OPA818 2.7-GHz, 13-V, Gain of 7-V/V Stable, FET-Input Operational Amplifier

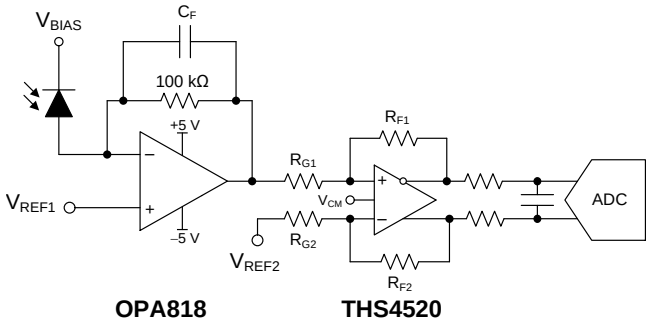
1 Features

- High speed:
  - Gain-bandwidth product: 2.7 GHz
  - Bandwidth (G = 7 V/V): 790 MHz
  - Large-signal bandwidth (2 V_{PP}): 400 MHz
  - Slew rate: 1400 V/µs
- Decompensated gain: 7-V/V stable
- Low noise:
  - Input voltage noise: 2.2 nV/√Hz
  - Input current noise: 2.5 fA/√Hz (f = 10 kHz)
- Input bias current: 4 pA (typ)
- Low input capacitance:
  - Common-mode: 1.9 pF
  - Differential mode: 0.5 pF
- Low distortion (G = 7 V/V, R_L = 1 kΩ, V_O = 2 V_{PP}):
  - HD2, HD3 at 1 MHz: –90 dBc, –96 dBc
  - HD2, HD3 at 50 MHz: –57 dBc, –72 dBc
- Wide supply range: 6 V to 13 V
- Output swing: 8 V_{PP} (V_S = 10 V)
- Supply current: 27.7 mA
- Shutdown supply current: 27 µA
- Temperature range: –40°C to +85°C

2 Applications

- Wideband transimpedance amplifiers (TIAs)
- Wafer scanning equipment
- Optical communication modules
- Optical time-domain reflectometry (OTDR)
- High-speed, high-gain, data acquisition
- Test and measurement front-end
- Medical and chemical analyzers

High-Speed Optical Front-End



3 Description

The OPA818 is a decompensated (gain = 7 V/V stable), voltage-feedback operational amplifier with a low-noise junction gate field-effect transistor (JFET) input stage that combines high gain-bandwidth with a wide supply range from 6 V to 13 V for high-speed and wide dynamic range applications. This amplifier is manufactured using Texas Instruments' proprietary, high-speed, silicon-germanium (SiGe) process to achieve significant performance improvements over other high-speed, FET-input amplifiers. A fast slew rate (1400 V/µs) provides high large-signal bandwidth and low distortion.

The 2.7-GHz gain-bandwidth, low 2.4-pF total input capacitance, and 2.2 nV/√Hz of noise makes the OPA818 an extremely versatile, wideband TIA photodiode amplifier for use in optical test and communication equipment, and many medical, scientific, and industrial instruments. The OPA818 can achieve over 85-MHz signal bandwidth in TIA configuration with 20-kΩ TIA gain (R_F) and 0.5-pF photodiode capacitance (C_D) with wide output swings. The decompensated, low-noise architecture with pico amperes of input bias current is also well-suited for high-gain test and measurement applications that have variable or high source impedance. Though normally stable in gains ≥ 7 V/V, the OPA818 can be used in applications with lower gains by applying noise-gain shaping techniques.

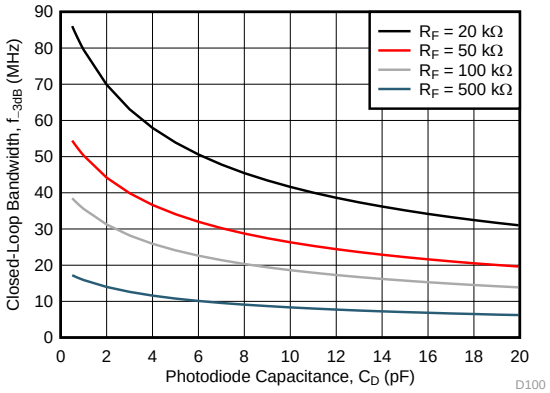
The OPA818 is available in an 8-lead WSON package with an exposed thermal pad for heat dissipation. This device is specified to operate over the industrial temperature range of –40°C to +85°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA818	WSON (8)	3.00 mm × 3.00 mm

(1) For all available packages, see the package option addendum at the end of the data sheet.

Photodiode Capacitance vs 3-dB Bandwidth



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Table of Contents

1 Features ... 1
2 Applications ... 1
3 Description ... 1
4 Revision History ... 2
5 Pin Configuration and Functions ... 3
6 Specifications ... 4
6.1 Absolute Maximum Ratings ... 4
6.2 ESD Ratings ... 4
6.3 Recommended Operating Conditions ... 4
6.4 Thermal Information ... 4
6.5 Electrical Characteristics: V_S = ±5 V ... 5
6.6 Typical Characteristics: V_S = ±5 V ... 7
7 Detailed Description ... 8
7.1 Overview ... 8
7.2 Functional Block Diagram ... 8
7.3 Feature Description ... 8
7.4 Device Functional Modes ... 11
8 Application and Implementation ... 12
8.1 Application Information ... 12
8.2 Typical Application ... 13
9 Power Supply Recommendations ... 16
10 Layout ... 17
10.1 Layout Guidelines ... 17
10.2 Layout Example ... 18
11 Device and Documentation Support ... 20
11.1 Receiving Notification of Documentation Updates 20
11.2 Community Resources ... 20
11.3 Trademarks ... 20
11.4 Electrostatic Discharge Caution ... 20
11.5 Glossary ... 20
12 Mechanical, Packaging, and Orderable Information ... 20
12.1 Package Option Addendum ... 21

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4 Revision History

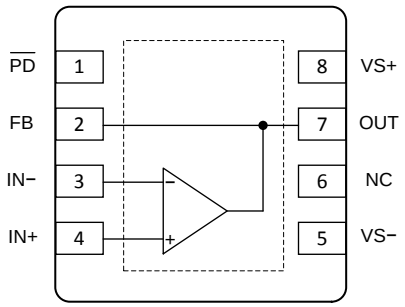
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
May 2019	*	Initial release.

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5 Pin Configuration and Functions

DRG Package
8-Pin WSON With Thermal Pad
Top View



NC - no internal connection

Pin Functions

PIN		TYPE	DESCRIPTION
NAME	WSON		
FB	2	Output	Feedback resistor connection (optional)
IN–	3	Input	Inverting input
IN+	4	Input	Noninverting input
NC	6	—	No connect (no internal connection to die)
OUT	7	Output	Output of amplifier
$\overline{PD}$	1	Input	Power down
VS–	5	Power	Negative power supply
VS+	8	Power	Positive power supply
Thermal pad		—	Electrically isolated from the die. Recommended connection to a heat spreading plane, typically GND.

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Voltage	Supply voltage, (V_{S+}) – ($V_{S–}$)		13.5	V
Voltage	Differential input voltage		±5	V
	Common-mode input voltage		$V_{S–}$ + 10	V
Current	Continuous input current		±10	mA
	Continuous output current(2)		45	
	Continuous current in feedback pin(2)		13	mA
Temperature	Junction temperature, T_J		105	°C
	Operating free-air, T_A	–40	85	
	Storage temperature, T_{stg}	–65	150	

(1) Stresses beyond those listed under *Absolute Maximum Rating* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Long-term continuous current for electromigration limits.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, allpins(1)	±TBD	V
		Charged device model (CDM), per JEDEC specificationJESD22-C101, all pins(2)	±TBD	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
V_S	Single-supply voltage	6	10	13	V
T_A	Ambient temperature	–40	25	85	°C

6.4 Thermal Information

THERMAL METRIC(1)		OPA818 DRG (SON) 8 PINS	UNIT
$R_{θJA}$	Junction-to-ambient thermal resistance	54.6	°C/W
$R_{θJC(top)}$	Junction-to-case (top) thermal resistance	56.0	°C/W
$R_{θJB}$	Junction-to-board thermal resistance	27.2	°C/W
$Ψ_{JT}$	Junction-to-top characterization parameter	1.8	°C/W
$Ψ_{JB}$	Junction-to-board characterization parameter	27.2	°C/W
$R_{θJC(bot)}$	Junction-to-case (bottom) thermal resistance	11.1	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.

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6.5 Electrical Characteristics: V_S = ±5 V

at T_A ≈ 25°C, V_{S+} = +5 V, $V_{S–}$ = –5 V, closed-loop gain (G) = 7 V/V, common-mode voltage (V_{CM}) = midsupply, R_F = 301 Ω, R_L = 100 Ω to midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
AC PERFORMANCE							
SSBW	Small-signal bandwidth	V_O = 100 mV_{PP}			790		MHz
		G = 10, V_O = 100 mV_{PP}			440		
PM	Phase margin				50		°
	Frequency response peaking				1.4		dB
LSBW	Large-signal bandwidth	V_O = 2 V_{PP}			400		MHz
GBWP	Gain-bandwidth product	G = 101 V/V, V_O = 100 mV_{PP}, R_F = 3.01 kΩ			2700		MHz
	Bandwdith for 0.1dB flatness	V_O = 100 mV_{PP}			125		MHz
SR	Slew rate (20%-80%)	V_O = 4-V step, rising and falling			1400		V/µs
		V_O = 4-V step, rising and falling, G = 10			1340		V/µs
t_r/t_f	Rise and fall time (10%-90%)	V_O = 350-mV step (input t_r/t_f = 0.4 ns)			0.52		ns
t_S	Settling time to 0.1%	V_O = 2-V step (input t_r = 0.8 ns)			5.7		ns
t_S	Settling time to 0.01%	V_O = 2-V step (input t_r = 0.8 ns)			12		ns
	Overshoot and undershoot	V_O = 2-V step (input t_r/t_f = 0.8 ns)			0.2%		
	Overdrive recovery time	V_O = ($V_{S–}$ – 1 V) to (V_{S+} + 1 V)					ns
HD2	Second-order harmonic distortion	V_O = 2 V_{PP}	f = 1 MHz		–84		dBc
			f = 10 MHz		–64		
			f = 50 MHz		–52		
		V_O = 2 V_{PP}, R_L = 1 kΩ,	f = 10 MHz		–71		
HD3	Third-order harmonic distortion	V_O = 2 V_{PP}	f = 1 MHz		–106		dBc
			f = 10 MHz		–96		
			f = 50 MHz		–74		
		V_O = 2 V_{PP}, R_L = 1 kΩ,	f = 10 MHz		–82		
e_n	Input voltage noise	f ≥ 150 kHz			2.2		nV/√Hz
		1/f corner			15		kHz
i_n	Input current noise	f = 10 kHz			2.5		fA/√Hz
		f = 1 MHz			145		fA/√Hz
Z_O	Closed-loop output impedance	f = 10 MHz			0.2		Ω
DC PERFORMANCE							
A_{OL}	Open-loop voltage gain	f = DC, V_O = ±2 V		85	92		dB
V_{OS}	Input offset voltage				0.35	1.25	mV
		T_A = –40°C to +85°C				1.8	
	Input offset voltage drift(1)	T_A = –40°C to +85°C			3	20	µV/°C
I_B	Input bias current(2)			–20	4	20	pA
		T_A = –40°C to +85°C		–500		500	
I_{OS}	Input offset current(2)			–20	1	20	pA
		T_A = –40°C to +85°C		–500		500	
CMRR	Common-mode rejection ratio	f = DC, V_{CM} = ±0.5 V		73	90		dB
		f = DC, V_{CM} = ±0.5 V, T_A = –40°C to +85°C		70			dB
	Internal feedback trace resistance	Device turned OFF, OUT to FB pin resistance		1.2	1.6	2	Ω

(1) Input offset voltage drift and input bias current drift are average values calculated by taking data at the end-points, computing the difference, and dividing by the temperature range.
(2) Current is considered positive out of the pin. I_{OS} = I_{B+} – $I_{B–}$.

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Electrical Characteristics: V_S = ±5 V (continued)

at T_A ≈ 25°C, V_{S+} = +5 V, $V_{S–}$ = –5 V, closed-loop gain (G) = 7 V/V, common-mode voltage (V_{CM}) = midsupply, R_F = 301 Ω, R_L = 100 Ω to midsupply (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT						
	Common-mode input impedance			500 || 1.9		GΩ || pF
	Differential input impedance			500 || 0.5		GΩ || pF
	Most positive input voltage(3)		V_{S+} – 3.6	V_{S+} – 3.2		V
	Most negative input voltage(3)			$V_{S–}$	$V_{S–}$ + 0.25	V
	ΔV_{OS} at most positive input voltage(4)	V_{CM} = V_{S+} – 3.6 V	–1	0.03	1	mV
		V_{CM} = V_{S+} – 3.6 V, T_A = -40°C to +85°C	–1.5		–1.5	mV
	ΔV_{OS} at most negative input voltage(4)	V_{CM} = $V_{S–}$ + 0.25 V	–1	–0.23	1	mV
		V_{CM} = $V_{S–}$ + 0.25 V, T_A = -40°C to +85°C	–1.5		–1.5	mV
OUTPUT						
V_{OH}	Output voltage swing high		V_{S+} – 1.2	V_{S+} – 1		V
		T_A = –40°C to +85°C	V_{S+} – 1.3			V
		R_L = 1 kΩ	V_{S+} – 1	V_{S+} – 0.9		V
		R_L = 1 kΩ, T_A = –40°C to +85°C	V_{S+} – 1.2			V
V_{OL}	Output voltage swing low			$V_{S–}$ + 1.2	$V_{S–}$ + 1.33	V
		T_A = –40°C to +85°C			$V_{S–}$ + 1.4	V
		R_L = 1 kΩ		$V_{S–}$ + 1.1	$V_{S–}$ + 1.2	V
		R_L = 1 kΩ, T_A = –40°C to +85°C			$V_{S–}$ + 1.3	V
I_{O_MAX}	Linear output drive	V_{OUT} = ±2.75 V, R_L to midsupply = 50 Ω, [ΔV_{OS} from no-load V_{OS}] ≤ 1 mV	±55			mA
		V_{OUT} = ±2.5 V, R_L to midsupply = 50 Ω, [ΔV_{OS} from no-load V_{OS}] ≤ 1 mV, T_A = –40°C to +85°C	±50			mA
I_{SC}	Output short-circuit current			±100		mA
C_{LOAD}	Capacitive load drive	30% overshoot, V_{OUT} step = 200 mV		2		pF
		G = 10, 30% overshoot		2		pF
POWER SUPPLY						
V_S	Single-supply operating range		6	10	13	V
I_Q	Quiescent current per channel	No load	27	27.7	29	mA
		No load, T_A = –40°C to +85°C	23		31.5	mA
	I_Q drift	No load, T_A = –40°C to +85°C		42		µA/°C
PSRR+	Positive power supply rejection ratio	ΔV_{S+} = ±0.25 V	75	95		dB
		ΔV_{S+} = ±0.25 V, T_A = –40°C to +85°C	70			dB
PSRR–	Negative power supply rejection ratio	$\Delta V_{S–}$ = ±0.25 V	80	94		dB
		$\Delta V_{S–}$ = ±0.25 V, T_A = –40°C to +85°C	74			dB
POWER DOWN						
V_{TH_EN}	Enable voltage threshold	Power on when $\overline{PD}$ > V_{TH_EN}, No Load	V_{S+} – 1			V
V_{TH_DIS}	Disable voltage threshold	Power down when $\overline{PD}$ < V_{TH_DIS}, No Load			V_{S+} – 3	V
	Power-down V_{CC} I_Q	No Load		27	40	µA
	$\overline{PD}$ pin bias current(2)	No load, $\overline{PD}$ = V_{S+}	–3	–2		µA
		No load, $\overline{PD}$ = $V_{S–}$		13	20	µA
	Turnon time delay	Time to V_O = 90% of final value		270		ns
	Turnoff time delay	Time to V_O = 10% of original value		230		ns

(3) Defined by ΔV_{OS} at most positive/negative input voltage specification
(4) ΔV_{OS} = |V_{OS} at specified V_{CM} – V_{OS} at 0 V V_{CM}|

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6.6 Typical Characteristics: V_S = ±5 V

at T_A ≈ 25°C, V_{S+} = +5 V, $V_{S–}$ = –5 V, closed-loop gain (G) = 7 V/V, V_{CM} = midsupply, R_F = 301 Ω, R_L = 100 Ω to midsupply, small-signal V_O = 100 mV_{PP}, large-signal V_O = 2 V_{PP} (unless otherwise noted)

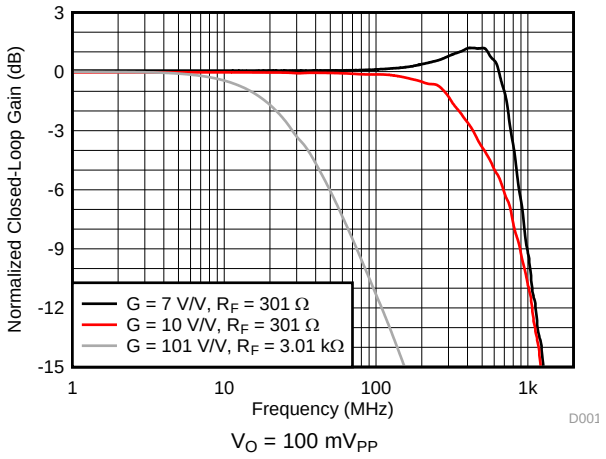


Figure 1. Noninverting Small-Signal Frequency Response

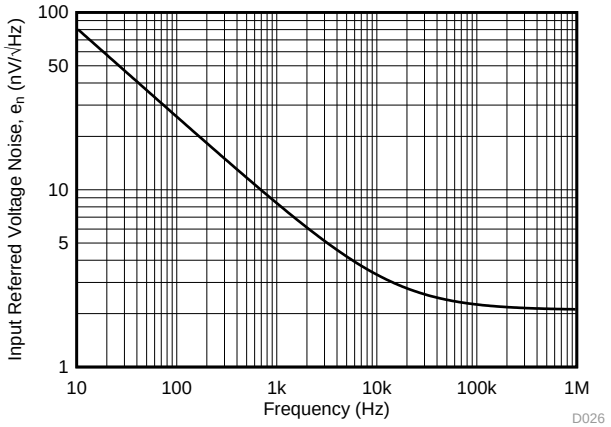


Figure 2. Voltage Noise Density Vs Frequency

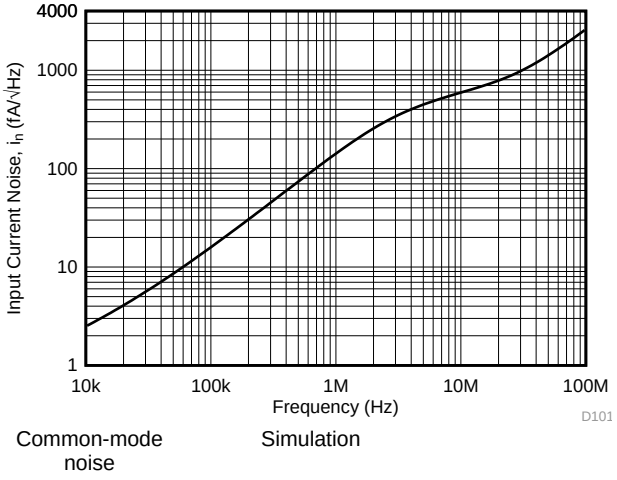


Figure 3. Current Noise Density Vs Frequency

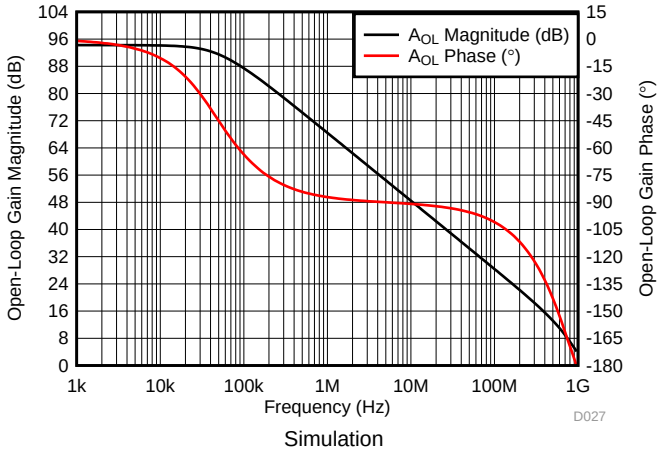


Figure 4. Open-Loop Gain Magnitude and Phase Vs Frequency

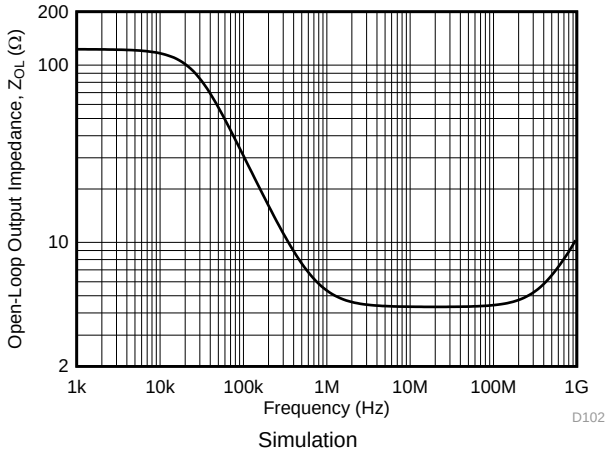


Figure 5. Open-Loop Output Impedance Vs Frequency

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7 Detailed Description

7.1 Overview

The OPA818 is a 13 V supply, 2.7 GHz gain-bandwidth product (GBWP), voltage feedback operational amplifier (op amp) featuring a 2.2nV/√Hz low noise JFET input stage. The OPA818 is decompensated to be normally stable in gains ≥ 7 V/V. The decompensated architecture allows for a favorable tradeoff of low quiescent current for a very high GBWP and low distortion performance in high gain applications. The high voltage capability combined with 1400 V/µs slew rate enables applications needing wide output swings (10 V_{PP} at V_S = 12 V) for high frequency signals such as those often found in optical front-end, test and measurement applications, and medical systems. The low noise JFET input with pico amperes of bias current makes the device particularly attractive for high transimpedance gain TIA applications and for test and measurement front-ends. OPA818 also features power down mode that disables the core amplifier for power savings.

OPA818 is built using TI's proprietary high-voltage high-speed complementary bipolar SiGe process.

7.2 Functional Block Diagram

The OPA818 is a conventional voltage feedback op amp with two high-impedance inputs and a low-impedance output. Standard amplifier configurations are supported like the two basic configurations shown in Figure 6 and Figure 7. The DC operating point for each configuration is level-shifted by the reference voltage (V_{REF}), which is typically set to midsupply in single-supply operation. V_{REF} is typically set to ground in split-supply applications.

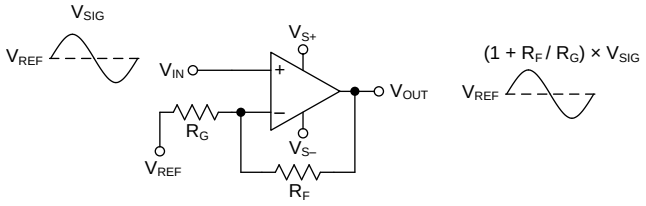


Figure 6. Noninverting Amplifier

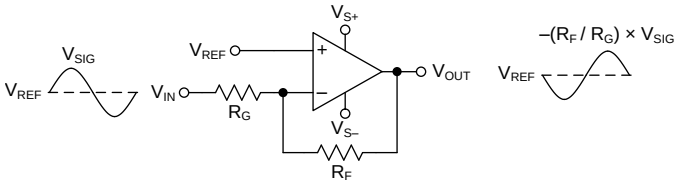


Figure 7. Inverting Amplifier

7.3 Feature Description

7.3.1 Input and ESD Protection

The OPA818 is built using a very high speed complementary bipolar process. The internal junction breakdown voltages are relatively low for these very small geometry devices. These breakdowns are reflected in the *Absolute Maximum Ratings* table. All device pins are protected with internal ESD protection diodes to the power supplies as shown in Figure 8.

These diodes provide moderate protection to input overdrive voltages beyond the supplies as well. The protection diodes can typically support 10-mA continuous current. Where higher currents are possible (for example, in systems with ±12-V supply parts driving into the OPA818), current limiting series resistors should be added in series with the two inputs to limit the current. Keep these resistor values as low as possible because high values degrade both noise performance and frequency response. There are no back-to-back ESD diodes between V_{IN+} and $V_{IN–}$. As a result, the differential input voltage between V_{IN+} and $V_{IN–}$ is entirely absorbed by the V_{GS} of the input JFET differential pair and must not exceed the voltage ratings shown in *Absolute Maximum Ratings* table.

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Feature Description (continued)

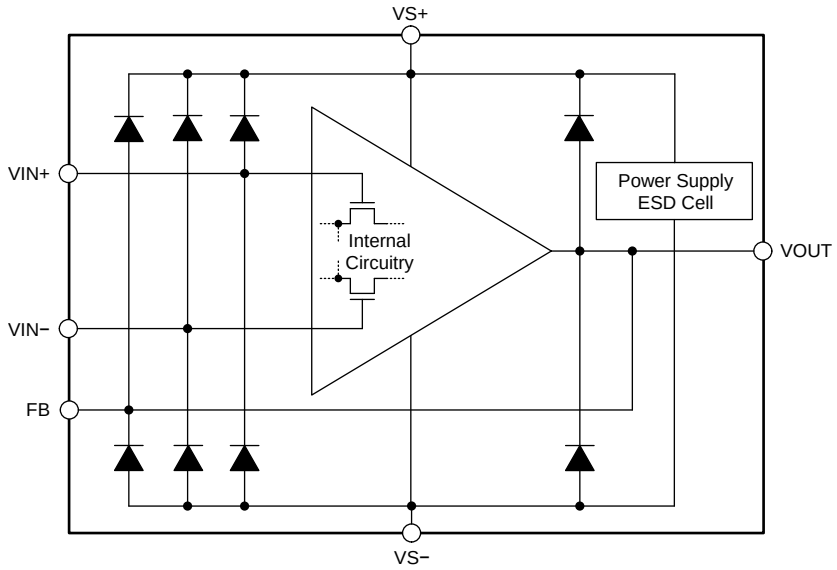


Figure 8. Internal ESD Protection

7.3.2 Feedback Pin

For high speed analog design, minimizing parasitic capacitances and inductances is critical to get the best performance from a high speed amplifier such as the OPA818. Parasitics are especially detrimental in the feedback path and at the inverting input. They result in undesired poles and zeroes in the feedback that could result in reduced phase margin or instability. Techniques used to correct for this phase margin reduction often result in reduced application bandwidth. To keep system engineers from making these tradeoff choices and to simplify the PCB layout, OPA818 features an FB pin on the same side as the inverting input pin, IN–. This allows for a very short feedback resistor, R_F, connection between the FB and the IN– pin as shown in Figure 9, thus minimizing parasitics with minimal PCB design effort. Internally the FB pin is connected to VOUT via metal routing on the silicon. Due to the fixed metal sizing of this connection, FB pin has limited current carrying capability and specifications in the *Absolute Maximum Ratings* must be adhered to for continuous operation.

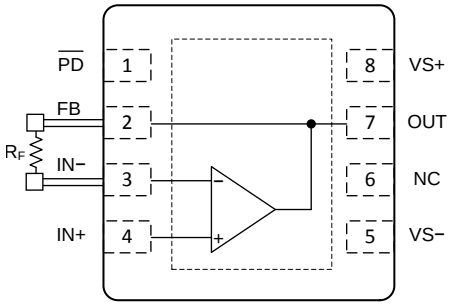


Figure 9. R_F Connection Between FB and IN– Pins

7.3.3 Decompensated Architecture With Wide Gain-Bandwidth Product

Figure 10 shows the open-loop gain and phase response of the OPA818. The GBWP of an op amp is measured in the 20 dB/decade constant slope region of the A_{OL} magnitude plot. The open-loop gain of 60 dB for the OPA818 is along this 20 dB/decade slope and the corresponding frequency intercept is at 2.7 MHz. Converting 60 dB to linear units (1000 V/V) and multiplying it with the 2.7 MHz frequency intercept gives the GBWP of OPA818 as 2.7 GHz. As can be inferred from the A_{OL} Bode plot, the second pole in the A_{OL} response occurs before A_{OL} magnitude drops below 0 dB (1 V/V). This results in phase change of more than 180° at 0 dB A_{OL}

ADVANCE INFORMATION

Feature Description (continued)

indicating that the amplifier will not be stable in a gain of 1 V/V. Amplifiers like OPA818 that are not unity-gain stable are referred to as decompensated amplifiers. The decompensated architecture typically allows for higher GBWP, higher slew rate, and lower noise compared to a unity-gain stable amplifier with equivalent quiescent current. The additional advantage of the decompensated amplifier is better distortion performance at higher frequencies in high gain applications for comparable quiescent current to a unity-gain stable amplifier.

OPA818 is stable in noise gain of 7 V/V (16.9 dB) or higher in conventional gain circuits as shown in Figure 6 and Figure 7. It has 790 MHz of SSBW in this gain configuration with approximately 50° phase margin.

The high GBWP and low voltage and current noise of OPA818 make it a very suitable amplifier for wideband moderate to high transimpedance gain applications. Transimpedance gains of 50kΩ or higher benefit from the low current noise JFET input. In a typical transimpedance (TIA) circuit as shown in Figure 13, unity-gain stable amplifier is not a requirement. At low frequencies, the noise gain of TIA is 0 dB (1 V/V) and at high frequencies the noise gain is set by the ratio of the total input capacitance (C_{TOT}) and the feedback capacitance (C_F). To maximize TIA closed-loop bandwidth, the feedback capacitance is generally smaller than the total input capacitance. This results in the ratio of total input capacitance to the feedback capacitance to be greater than 1, which is ultimately the noise gain of the TIA at higher frequencies. The blog series, *What you need to know about transimpedance amplifiers – part 1* and *What you need to know about transimpedance amplifiers – part 2* describe TIA compensation techniques in greater detail.

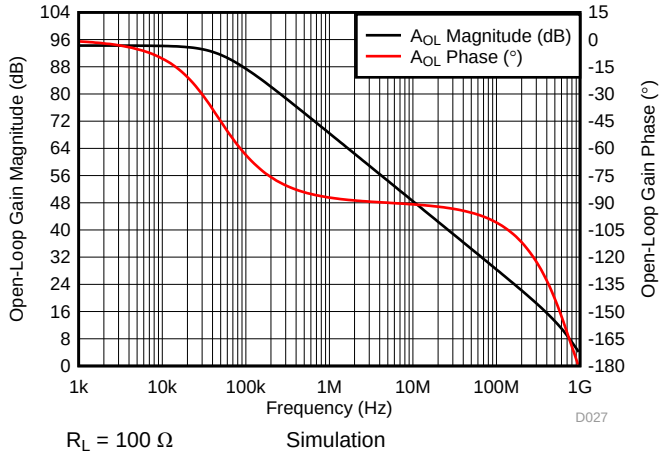


Figure 10. Open-Loop Gain Magnitude and Phase Vs Frequency

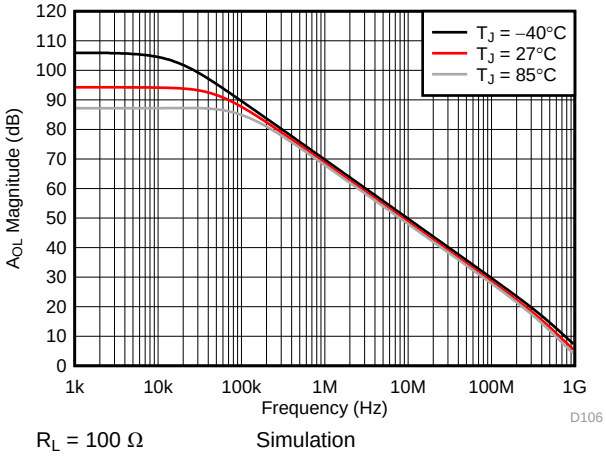


Figure 11. Open-Loop Gain Magnitude vs Temperature

7.3.4 Low Input Capacitance

Often two primary considerations for TIA applications are maximizing TIA closed-loop bandwidth and minimizing the total output noise to maximize Signal-to-Noise Ratio (SNR). The total input capacitance (C_{TOT}) of TIA circuit causes a zero in the noise gain in combination with the transimpedance gain (feedback resistor, R_F) at frequency $1/(2\pi R_F C_{TOT})$. For a fixed R_F, this zero is at a lower frequency for higher C_{TOT} thus increasing the noise gain at lower frequency resulting in lower equivalent closed-loop bandwidth and higher total output noise compared to a lower C_{TOT}. By choosing an amplifier like OPA818 that features a low input capacitance (2.4 pF combined common-mode and differential) for TIA application, the system designer can realize high closed-loop bandwidth at low total output noise or have the flexibility to choose a photodiode with relatively higher capacitance. The C_{TOT} includes the input capacitance of the amplifier, the photodiode capacitance, and the PCB parasitic capacitance at the inverting input.

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7.4 Device Functional Modes

7.4.1 Split-Supply Operation (+4/–2 V to ±6.5 V)

In typical split-supply operation, the mid-point between the power rails is ground. Mid-point at ground in split-supply configuration is a valid operating condition for OPA818 when symmetric supply voltages that are greater than or equal to ±4 V are used. This facilitates interfacing the OPA818 with common lab equipment such as signal generators, network analyzers, oscilloscopes, and spectrum analyzers most of which have inputs and outputs referenced to ground. However, when split-supply voltages less than ±4 V are used, care must be taken that the input common-mode range is not violated because the typical input common-mode range of OPA818 includes $V_{S–}$ and extends up to 3.2 V from V_{S+}. For example, when ±3 V supplies are used, the input common-mode of the signal must be typically 3.2 V from V_{S+} and 3.6 V from V_{S+} under maximum specified input common-mode range. This means ground is not included in the input common-mode range with ±3 V supplies resulting in erroneous operation if the input signal has ground as the mid-point. To prevent this situation, +4/–2 V supplies can be used.

7.4.2 Single-Supply Operation (6 V to 13 V)

Many newer systems use single power supply to improve efficiency and reduce the cost of the extra power supply. The OPA818 is designed for use with split-supply configuration; however, it can be used with a single-supply with no change in performance, as long as the input and output are biased within the linear operation of the device. To change the circuit from split supply to single supply, level shift all the voltages to midsupply using V_{REF}. As described in *Split-Supply Operation (+4/–2 V to ±6.5 V)* , additional consideration must be given to the input common-mode range so as not to violate it when operating with supplies less than 8 V. One of the advantages of configuring an amplifier for single-supply operation is that the effects of –PSRR will be minimized because the low supply rail has been grounded.

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8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

8.1.1 Wideband, Noninverting Operation

The OPA818 provides a unique combination of high GBWP, low-input voltage noise, and the DC precision of a trimmed JFET-input stage to provide an exceptional high input impedance for a voltage-feedback amplifier. Its very high GBWP of 2.7 GHz can be used to either deliver high-signal bandwidths at high gains, or to extend the achievable bandwidth or gain in photodiode-transimpedance applications. To achieve the full performance of the OPA818, careful attention to printed circuit board (PCB) layout and component selection is required as discussed in the following sections of this data sheet.

Figure 12 shows the noninverting gain of +7 V/V circuit used as the basis for most of the*Typical Characteristics: V_S = ±5 V*. Most of the curves were characterized using signal sources with 50-Ω driving impedance, and with measurement equipment presenting a 50-Ω load impedance. In Figure 12, the 49.9-Ω shunt resistor at the V_{IN} terminal matches the source impedance of the test generator, while the 49.9-Ω series resistor at the V_O terminal provides a matching resistor for the measurement equipment load. Generally, data sheet voltage swing specifications are at the output pin (V_O in Figure 12) while output power specifications are at the matched 50-Ω load. The total 100-Ω load at the output combined with the 350-Ω total feedback network load, presents the OPA818 with an effective output load of 78 Ω for the circuit of Figure 12.

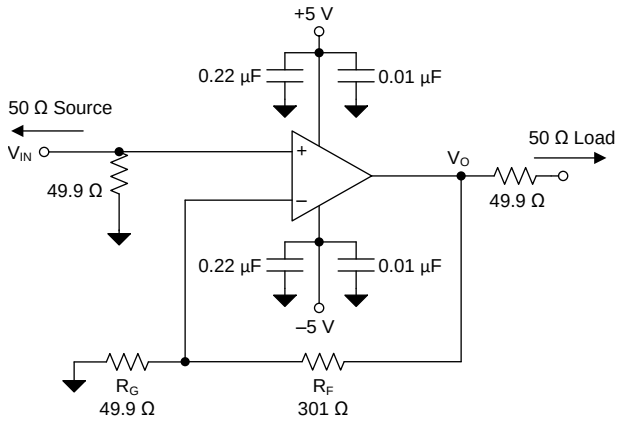


Figure 12. Noninverting G = +7 V/V Configuration and Test Circuit

Voltage-feedback operational amplifiers, unlike current feedback products, can use a wide range of resistor values to set their gain. To retain a controlled frequency response for the noninverting voltage amplifier of Figure 12, the parallel combination of R_F || R_G should always be less than 50Ω. In the noninverting configuration, the parallel combination of R_F || R_G will form a pole with the parasitic input capacitance at the inverting node of the OPA818 (including layout parasitics). For best performance, this pole should be at a frequency greater than the closed loop bandwidth for the OPA818.

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Application Information (continued)

8.1.2 Wideband, Transimpedance Design Using OPA818

With high GBWP, low input voltage and current noise, and low input capacitance, the OPA818 design is optimized for wideband, low-noise transimpedance applications. The high voltage capability allows greater flexibility of supply voltages along with wider output voltage swings. Figure 13 shows an example circuit of a typical photodiode amplifier circuit. Generally the photodiode is reverse biased in a TIA application so the photodiode current in the circuit ofFigure 13 flows into the op amp feedback loop resulting in an output voltage that reduces from V_{REF} with increasing photodiode current. In this type of configuration and depending on the application needs, V_{REF} can be biased closer to V_{S+} to achieve the desired output swing. Input common-mode range must be considered so as not to violate it when V_{REF} bias is used.

The key design elements that determine the closed-loop bandwidth, f_{-3dB}, of the circuit are below:

1. The op amp GBWP
2. The transimpedance gain, R_F, and,
3. The total input capacitance, CTOT, that includes photodiode capacitance, input capacitance of the amplifier (common-mode and differential capacitance), and PCB parasitic capacitance

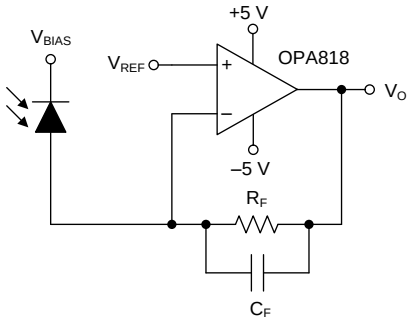


Figure 13. Wideband, Low-Noise, Transimpedance Amplifier

Equation 1 shows the relationship between the above mentioned three elements for a Butterworth response.

$$f_{-3dB} = \sqrt{\frac{GBWP}{2\pi R_F C_{TOT}}} \quad (1)$$

The feedback resistance R_F and the total input capacitance C_{TOT} cause a zero in the noise gain that results in instability if left uncompensated. To counteract the effect of the zero, a pole is inserted in the noise gain by adding the feedback capacitor, C_F. . The *Transimpedance Considerations for High-Speed Amplifiers* application report discusses theories and equations that show how to compensate a transimpedance amplifier for a particular gain and input capacitance. The bandwidth and compensation equations from the application report are available in a Microsoft Excel™ calculator. *What You Need To Know About Transimpedance Amplifiers – Part 1* provides a link to the calculator.

8.2 Typical Application

The high GBWP and low input voltage and current noise for the OPA818 make it an excellent wideband transimpedance amplifier for moderate to high transimpedance gains.

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Typical Application (continued)

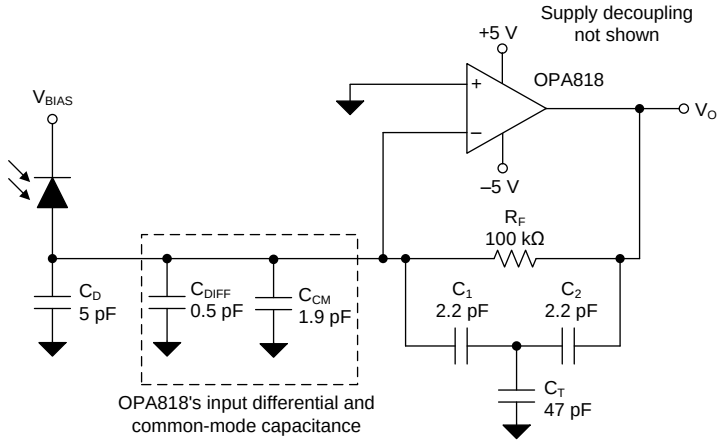


Figure 14. Wideband, High-Sensitivity, Transimpedance Amplifier

8.2.1 Design Requirements

Design a high-bandwidth, high-transimpedance-gain amplifier with the design requirements shown in Table 1.

Table 1. Design Requirements

TARGET BANDWIDTH (MHz)	TRANSIMPEDANCE GAIN (kΩ)	PHOTODIODE CAPACITANCE (pF)
24	100	5

8.2.2 Detailed Design Procedure

Designs that require high bandwidth from a large area detector with relatively high transimpedance gain benefit from the low input voltage noise of the OPA818. This input voltage noise is peaked up over frequency by the diode source capacitance, and can, in many cases, become the limiting factor to input sensitivity. Figure 14 shows the transimpedance circuit with the parameters as defined in *Design Requirements*. To use the Microsoft Excel™ calculator available at *What You Need To Know About Transimpedance Amplifiers – Part 1* to help with the component selection, total input capacitance, C_{TOT},needs to be determined. C_{TOT} is referred as C_{IN} in the calculator. C_{TOT} is the sum of C_D, C_{DIFF}, and C_{CM} which is 7.4 pF. Using this value of C_{TOT}, and the targeted closed-loop bandwidth (f_{-3dB}) of 24 MHz and transimpedance gain of 100 kΩ results in a need for an amplifier with approximately 2.68 GHz GBWP and a feedback capacitance (C_F) of 0.092 pF as shown in Figure 15. These results are for a Butterworth response with a Q = 0.707 and a phase margin of approximately 65° which corresponds to 4.3% overshoot.

Calculator II		
Closed-loop TIA Bandwidth (f_{-3dB})	24.00	***MHz***
Feedback Resistance (R_F)	100.00	***kOhm***
Input Capacitance (C_{IN})	7.40	***pF***
Opamp Gain Bandwidth Product (GBP)	2678.14	***MHz***
Feedback Capacitance (C_F)	0.092	***pF***

Figure 15. Results of Inputting Design Parameters in the TIA Calculator

With OPA818's 2.7 GHz GBWP, it will be a suitable amplifier for the design requirements. A challenge with the calculated component results is practically realizing a 0.092 pF capacitor. Such a small capacitor can be realized by using a capacitive tee network formed by C_1, C_2, and C_T such as that shown in Figure 14. The equivalent capacitance, C_{EQ}, of the tee network is given by Equation 2.

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$$C_{EQ} = \frac{C_1 \times C_2}{C_1 + C_2 + C_T} \quad (2)$$

The tee network forms a capacitive attenuator from input to output with C_1 and C_T, and from output to input with C_2 and C_T. With the value of C_T being higher than C_1 or C_2, only a fraction of the output signal is seen by C_1. This results in a much smaller shunting current provided to the input through C_1 and this reduced shunting current effect is equivalent to how a much smaller capacitor behaves (at a fixed frequency, smaller capacitor has higher impedance and thus reduced current). It is recommended to keep the same level of attenuation from input to output and vice versa. To find the appropriate capacitor values for the tee network, chose an arbitrarily low but practically realizable and equal values for capacitors C_1 and C_2, set $C_{EQ} = C_{TOT}$, and use Equation 3 to get the value of the tunable capacitor, C_T. The values of capacitors C_1, C_2, and C_T in Figure 14 were determined using this process.

$$C_T = \frac{C_1 \times C_2 - (C_1 + C_2) \times C_{EQ}}{C_{EQ}} \quad (3)$$

Figure 16 shows the TINA simulated closed-loop bandwidth response of the circuit in Figure 14. The circuit was designed for f_{-3dB} = 24 MHz and the simulated closed-loop 3-dB frequency is 24.6 MHz with about 0.1 dB peaking. The OPA818 TINA model models the input common-mode and differential capacitors so they should not be added externally when simulating in TINA. The noise simulation of the TIA circuit is shown in Figure 17. The output referred voltage noise is shown on the Y-axis to the left and the input referred current noise, which is essentially output referred voltage noise divided by the transimpedance gain of 100k, is shown on the secondary Y-axis to the right. The simulation results are fairly accurate because the OPA818 TINA model closely models the voltage and current noise performance of the amplifier. The flat-band output voltage noise is 41 nV/√Hz that is equivalent to 0.41 pA/√Hz of input referred current noise. The noise in relatively low frequency region where the noise gain of the amplifier is 1 V/V is dominated by the thermal noise of the 100 kΩ resistor (40.7 nV/√Hz at 27°C). At mid frequencies beyond the zero formed by R_F and C_{TOT}, the noise gain of the amplifier amplifies the voltage noise of the amplifier. The amplifier's noise starts to become the dominant noise contributor from this frequency onwards before the output noise starts to roll off at frequencies beyond the 3-dB closed-loop bandwidth. When looked at integrated root-mean-square (RMS) noise, the mid-frequency noise will be a significant contributor and hence using a 2.2 nV/√Hz low-noise amplifier like OPA818 is advantageous to minimize total RMS noise in the system.

8.2.3 Application Curves

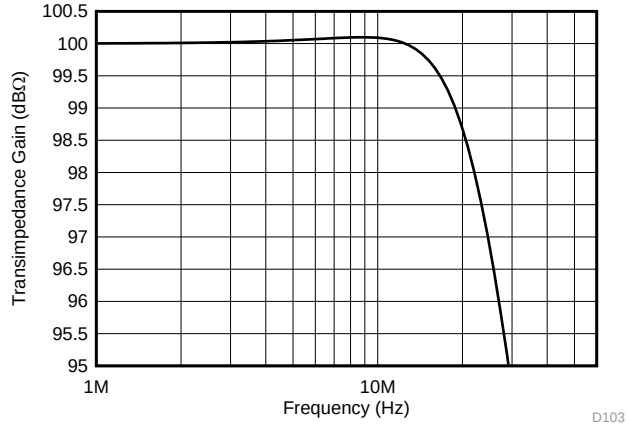


Figure 16. Simulated Closed-Loop Bandwidth TIA Response

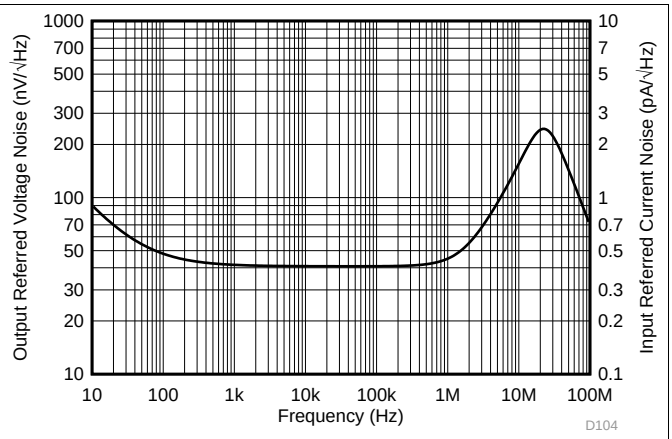


Figure 17. Simulated TIA Noise

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9 Power Supply Recommendations

The OPA818 is intended for operation on supplies from 6 V (+4/–2 V) to 12 V (±6 V). OPA818 supports single-supply, split and balanced bipolar supplies and unbalanced bipolar supplies. When operating at supplies below 8 V, the midsupply will be outside the input common-mode range of the amplifier. Under these supply conditions, the common-mode must be biased appropriately for linear operation. Thus the limit to lower supply voltage operation is the useable input voltage range for the JFET-input stage. Operating from a single supply of 12 V can have numerous advantages. With the negative supply at ground, the DC errors due to the –PSRR term can be minimized. Typically, AC performance improves slightly at 12-V operation with minimal increase in supply current.

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10 Layout

10.1 Layout Guidelines

Achieving optimum performance with a high-frequency amplifier like the OPA818 requires careful attention to board layout parasitics and external component types. Recommendations that will optimize performance include.

1. **Minimize parasitic capacitance** to any AC ground for all of the signal I/O pins. Parasitic capacitance on the output and inverting input pins can cause instability. On the noninverting input, parasitic capacitance can react with the source impedance to cause unintentional bandlimiting. Ground and power metal planes act as one of the plates of a capacitor while the signal trace metal acts as the other separated by PCB dielectric. To reduce this unwanted capacitance, a plane cutout around and underneath the signal I/O pins on all ground and power planes is recommended. Otherwise, ground and power planes should be unbroken elsewhere on the board. When configuring the amplifier as a TIA, if the required feedback capacitor is under 0.15 pF, consider using two series resistors, each of half the value of a single resistor in the feedback loop to minimize the parasitic capacitance from the resistor.
2. **Minimize the distance** (less than 0.25") from the power-supply pins to high-frequency decoupling capacitors. Use high quality, 100-pF to 0.1-µF, C0G and NPO-type decoupling capacitors with voltage ratings at least three times greater than the amplifiers maximum power supplies to ensure that there is a low-impedance path to the amplifiers power-supply pins across the amplifiers gain bandwidth specification. At the device pins, do not allow the ground and power plane layout to be in close proximity to the signal I/O pins. Avoid narrow power and ground traces to minimize inductance between the pins and the decoupling capacitors. The power-supply connections must always be decoupled with these capacitors. Larger (2.2-µF to 6.8-µF) decoupling capacitors, effective at lower frequency, must be used on the supply pins. These are placed further from the device and are shared among several devices in the same area of the PC board.
3. **Careful selection and placement of external components will preserve the high frequency performance of the OPA818.** Resistors should be of very low reactance type. Surface-mount resistors work best and allow a tighter overall layout. Metal film and carbon composition axially leaded resistors can also provide good high frequency performance. Again, keep their leads and PCB trace length as short as possible. Never use wirewound type resistors in a high frequency application. Because the output pin and inverting input pin are the most sensitive to parasitic capacitance, always position the feedback and series output resistor, if any, as close as possible to the inverting input and the output pin, respectively. Other network components, such as noninverting input termination resistors, should also be placed close to the package. Even with a low parasitic capacitance shunting the external resistors, excessively high resistor values can create significant time constants that can degrade performance. When OPA818 is configured as a conventional voltage amplifier, keep the resistor values as low as possible and consistent with the load driving considerations. Lower resistor values minimize the effect of parasitic capacitance and reduce resistor noise terms but because the feedback network (R_F + R_G for noninverting and R_F for inverting configuration) acts as a load on the amplifier, lower resistor values increase the dynamic power consumption and the effective load on the output stage. Transimpedance applications (see Figure 13) can use feedback resistors as required by the application and as long as the feedback compensation capacitor is set considering all parasitic capacitance terms on the inverting node.
4. **Heat dissipation is important for a high voltage device like OPA818**. For good thermal relief, the thermal pad should be connected to a heat spreading plane that is preferably on the same layer as OPA818 or connected by as many vias as possible if the plane is on a different layer. It is recommended to have at least one heat spreading plane on the same layer as the OPA818 that makes a direct connection to the thermal pad with wide metal for good thermal conduction when operating at high ambient temperatures. If more than one heat spreading planes are available, connecting them by a number of vias further improves the thermal conduction.
5. **Socketing a high speed part like the OPA818 is not recommended.** The additional lead length and pin-to-pin capacitance introduced by the socket can create an extremely troublesome parasitic network which can make it almost impossible to achieve a smooth, stable frequency response. Best results are obtained by soldering the OPA818 onto the board.

10.1.1 Thermal Considerations

The OPA818 will not require heatsinking or airflow in most applications. Maximum allowed junction temperature will set the maximum allowed internal power dissipation as described below. In no case should the maximum junction temperature be allowed to exceed 105°C.

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Layout Guidelines (continued)

Operating junction temperature (T_J) is given by $T_A + P_D \times R_{\theta JA}$. The total internal power dissipation (P_D) is the sum of quiescent power (P_{DQ}) and additional power dissipated in the output stage (P_{DL}) to deliver load power. Quiescent power is simply the specified no-load supply current times the total supply voltage across the part. P_{DL} will depend on the required output signal and load but would, for a grounded resistive load, be at a maximum when the output is fixed at a voltage equal to 1/2 of either supply voltage (for balanced bipolar supplies). Under this condition $P_{DL} = V_S{}^2/(4 \times R_L)$ where R_L includes feedback network loading.

Note that it is the power in the output stage and not into the load that determines internal power dissipation.

As a worst-case example, compute the maximum T_J using OPA818 in the circuit of Figure 12 operating at the maximum specified ambient temperature of +85°C and driving a grounded 100-Ω load.

$P_D = 10\ V \times 27.7\ mA + 5^2/(4 \times (100\ \Omega \parallel 350.9\ \Omega)) \approx 357\ mW$

Maximum $T_J = 85°C + (0.357\ W \times 54.6°C/W) = 104.5°C$.

All actual applications will be operating at lower internal power and junction temperature.

10.2 Layout Example

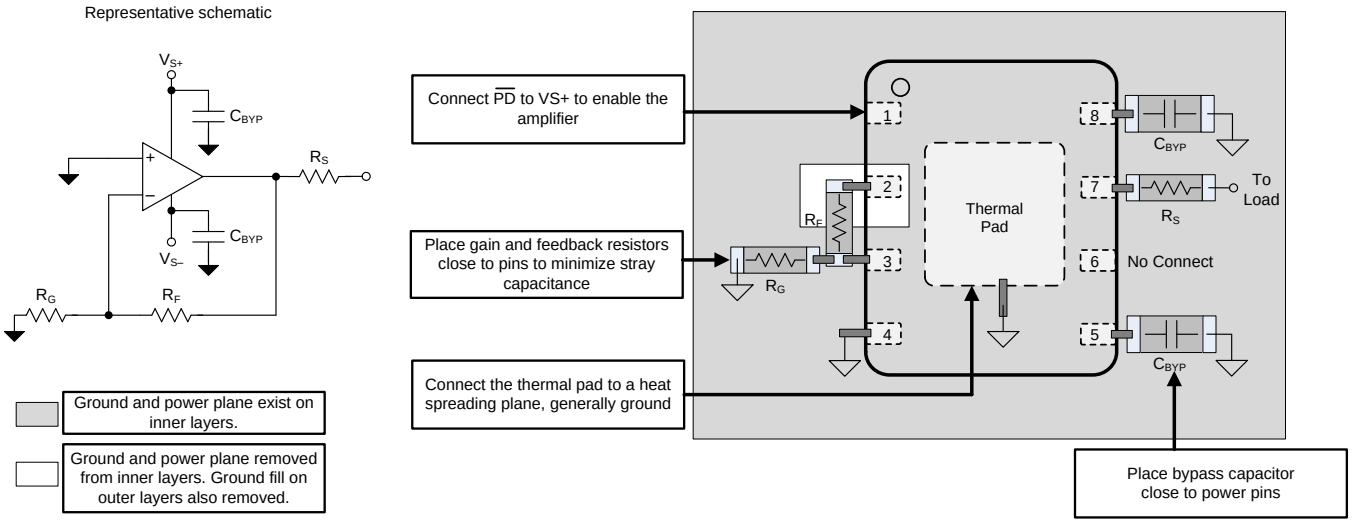


Figure 18. Layout Recommendation

When configuring the OPA818 as a transimpedance amplifier additional care must be taken to minimize the inductance between the avalanche photodiode (APD) and the amplifier. Always place the photodiode on the same side of the PCB as the amplifier. Placing the amplifier and the APD on opposite sides of the PCB increases the parasitic effects due to via inductance. APD packaging can be quite large which often requires the APD to be placed further away from the amplifier than ideal. The added distance between the two device results in increased inductance between the APD and op amp feedback network as shown in Equation 4. The added inductance is detrimental to a decompensated amplifier's stability since it isolates the APD capacitance from the noise gain transfer function. The noise gain is given by Equation 4. The added PCB trace inductance between the feedback network increases the denominator in Equation 4 thereby reducing the noise gain and the phase margin. In cases where a leaded APD in a TO can is used inductance should be further minimized by cutting the leads of the TO can as short as possible. Also, edge mounting the photodiode on the PCB should be considered vs through hole if the application allows.

The layout shown in Figure 19 can be improved by following some of the guidelines shown in Figure 20. The two key rules to follow are:

- Add an isolation resistor R_{ISO} as close as possible to the inverting input of the amplifier. Select the value of R_{ISO} to be between 10 Ω and 20 Ω. The resistor dampens the potential resonance caused by the trace inductance and the amplifiers internal capacitance.
- Close the loop between the feedback elements (R_F and C_F) and R_{ISO} as close to the APD pins as possible. This ensures a more balanced layout and reduces the inductive isolation between the APD and the feedback

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Layout Example (continued)

network.

$$\text{Noise Gain} = \left(1 + \frac{Z_F}{Z_{IN}}\right) \quad (4)$$

where

- Z_F is the total impedance of the feedback network
- Z_{IN} is the total impedance of the input network

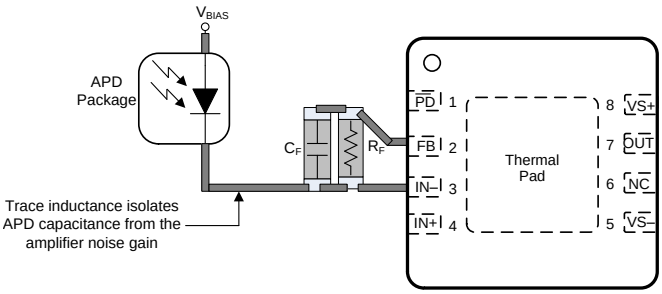


Figure 19. Non-Ideal TIA Layout

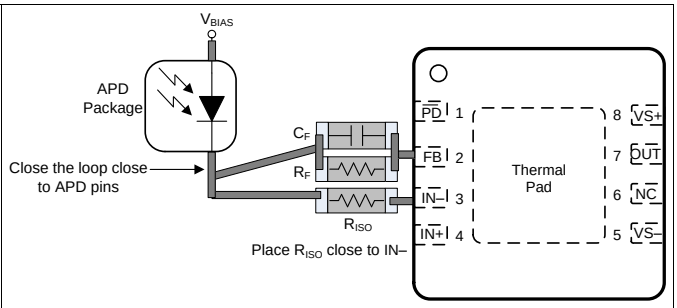


Figure 20. Improved TIA Layout

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11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

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11.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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12.1 Package Option Addendum

12.1.1 Packaging Information

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish(3)	MSL Peak Temp (4)	Op Temp (°C)	Device Marking(5)(6)
XOPA818IDRGT	PREVIEW	WSON	DRG	8	250	TBD	Call TI	Call TI	-40 to 85	

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PRE_PROD Unannounced device, not in production, not available for mass market, nor on the web, samples not available.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

(4) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(5) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device

(6) Multiple Device markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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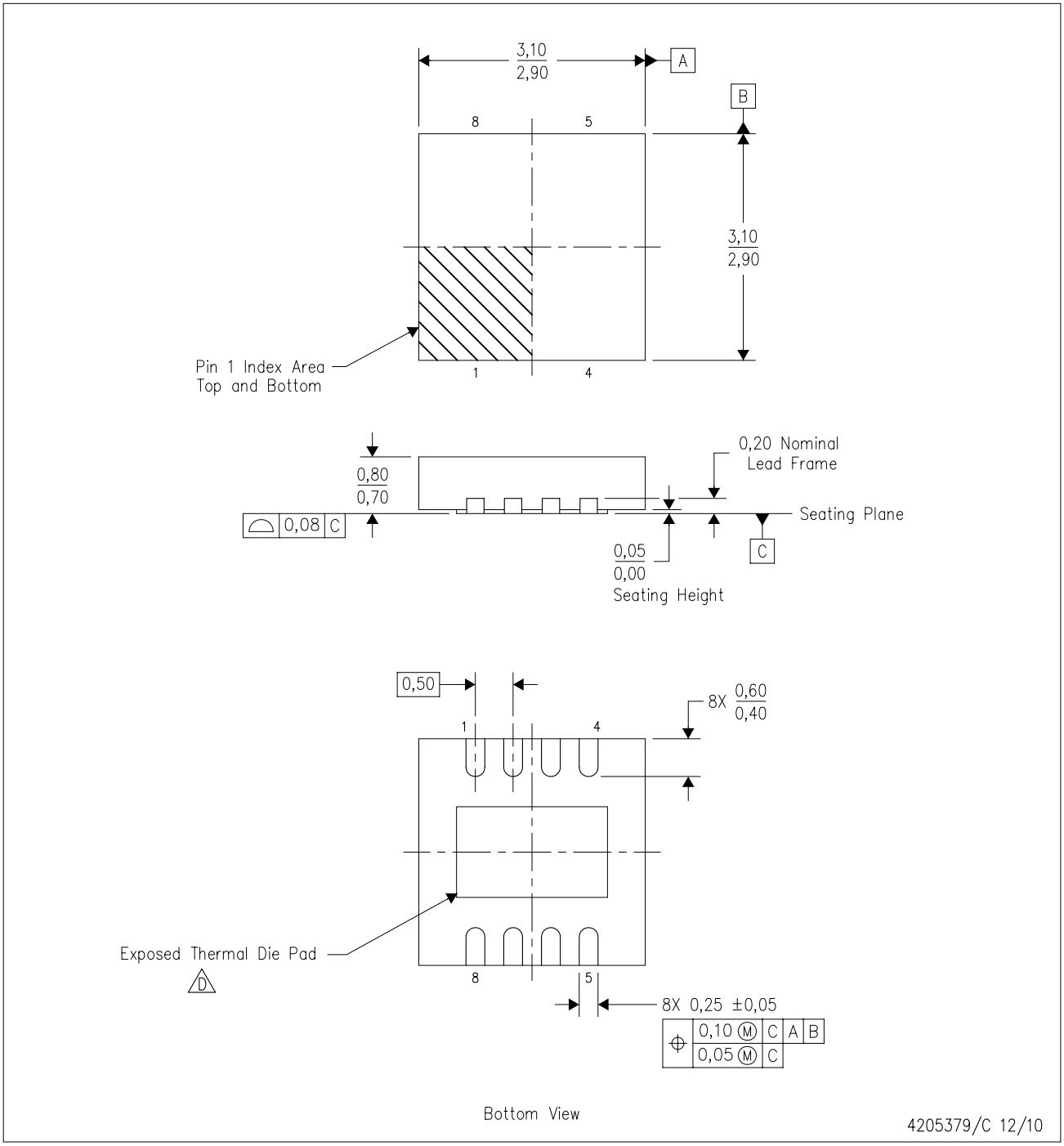
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ADVANCE INFORMATION

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MECHANICAL DATA

DRG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. SON (Small Outline No–Lead) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
E. JEDEC MO–229 package registration pending.

ADVANCE INFORMATION

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THERMAL PAD MECHANICAL DATA

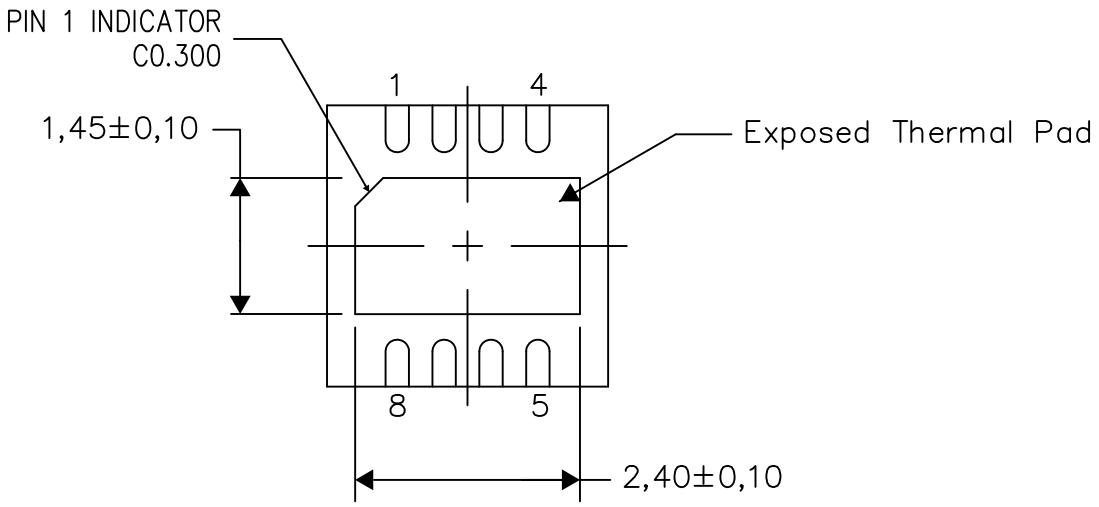
DRG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

Exposed Thermal Pad Dimensions

4206881–3/I 03/15

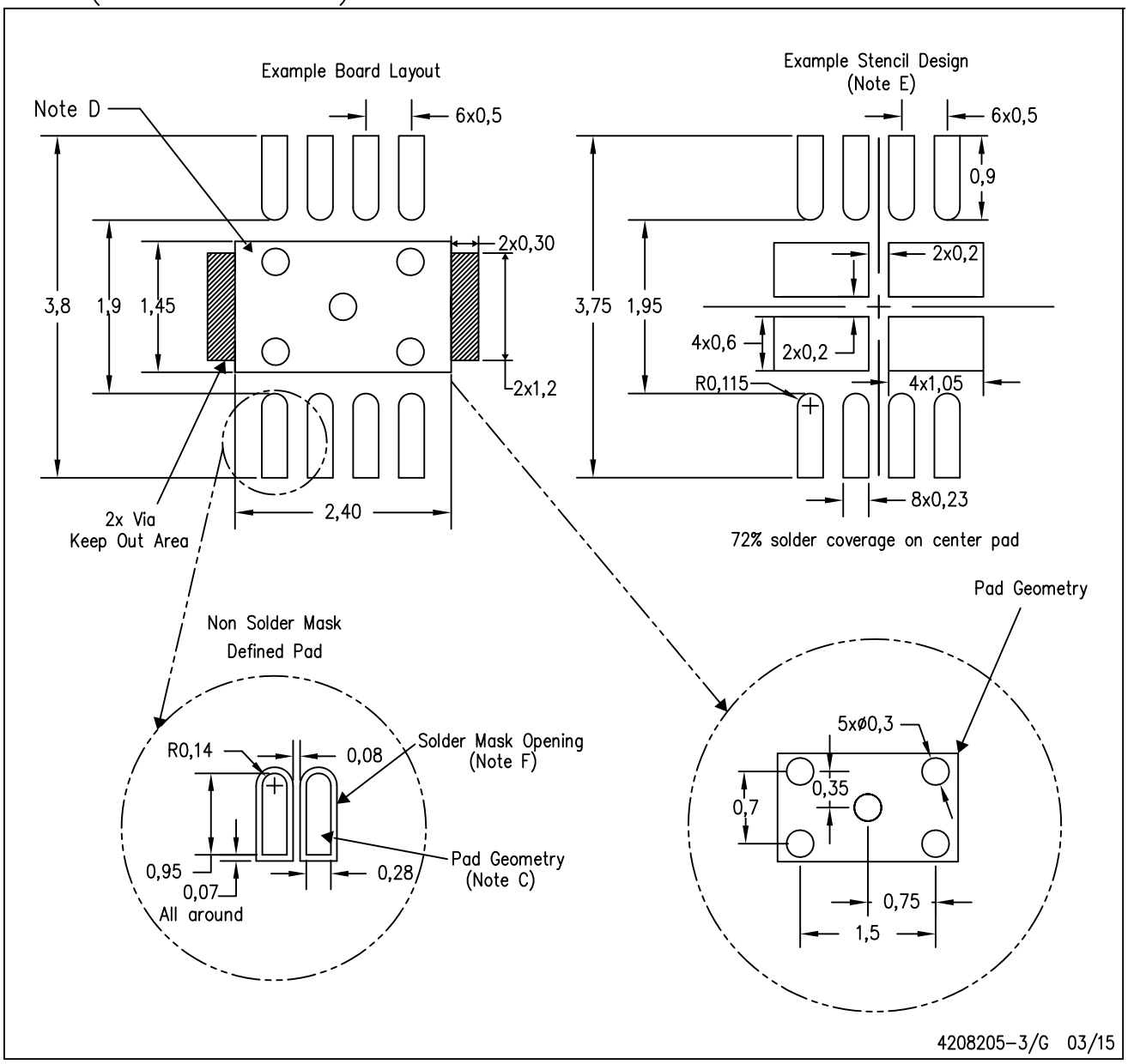
NOTE: All linear dimensions are in millimeters

ADVANCE INFORMATION

ADVANCE INFORMATION

LAND PATTERN DATA

DRG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–SM–782 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA818IDRGR	PREVIEW	SON	DRG	8	3000	TBD	Call TI	Call TI	-40 to 125		
OPA818IDRGT	PREVIEW	SON	DRG	8	250	TBD	Call TI	Call TI	-40 to 125		

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

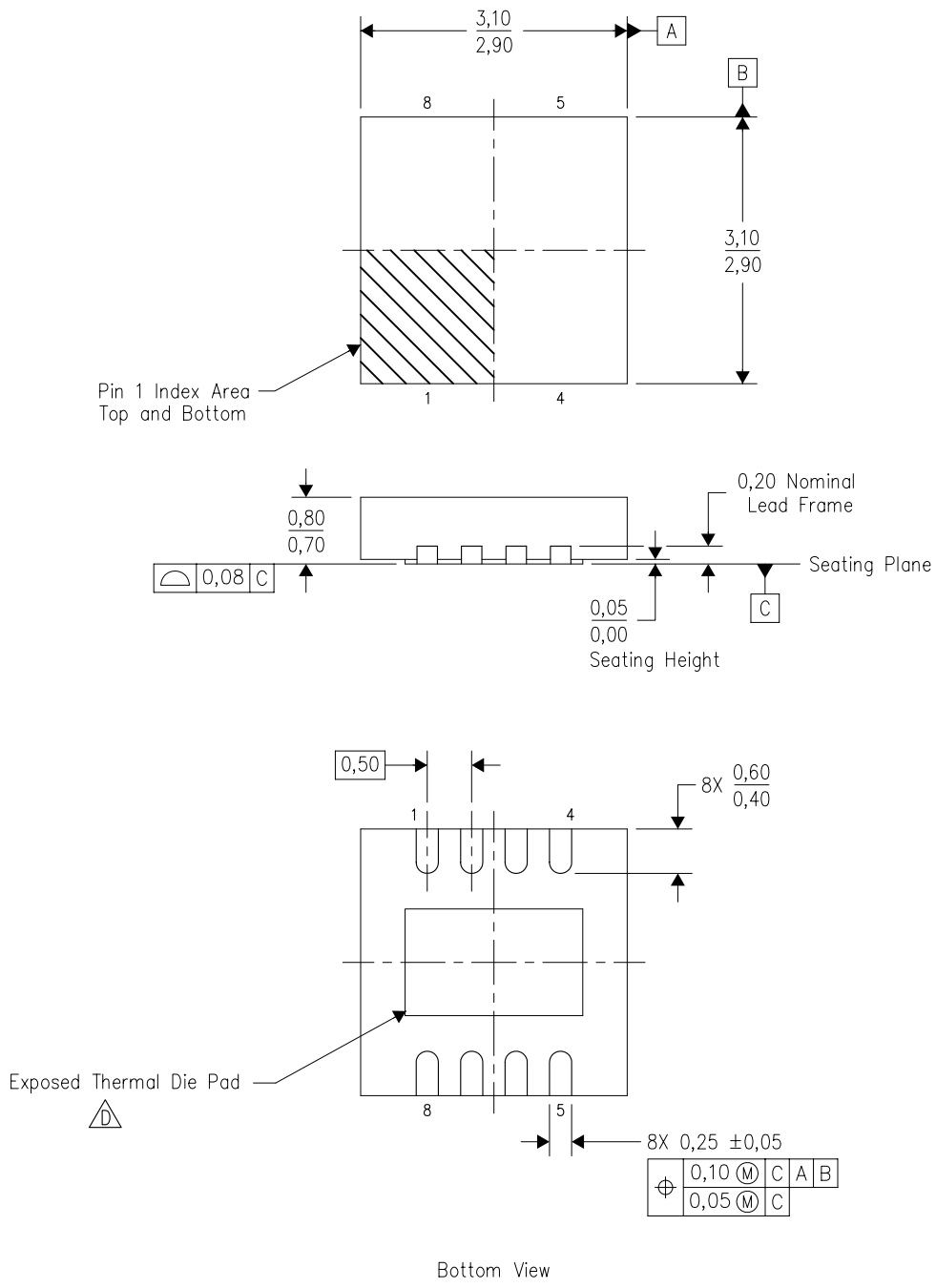
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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