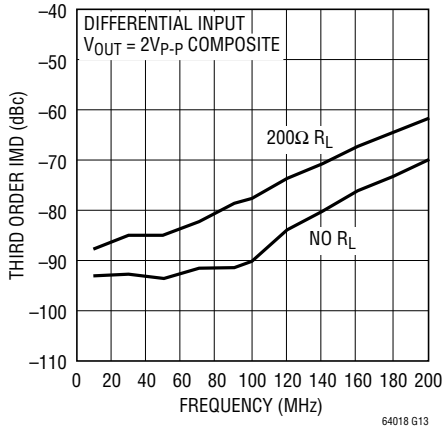### Overdrive Recovery Response

### 1% Settling Time for 2V Output Step

### Harmonic Distortion vs Frequency

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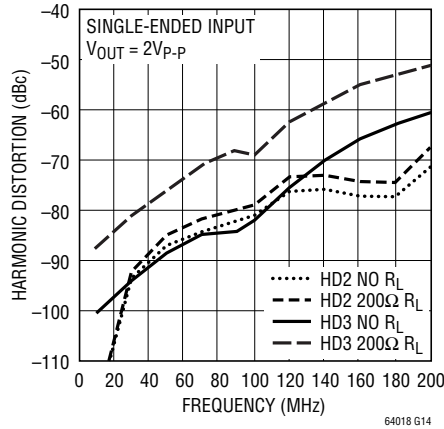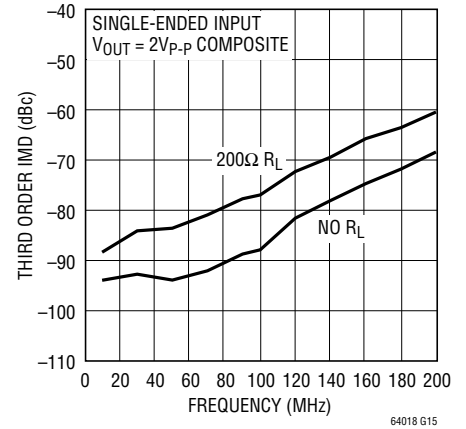
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# TYPICAL PERFORMANCE CHARACTERISTICS

### Third Order Intermodulation Distortion vs Frequency



DIFFERENTIAL INPUT
$V_{OUT}$ = 2$V_{P-P}$ COMPOSITE

200Ω $R_L$

NO $R_L$

THIRD ORDER IMD (dBc)

FREQUENCY (MHz)

64018 G13

### Harmonic Distortion vs Frequency



SINGLE-ENDED INPUT
$V_{OUT}$ = 2$V_{P-P}$

HD2 NO $R_L$
HD2 200Ω $R_L$
HD3 NO $R_L$
HD3 200Ω $R_L$

HARMONIC DISTORTION (dBc)

FREQUENCY (MHz)

64018 G14

### Third Order Intermodulation Distortion vs Frequency



SINGLE-ENDED INPUT
$V_{OUT}$ = 2$V_{P-P}$ COMPOSITE

200Ω $R_L$

NO $R_L$

THIRD ORDER IMD (dBc)

FREQUENCY (MHz)

64018 G15

### Equivalent Output 1dB Compression Point vs Frequency



DIFFERENTIAL INPUT
$R_L$ = 375Ω
TEST CIRCUIT A (NOTE 7)

OUTPUT 1dB COMPRESSION POINT (dBm)

FREQUENCY (MHz)

64018 G16
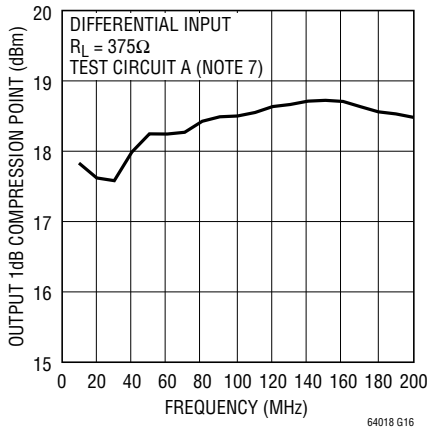
### Equivalent Output Third Order Intercept Point vs Frequency



NO $R_L$

200Ω $R_L$

DIFFERENTIAL INPUT
(NOTE 7)

OUTPUT IP3 (dBm)

FREQUENCY (MHz)

64018 G17

### Turn-On Time



$I_{CC}$

−OUT

+OUT

ENABLE

$R_L$ = 87.5Ω PER OUTPUT

VOLTAGE (V)

$I_{CC}$ (mA)

TIME (ns)

64018 G18

### Turn-Off Time



$R_L$ = 87.5Ω PER OUTPUT

+OUT

−OUT

ENABLE

$I_{CC}$

VOLTAGE (V)

$I_{CC}$ (mA)

TIME (ns)

64018 G19
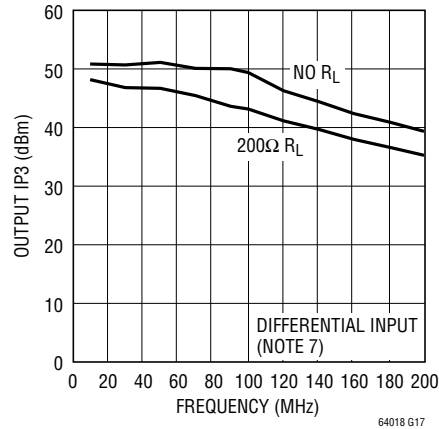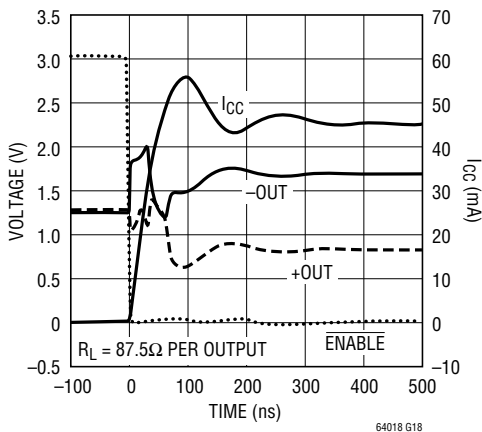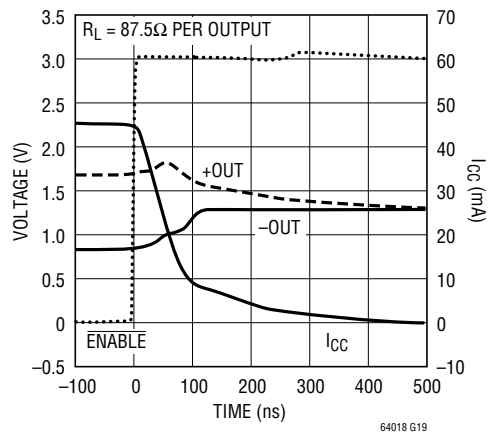
# PIN FUNCTIONS

**V⁺ (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.

**$V_{OCM}$ (Pin 2):** This pin sets the output common mode voltage. A 0.1μF external bypass capacitor is recommended.

**V⁻ (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 resistors, $R_{OUT}$ 12.5Ω.

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

**$\overline{ENABLE}$ (Pin 11):** This pin is a logic input referenced to $V_{EE}$. 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⁻. The Exposed Pad must be connected to same voltage/ground as pins 4, 9, 12.

# BLOCK DIAGRAM
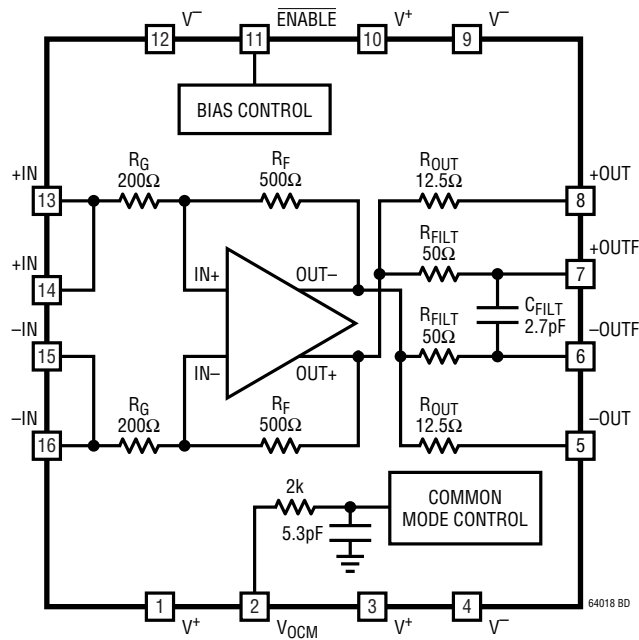
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# APPLICATIONS INFORMATION

## Circuit Operation

The LTC6401-8 is a low noise and low distortion fully differential op amp/ADC driver with:

- Operation from DC to 2.2GHz –3dB bandwidth

- Fixed gain of 2.5V/V (8dB)

- Differential input impedance 400Ω

- Differential output impedance 25Ω

- Differential impedance of output filter 100Ω

The LTC6401-8 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 200Ω/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 LTC6401-8 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 approximately 250mV above $V_{OCM}$ and thus no external circuitry is needed for bias. The LTC6401-8 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 LTC6401-8 is 400Ω. Usually the differential inputs need to be terminated to a lower value impedance, e.g. 50Ω, in order to provide an impedance match for the source. Several choices are available. One approach is to use a differential shunt resistor (Figure 1). Another approach is to employ a wideband transformer and shunt resistor (Figure 2). Both methods provide a wideband match. The termination resistor or the transformer must be placed close to the input pins in order to minimize the reflection due to input mismatch. Alternatively, one could apply a narrowband impedance match at the inputs of the LTC6401-8 for frequency selection and/or noise reduction.
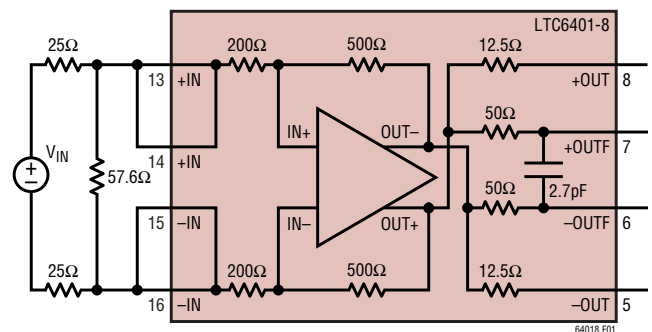


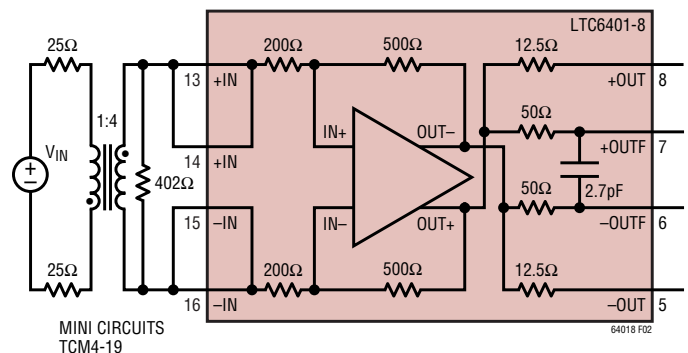**Figure 1. Input Termination for Differential 50Ω Input Impedance Using Shunt Resistor**



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

# APPLICATIONS INFORMATION

Referring to Figure 3, LTC6401-8 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 322Ω and $R_T$ is 59Ω in order to match to a 50Ω source impedance.
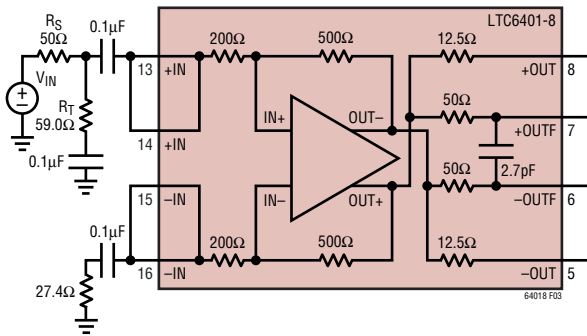


**Figure 3. Input Termination for Single-Ended 50Ω Input Impedance**

The LTC6401-8 is unconditionally stable, i.e. differential stability factor Kf>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:

$$A_V = \left| \frac{V_{OUT}}{V_{IN}} \right| = \frac{1000}{R_S + 400} \cdot \frac{R_L}{25 + R_L}$$

The noise performance of the LTC6401-8 also depends upon the source impedance and termination. For example, an input 1:4 transformer in Figure 2 improves SNR by adding 6dB gain at the inputs. A trade-off between gain
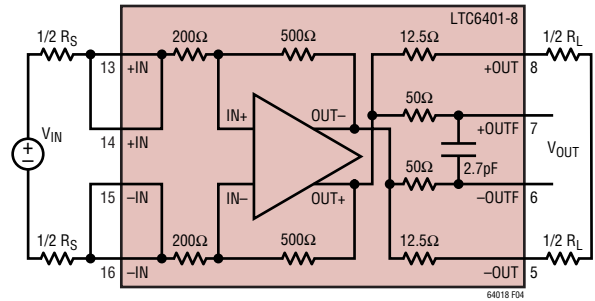


**Figure 4. Calculate Differential Gain**

and noise is obvious when constant noise figure circle and constant gain circle are plotted within the 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 LTC6401-8 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.

The internal low pass filter outputs at +OUTF/–OUTF have a –3dB bandwidth of 590MHz. External capacitors can reduce the lowpass filter bandwidth as shown in Figure 5. A bandpass filter is easily implemented with
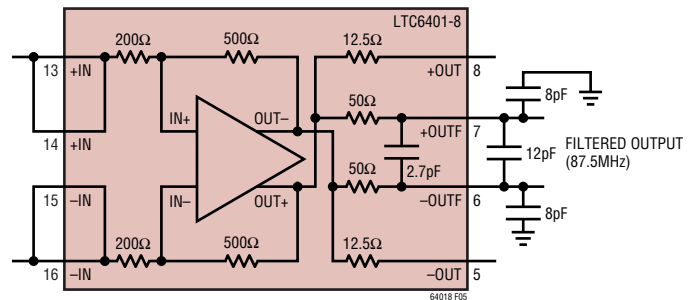


**Figure 5. LTC6401-8 Internal Filter Topology Modified for Low Filter Bandwidth (Three External Capacitors)**

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# APPLICATIONS INFORMATION

only a few components as shown in Figure 6. Three 39pF capacitors and a 16nH inductor create a bandpass filter with 165MHz center frequency, –3dB frequencies at 138MHz and 200MHz.
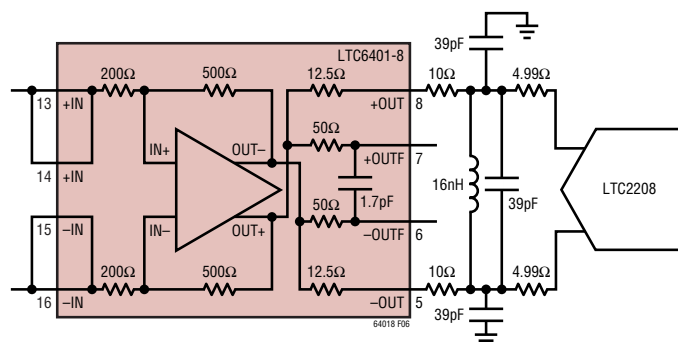


**Figure 6. LTC6401-8 Modified 165MHz for Bandpass Filtering (Three External Capacitors, One External Inductor)**

## Output Common Mode Adjustment

The LTC6401-8'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 14MHz, 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 –3dB bandwidth around 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 LT22xx families, the $V_{OCM}$ pin can be connected to the $V_{CM}$ pin of the ADC.

## Driving A/D Converters

The LTC6401-8 has been specifically designed to interface directly with high speed A/D converters. Figure 7 shows the
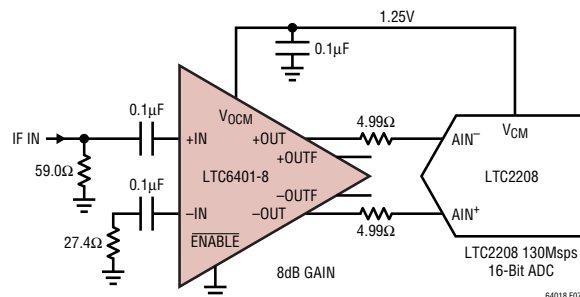


**Figure 7. Single-Ended Input to LTC6401-8 and LTC2208**

LTC6401-8 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. $V_{OCM}$ of the LTC6401-8 is connected to $V_{CM}$ of the LTC2208 at 1.25V. Alternatively, an input single-ended signal can be converted to differential signal via a balun and fed to the input of the LTC6401-8.

Figure 8 summarizes the IMD3 performance of the whole system as shown in Figure 7.
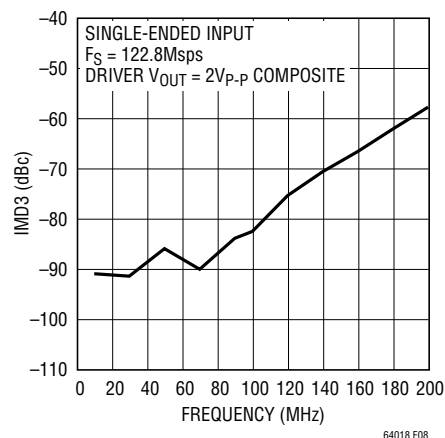


**Figure 8. IMD3 for the Combination of LTC6401-8 and LTC2208**

# APPLICATIONS INFORMATION

**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 2.2GHz to approximately 1.65GHz.

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.
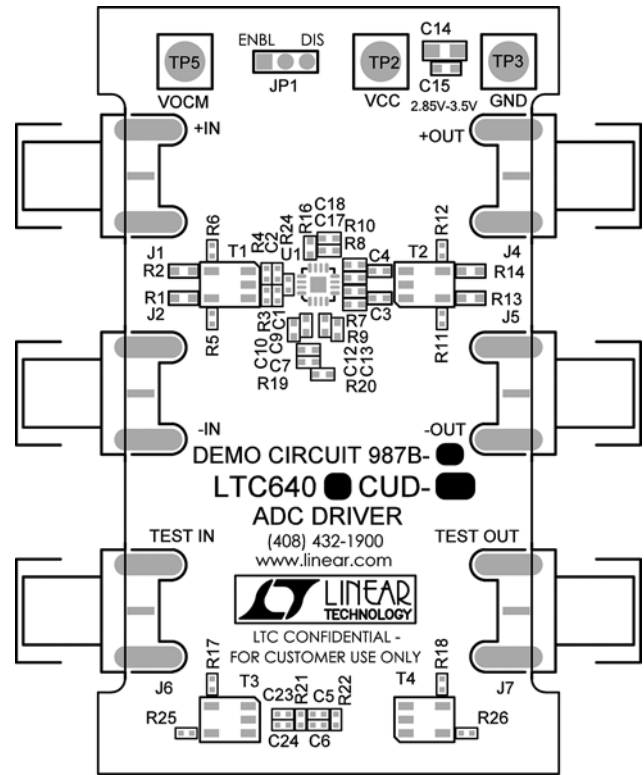


**Figure 9. Top Silkscreen for DC987B. Test Circuit A**

# TYPICAL APPLICATIONS

## Demo Circuit 987B Schematic (Test Circuit A)



| VERSION | IC | R3 | R4 | T1 | SL1 | SL2 | SL3 |
|---------|-----|-----|-----|-----|-----|-----|-----|
| -E | LTC6401CUD-8 | 200Ω | 200Ω | MINI-CIRCUITS TCM4-19 (1:4) | 6dB | 8dB | 2dB |

SL = SIGNAL LEVEL

NOTE: UNLESS OTHERWISE SPECIFIED.
(1) DO NOT STUFF.
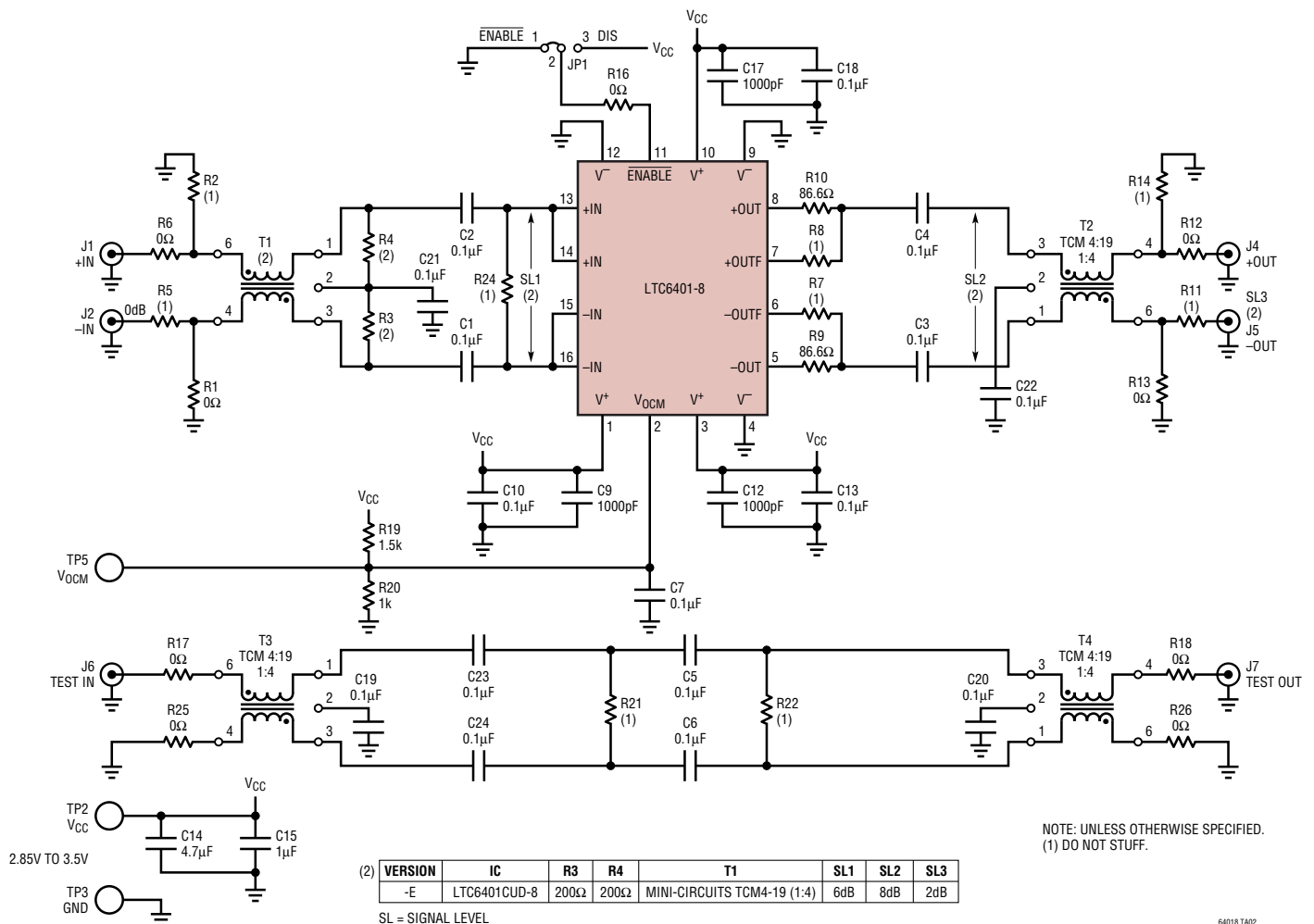
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# TYPICAL APPLICATIONS

**Test Circuit B, 4-Port Analysis**

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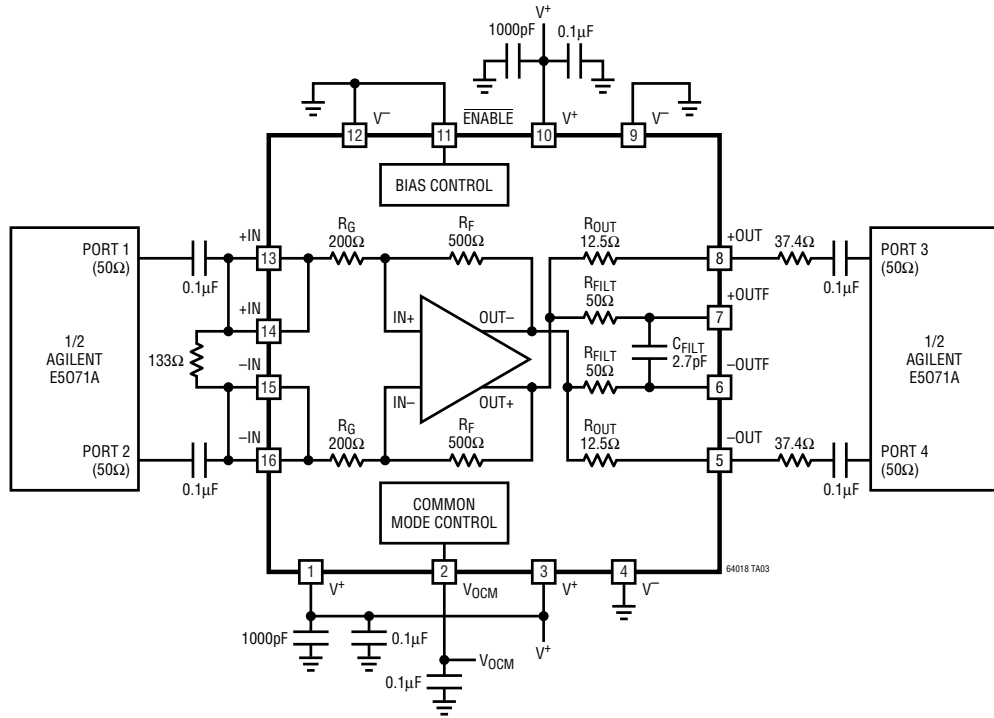
# PACKAGE DESCRIPTION

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

RECOMMENDED SOLDER PAD PITCH AND DIMENSIONS

3.50 ± 0.05

2.10 ± 0.05

1.45 ± 0.05 (4 SIDES)

0.70 ±0.05

PACKAGE OUTLINE

0.25 ±0.05

0.50 BSC

BOTTOM VIEW—EXPOSED PAD
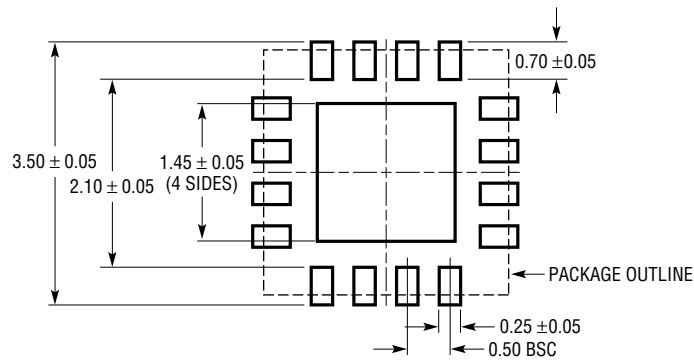
3.00 ± 0.10 (4 SIDES)

0.75 ± 0.05

PIN 1 TOP MARK (NOTE 6)

R = 0.115 TYP

PIN 1 NOTCH R = 0.20 TYP OR 0.25 × 45° CHAMFER

15   16

0.40 ± 0.10

1

2

1.45 ± 0.10 (4-SIDES)

(UD16) QFN 0904

0.200 REF

0.00 – 0.05

0.25 ± 0.05

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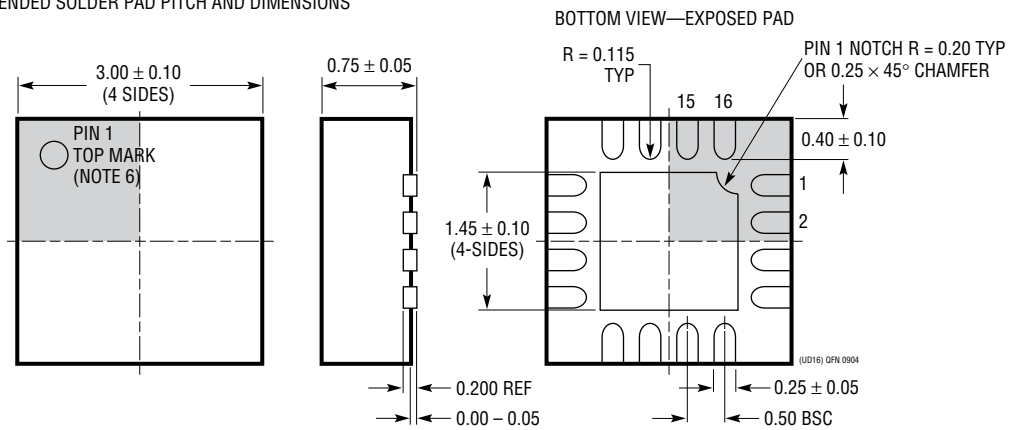
NOTE:
1. DRAWING CONFORMS TO JEDEC PACKAGE OUTLINE MO-220 VARIATION (WEED-2)
2. DRAWING NOT TO SCALE
3. ALL DIMENSIONS ARE IN MILLIMETERS
4. DIMENSIONS OF EXPOSED PAD ON BOTTOM OF PACKAGE DO NOT INCLUDE
   MOLD FLASH. MOLD FLASH, IF PRESENT, SHALL NOT EXCEED 0.15mm ON ANY SIDE
5. EXPOSED PAD SHALL BE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

## RELATED PARTS

| PART NUMBER | DESCRIPTION | COMMENTS |
|---|---|---|
| **High-Speed Differential Amplifiers/Differential Op Amps** | | |
| LT®1993-2 | 800MHz Differential Amplifier/ADC Driver | $A_V$ = 2V/V, OIP3 = 38dBm at 70MHz |
| LT1993-4 | 900MHz Differential Amplifier/ADC Driver | $A_V$ = 4V/V, OIP3 = 40dBm at 70MHz |
| LT1993-10 | 700MHz Differential Amplifier/ADC Driver | $A_V$ = 10V/V, OIP3 = 40dBm at 70MHz |
| LT1994 | Low Noise, Low Distortion Differential Op Amp | 16-Bit SNR and SFDR at 1MHz, Rail-to-Rail Outputs |
| LT5514 | Ultralow Distortion IF Amplifier/ADC Driver with Digitally Controlled Gain | OIP3 = 47dBm at 100MHz, Gain Control Range 10.5dB to 33dB |
| LT5524 | Low Distortion IF Amplifier/ADC Driver with Digitally Controlled Gain | OIP3 = 40dBm at 100MHz, Gain Control Range 4.5dB to 37dB |
| LTC6400-20 | 1.8GHz Low Noise, Low Distortion, Differential ADC Driver | $A_V$ = 20dB, 90mA Supply Current, IMD3 = –65dBc at 300MHz |
| LTC6400-26 | 1.9GHz Low Noise, Low Distortion, Differential ADC Driver | $A_V$ = 26dB, 85mA Supply Current, IMD3 = –71dBc at 300MHz |
| LTC6401-20 | 1.3GHz Low Noise, Low Distortion, Differential ADC Driver | $A_V$ = 20dB, 50mA Supply Current, IMD3 = –74dBc at 140MHz |
| LTC6401-26 | 1.6GHz Low Noise, Low Distortion, Differential ADC Driver | $A_V$ = 26dB, 45mA Supply Current, IMD3 = –72dBc at 140MHz |
| LT6402-6 | 300MHz Differential Amplifier/ADC Driver | $A_V$ = 6dB, Distortion < –80dBc at 25MHz |
| LT6402-12 | 300MHz Differential Amplifier/ADC Driver | $A_V$ = 12dB, Distortion < –80dBc at 25MHz |
| LT6402-20 | 300MHz Differential Amplifier/ADC Driver | $A_V$ = 20dB, Distortion < –80dBc at 25MHz |
| LTC6404-1 | 600MHz Low Noise Differential ADC Driver | $e_n$ = 1.5nV/$\sqrt{\text{Hz}}$, Rail-to-Rail Outputs |
| LTC6406 | 3GHz Rail-to-Rail Input Differential Op Amp | 1.6nV/$\sqrt{\text{Hz}}$ Noise, –72dBc Distortion at 50MHz, 18mA |
| LT6411 | Low Power Differential ADC Driver/Dual Selectable Gain Amplifier | 16mA Supply Current, IMD3 = –83dBc at 70MHz, $A_V$ = 1, –1 or 2 |
| **High-Speed Single-Ended Output Op Amps** | | |
| LT1812/LT1813/LT1814 | High Slew Rate Low Cost Single/Dual/Quad Op Amps | 8nV/$\sqrt{\text{Hz}}$ Noise, 750V/µs, 3mA Supply Current |
| LT1815/LT1816/LT1817 | Very High Slew Rate Low Cost Single/Dual/Quad Op Amps | 6nV/$\sqrt{\text{Hz}}$ Noise, 1500V/µs, 6.5mA Supply Current |
| LT1818/LT1819 | Ultra High Slew Rate Low Cost Single/Dual Op Amps | 6nV/$\sqrt{\text{Hz}}$ Noise, 2500V/µs, 9mA Supply Current |
| LT6200/LT6201 | Rail-to-Rail Input and Output Low Noise Single/Dual Op Amps | 0.95nV/$\sqrt{\text{Hz}}$ Noise, 165MHz GBW, Distortion = –80dBc at 1MHz |
| LT6202/LT6203/LT6204 | Rail-to-Rail Input and Output Low Noise Single/Dual/Quad Op Amps | 1.9nV/$\sqrt{\text{Hz}}$ Noise, 3mA Supply Current, 100MHz GBW |
| LT6230/LT6231/LT6232 | Rail-to-Rail Output Low Noise Single/Dual/Quad Op Amps | 1.1nV/$\sqrt{\text{Hz}}$ Noise, 3.5mA Supply Current, 215MHz GBW |
| LT6233/LT6234/LT6235 | Rail-to-Rail Output Low Noise Single/Dual/Quad Op Amps | 1.9nV/$\sqrt{\text{Hz}}$ Noise, 1.2mA Supply Current, 60MHz GBW |
| **Integrated Filters** | | |
| LTC1562-2 | Very Low Noise, 8th Order Filter Building Block | Lowpass and Bandpass Filters up to 300kHz |
| LT1568 | Very Low Noise, 4th Order Filter Building Block | Lowpass and Bandpass Filters up to 10MHz |
| LTC1569-7 | Linear Phase, Tunable 10th Order Lowpass Filter | Single-Resistor Programmable Cut-Off to 300kHz |
| LT6600-2.5 | Very Low Noise Differential 2.5MHz Lowpass Filter | SNR = 86dB at 3V Supply, 4th Order Filter |
| LT6600-5 | Very Low Noise Differential 5MHz Lowpass Filter | SNR = 82dB at 3V Supply, 4th Order Filter |
| LT6600-10 | Very Low Noise Differential 10MHz Lowpass Filter | SNR = 82dB at 3V Supply, 4th Order Filter |
| LT6600-15 | Very Low Noise Differential 15MHz Lowpass Filter | SNR = 76dB at 3V Supply, 4th Order Filter |
| LT6600-20 | Very Low Noise Differential 20MHz Lowpass Filter | SNR = 76dB at 3V Supply, 4th Order Filter |

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