LMH32401-Q1 Automotive, 450-MHz, Programmable-Gain, Differential-Output Transimpedance Amplifier

1 Features

- AEC-Q100 qualified for automotive applications:
  - Temperature grade 1: –40°C to +125°C, T_A
- Integrated programmable gain: 2 kΩ or 20 kΩ
- Performance at gain = 2 kΩ, C_{PD} = 1 pF:
  - Bandwidth: 450 MHz
  - Input-referred noise: 250 nA_{RMS}
  - Rise and fall time: 0.8 ns
- Performance at gain = 20 kΩ, C_{PD} = 1 pF:
  - Bandwidth: 275 MHz
  - Input-referred noise: 49 nA_{RMS}
  - Rise and fall time: 1.3 ns
- Integrated ambient light cancellation
- Integrated 100-mA protection clamp
- Integrated output multiplexer
- Wide output swing: 1.5 V_{PP}
- Quiescent current: 30 mA
- Package: 16-pin, wettable-flank VQFN

2 Applications

- Mechanically scanning LIDAR
- Solid-state scanning LIDAR
- Industrial robot LIDAR
- Smart munitions

3 Description

The LMH32401-Q1 automotive device is a programmable-gain, single-ended-input to differential-output transimpedance amplifier for light detection and ranging (LIDAR) applications.

The LMH32401-Q1 can be configured in a gain of 2 kΩ or 20 kΩ. The LMH32401-Q1 has 1.5 V_{PP} of output swing and is designed to drive a 100-Ω load.

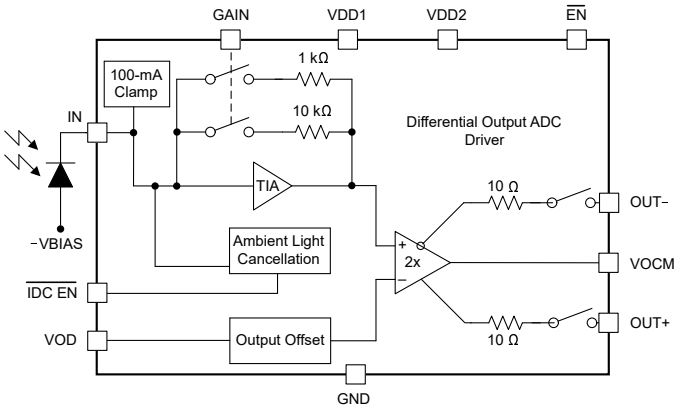
The LMH32401-Q1 has an integrated 100-mA clamp that protects the amplifier and allows the device to rapidly recover from an overloaded input condition. The LMH32401-Q1 also features an integrated ambient-light cancellation circuit. To save board space, as well as reduce system cost, use this circuit instead of ac coupling between the photodiode (PD) or avalanche photodiode (APD) and the amplifier. The ambient-light cancellation circuit can be disabled in cases where dc coupling is required.

To conserve power when the amplifier is not being used, the LMH32401-Q1 provides a low-power mode using the $\overline{EN}$ pin. When the amplifier is in low-power mode, the output pins are in a high-impedance state. This feature allows several LMH32401-Q1 amplifiers to be multiplexed to a single ADC with the $\overline{EN}$ control pin serving as the multiplexer select function.

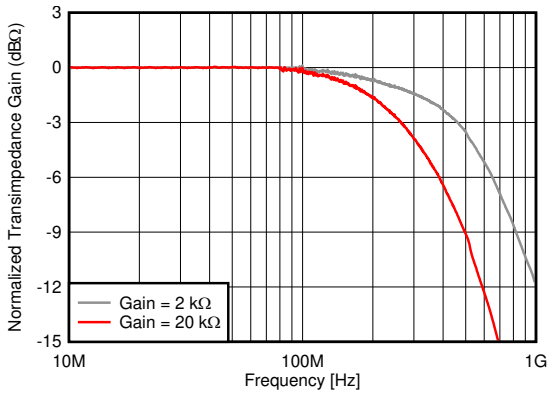
Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
LMH32401-Q1	Wettable-flank RGT (VQFN,16)	3 mm × 3 mm

(1) For all available packages, see the package option addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Simplified Block Diagram



Closed-Loop Transimpedance Bandwidth

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4 Revision History

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

Changes from Revision * (April 2023) to Revision A (August 2023)	Page
• Changed device data sheet status from advanced information (preview) to production data (active)	1

5 Pin Configuration and Functions

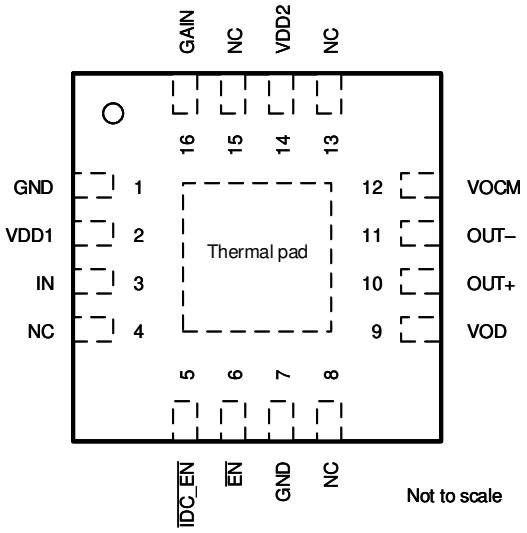


Figure 5-1. RGT Package, 16-Pin VQFN With Wettable Flanks and Exposed Thermal Pad (Top View)

Table 5-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
$\overline{EN}$	6	Input	Device enable pin. $\overline{EN}$ = logic low = normal operation (default)(1). $\overline{EN}$ = logic high = power-off mode.
GAIN	16	Input	Gain setting. GAIN = low = 2 kΩ (default)(1). GAIN = high = 20 kΩ.
GND	1, 7	Input	Amplifier ground
$\overline{IDC\_EN}$	5	Input	Ambient light cancellation (ALC) loop enable. $\overline{IDC\_EN}$ = logic low = enable dc current cancellation (default)(1). $\overline{IDC\_EN}$ = logic high = disable dc current cancellation.
IN	3	Input	Transimpedance amplifier input
NC	4, 8, 13, 15	—	Do not connect
OUT–	11	Output	Inverting amplifier output. When light is incident on the photodiode, the output pin transitions in a negative direction from the no-light condition (APD anode connected to negative bias).
OUT+	10	Output	Noninverting amplifier output. When light is incident on the photodiode, the output pin transitions in a positive direction from the no-light condition (APD anode connected to negative bias).
VDD1	2	Input	Positive power supply for the transimpedance amplifier stage
VDD2	14	Input	Positive power supply for the differential amplifier stage. Tie VDD1 and VDD2 to the same power supply with independent power-supply bypassing.
VOCM	12	Input	Differential-amplifier common-mode output setting
VOD	9	Input	Differential-amplifier differential output offset setting
Thermal pad	Thermal pad	—	Connect the thermal pad to GND or the most negative power supply of the device under test (DUT).

(1) Drive a digital pin with a low-impedance source rather than leaving the pin floating because fast-moving transients can couple into the pin and inadvertently change the logic level.

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V_{DD1}, V_{DD2}	Total supply voltage, V_{DD} (2)		3.65	V
	Voltage at output pins	0	V_{DD}	V
	Voltage at logic pins	–0.25	V_{DD}	V
I_{IN}	Continuous current into IN		25	mA
I_{OUT}	Continuous output current		35	mA
T_J	Junction temperature		150	°C
T_A	Operating free-air temperature	–40	125	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) Tie VDD1 and VDD2 to the same supply and use separate power-supply bypass capacitors.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002(1) HBM ESD classification level 1C	±1500	V
		Charged device model (CDM), per AEC Q100-011 CDM ESD classification level C6	±1000	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{DD}	Total supply voltage	3	3.3	3.45	V
T_A	Operating free-air temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC(1)		LMH32401-Q1 (2)	UNIT
		RGT (VQFN)	
		16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	56.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	67	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	31.3	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	3.7	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	31.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	15.6	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.
(2) Thermal information is applicable to packaged parts only.

6.5 Electrical Characteristics: Gain = 2 kΩ

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} (1) = 1 pF, $\overline{EN}$ = 0 V, V_{GAIN} = 0 V, $\overline{IDC\_EN}$ = 3.3 V, R_L = 100 Ω, and T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
AC PERFORMANCE						
SSBW	Small-signal bandwidth	V_{OUT} = 100 mV_{PP}		450		MHz
LSBW	Large-signal bandwidth	V_{OUT} = 1 V_{PP}		450		MHz
t_R, t_F	Rise and fall time	V_{OUT} = 100 mV_{PP}, pulse duration = 10 ns		0.8		ns
	Slew rate(2)	V_{OUT} = 1 V_{PP}, pulse duration = 10 ns		1100		V/µs
	Overload pulse extension(3)	I_{IN} = 10 mA, pulse duration = 10 ns		4		ns
i_N	Integrated input current noise	f = 500 MHz		250		nA_{RMS}
DC PERFORMANCE						
Z_{21}	Small-signal transimpedance gain(4)		1.75	2	2.25	kΩ
V_{OD}	Differential output offset voltage ($V_{OUT-} – V_{OUT+}$)		–12	3.5	12	mV
$\Delta V_{OD}/\Delta T_A$	Differential output offset voltage drift			±5.5		µV/°C
INPUT PERFORMANCE						
R_{IN}	Input resistance		60	100	120	Ω
V_{IN}	Default input bias voltage	Input pin floating	2.42	2.47	2.52	V
$\Delta V_{IN}/\Delta T_A$	Default input bias voltage drift	Input pin floating		1.1		mV/°C
I_{IN_LIN}	DC input current range	Z_{21} < 3-dB degradation from I_{IN} = 50 µA	600	705		µA

(1) Input capacitance of photodiode.
(2) Average of rising and falling slew rate.
(3) Pulse duration extension measured at 50% of pulse height of a square wave.
(4) Gain measured at the amplifier output pins when driving a 100-Ω resistive load. At higher resistor loads, the gain increases.

6.6 Electrical Characteristics: Gain = 20 kΩ

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} (1) = 1 pF, $\overline{EN}$ = 0 V, V_{GAIN} = 3.3 V, $\overline{IDC\_EN}$ = 3.3 V, R_L = 100 Ω, and T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
AC PERFORMANCE						
SSBW	Small-signal bandwidth	V_{OUT} = 100 mV_{PP}		275		MHz
LSBW	Large-signal bandwidth	V_{OUT} = 1 V_{PP}		275		MHz
t_R, t_F	Rise and fall time	V_{OUT} = 100 mV_{PP}, pulse duration = 10 ns		1.3		ns
	Slew rate(2)	V_{OUT} = 1 V_{PP}, pulse duration = 10 ns		700		V/µs
	Overload pulse extension(3)	I_{IN} = 10 mA, pulse duration = 10 ns		4		ns
i_N	Integrated input current noise	f = 250 MHz		49		nA_{RMS}
DC PERFORMANCE						
Z_{21}	Small-signal transimpedance gain(4)		17	20	22.5	kΩ
V_{OD}	Differential output offset voltage ($V_{OUT-} – V_{OUT+}$)		–20	5	20	mV
$\Delta V_{OD}/\Delta T_A$	Differential output offset voltage drift			±17.5		µV/°C
INPUT PERFORMANCE						
R_{IN}	Input resistance		270	350	410	Ω
V_{IN}	Default input bias voltage	Input pin floating	2.42	2.47	2.52	V
$\Delta V_{IN}/\Delta T_A$	Default input bias voltage drift	Input pin floating		1.1		mV/°C
I_{IN_LIN}	DC input current range	Z_{21} < 3-dB degradation from I_{IN} = 5 µA	60	72		µA

(1) Input capacitance of photodiode.
(2) Average of rising and falling slew rate.
(3) Pulse duration extension measured at 50% of pulse height of a square wave.
(4) Gain measured at the amplifier output pins when driving a 100-Ω resistive load. At higher resistor loads, the gain increases.

6.7 Electrical Characteristics: Both Gains

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} (1) = 1 pF, $\overline{EN}$ = 0 V, V_{GAIN} = 0 V or 3.3 V, $\overline{IDC\_EN}$ = 3.3 V, R_L = 100 Ω, and T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT PERFORMANCE						
V_{OH}	Single-sided output voltage swing (high) (2)	T_A = 25°C	2.87	2.9		V
V_{OL}	Single-sided output voltage swing (low)(2)	T_A = 25°C		0.36	0.39	V
I_{OUT_LIN}	Linear output drive (sink and source)	T_A = 25°C, I_{IN} = 500 µA, gain = 2 kΩ, R_L = 25 Ω	24	26.6	32	mA
		T_A = –40°C, I_{IN} = 500 µA, gain = 2 kΩ, R_L = 25 Ω		27.1		
		T_A = 125°C, I_{IN} = 500 µA, gain = 2 kΩ, R_L = 25 Ω		25.1		
I_{SC}	Output short-circuit current (differential) (3)			70		mA
Z_{OUT}	DC output impedance (differential)	amplifier enabled	18	21	24	Ω
		amplifier in shutdown	2.8	3.3		kΩ
OUTPUT COMMON-MODE CONTROL (V_{OCM}) PERFORMANCE						
SSBW	Small-signal bandwidth	V_{OCM} = 100 mV_{PP} at VOCM pin		285		MHz
LSBW	Large-signal bandwidth	V_{OCM} = 1 V_{PP} at VOCM pin		85		MHz
e_N	Output common-mode noise	f = 10 MHz, 1-nF capacitor to GND on VOCM pin		17.8		nV/√Hz
A_V	Gain, (ΔV_{OCM} / ΔV_{VOCM})	IN floating, V_{VOCM} = 1.1 V (driven)		1		V/V
	Gain error	T_A = 25°C, V_{VOCM} = 0.7 V to 2.3 V	–2%	0.5%	2%	
		T_A = –40°C to +125°C, V_{VOCM} = 0.7 V to 2.3 V		±1%		
	Input impedance			17		kΩ
$VOCM_{OS}$	VOCM pin default offset from 1.1 V	VOCM floating, (V_{VOCM} measured –1.1 V)	0	10	20	mV
ΔV_{OCM}/ ΔI_{IN}	V_{OCM} error vs Input current	Gain = 20 kΩ, VOCM driven to 1.1 V		–15		µV/µA
V_{OCM}	Output common-mode voltage, (V_{OUT+} + $V_{OUT–}$) / 2	T_A = 25°C, VOCM pin floating	1.05	1.1	1.15	V
	Output common-mode voltage drift, (ΔV_{OCM} / ΔT_A)	T_A = –40°C to +125°C, VOCM pin floating		75		µV/°C
V_{OCM}	Output common-mode voltage, (V_{OUT+} + $V_{OUT–}$) / 2	T_A = 25°C, VOCM pin driven to 1.1 V	1.05	1.1	1.15	V
	Output common-mode voltage drift, (ΔV_{OCM} / ΔT_A)	T_A = –40°C to +125°C, VOCM pin driven to 1.1 V		–14		µV/°C

6.7 Electrical Characteristics: Both Gains (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} (1) = 1 pF, $\overline{EN}$ = 0 V, V_{GAIN} = 0 V or 3.3 V, $\overline{IDC\_EN}$ = 3.3 V, R_L = 100 Ω, and T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT DIFFERENTIAL OFFSET (V_{OD}) PERFORMANCE						
SSBW	Small-signal bandwidth	V_{OD} = 100 mV_{PP} at VOD pin		45		MHz
LSBW	Large-signal bandwidth	V_{OD} = 1 V_{PP}		14		MHz
V_{OS_D}	Differential output offset, V_{OUT} = (V_{OUT-} – V_{OUT+})	IN floating, V_{VOD} = 0.5 V	490	510	530	mV
	Differential output offset drift, ΔV_{OS_D} / ΔT_A	IN floating, V_{VOD} = 0.5 V		0.03		mV/°C
V_{OS_D}	Differential output offset, V_{OUT} = (V_{OUT-} – V_{OUT+})	IN floating, VOD floating	490	510	530	mV
	Differential output offset drift, ΔV_{OS_D} / ΔT_A	IN floating, VOD floating		0.04		mV/°C
A_V	Gain, (ΔV_{OUT} / ΔV_{VOD}), where V_{OUT} = (V_{OUT-} – V_{OUT+})	IN floating, V_{VOCM} = 1.1 V (driven)		1.01		V/V
	Gain error	T_A = 25°C, V_{VOD} = 0 V to 1.2 V	–5%	–1%	5%	
		T_A = –40°C to +125°C, V_{VOD} = 0 V to 1.2 V		±1.5%		
	Input impedance			2.5		kΩ
AMBIENT LIGHT CANCELLATION PERFORMANCE ($\overline{IDC\_EN}$ = 0 V) (4)						
	Settling time (within V_{OD} limit)	I_{IN} = 0 µA → 100 µA, gain = 2 kΩ		18		µs
		I_{IN} = 0 µA → 10 µA, gain = 20 kΩ		2.5		
		I_{IN} = 100 µA → 0 µA, gain = 2 kΩ		35		
		I_{IN} = 10 µA → 0 µA, gain = 20 kΩ		13		
	Ambient light current cancellation range	Differential output offset (V_{OUT-} – V_{OUT+}) shift from I_{DC} = 10 µA < ±10 mV	2	3		mA
POWER SUPPLY						
I_Q	Quiescent current, total	T_A = 25°C	24	30	33.5	mA
		T_A = 125°C		32		
		T_A = –40°C		27		
PSRR+	Positive power-supply rejection ratio, VDD1 = VDD2		54	66		dB
SHUTDOWN						
I_Q	Quiescent current, amplifier disabled ($\overline{EN}$ = V_{DD})	T_A = 25°C	2.4	3.3	4.2	mA
		T_A = –40°C		2.75		
		T_A = 125°C		5.2		
	Enable pin input bias current	T_A = 25°C		75	120	µA

(1) Input capacitance of photodiode.
(2) Output levels achieved by adjusting VOCM, VOD, and input current.
(3) Device cannot withstand continuous short-circuit between the differential outputs.
(4) Enabling the ambient light cancellation loop adds noise to the system.

6.8 Electrical Characteristics: Logic Threshold and Switching Characteristics

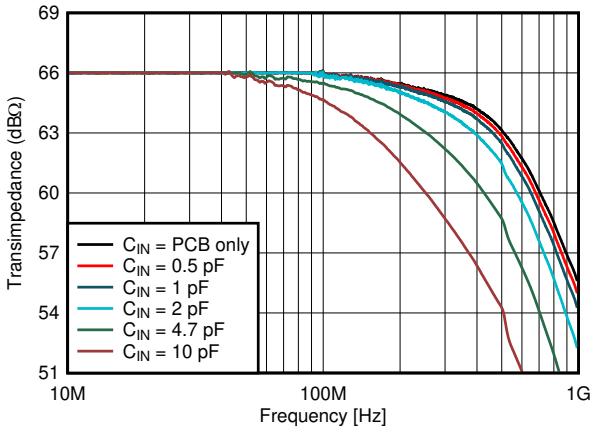
at V_{DD} = 3.3 V, V_{OCM} = Open, V_{OD} = 0 V, C_{PD} (1) = 1 pF, $\overline{EN}$ = 0 V, V_{GAIN} = 0 V or 3.3 V, $\overline{IDC\_EN}$ = 3.3 V, R_L = 100 Ω, and T_A = 25°C. (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
LOGIC THRESHOLD PERFORMANCE						
	High-gain enable, threshold voltage	Enabled when greater than this voltage		1.8	2	V
	Low-gain enable, threshold voltage	Enabled when less than this voltage	0.8	1		V
	$\overline{EN}$ control, disable threshold voltage	Disabled when greater than this voltage		1.8	2	V
	$\overline{EN}$ control, enable threshold voltage	Enabled when less than this voltage	0.8	1		V
	$\overline{IDC\_EN}$ control, disable threshold voltage	Disabled when greater than this voltage		1.8	2	V
	$\overline{IDC\_EN}$ control, enable threshold voltage	Enabled when less than this voltage	0.8	1		V
GAIN CONTROL TRANSIENT PERFORMANCE						
	High-gain to low-gain transition time, (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP} (initial condition), I_{DC} = 0 µA		90		ns
	Low-gain to high-gain transition time, (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP} (final condition), I_{DC} = 0 µA		750		ns
	High-gain to low-gain transition time, (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP} (initial condition), I_{DC} = 100 µA		4		µs
	Low-gain to high-gain transition time, (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP} (final condition), I_{DC} = 100 µA		4		µs
$\overline{EN}$ CONTROL TRANSIENT PERFORMANCE						
	Enable transition time (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 0 µA, gain = 2 kΩ		125		ns
	Disable transition time (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 0 µA, gain = 2 kΩ		3		ns
	Enable transition time (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 0 µA, gain = 20 kΩ		850		ns
	Disable transition time (1% settling)	Ambient loop disabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 0 µA, gain = 20 kΩ		3		ns
	Enable transition time (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 100 µA, gain = 2 kΩ		10		µs
	Disable transition time (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 100 µA, gain = 20 kΩ		3.5		ns
	Enable transition time (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 100 µA, gain = 20 kΩ		4		µs
	Disable transition time (1% settling)	Ambient loop enabled, f_{IN} = 25 MHz, V_{OUT} = 1 V_{PP}, I_{DC} = 100 µA, gain = 2 kΩ		3		ns

(1) Input capacitance of photodiode.

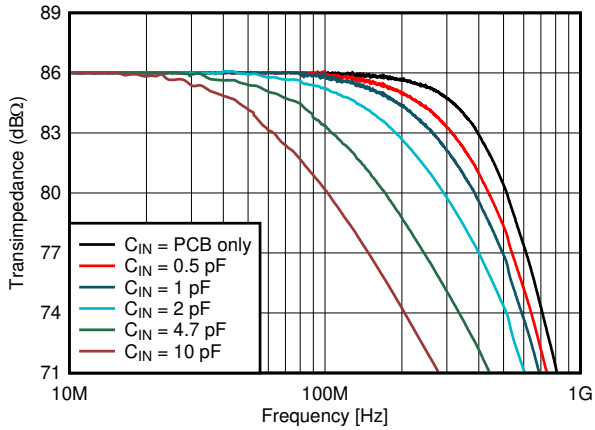
6.9 Typical Characteristics

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



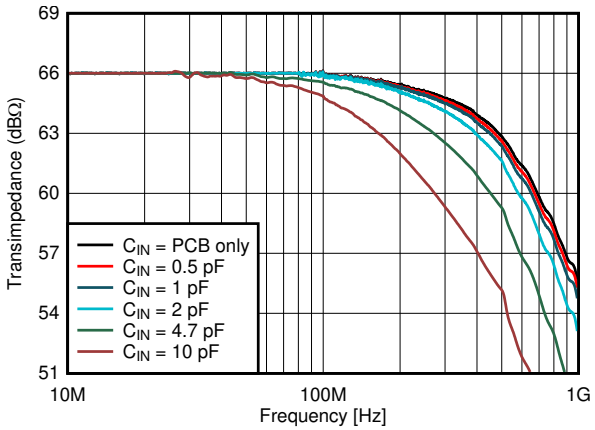
Gain = 2 kΩ, V_{OUT} = 100 mV_{PP}

Figure 6-1. Small-Signal Response vs Input Capacitance



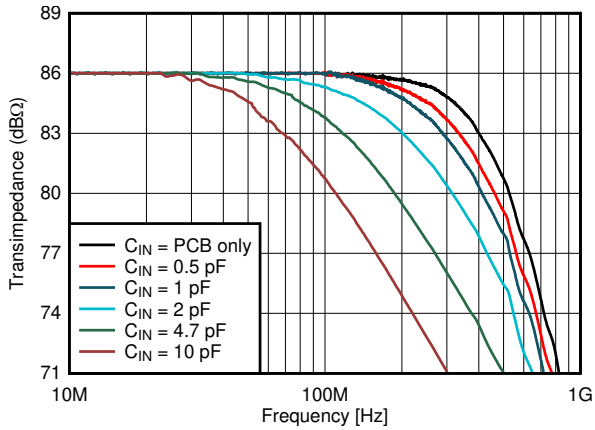
Gain = 20 kΩ, V_{OUT} = 100 mV_{PP}

Figure 6-2. Small-Signal Response vs Input Capacitance



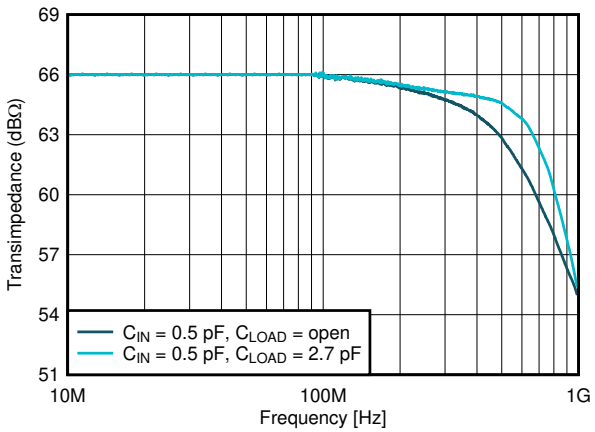
Gain = 2 kΩ, V_{OUT} = 1 V_{PP}

Figure 6-3. Large-Signal Response vs Input Capacitance



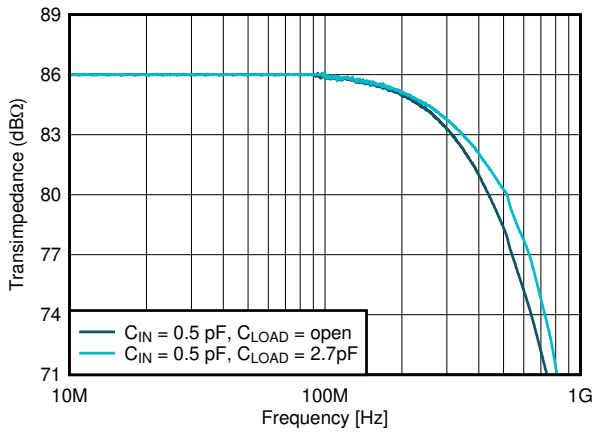
Gain = 20 kΩ, V_{OUT} = 1 V_{PP}

Figure 6-4. Large-Signal Response vs Input Capacitance



Gain = 2 kΩ, V_{OUT} = 100 mV_{PP}

Figure 6-5. Small-Signal Response vs Load Capacitance

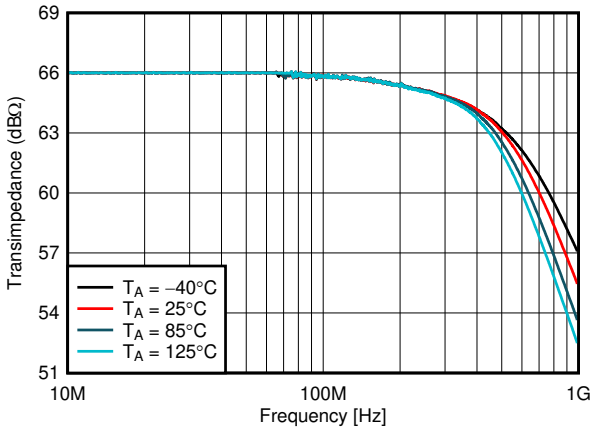


Gain = 20 kΩ, V_{OUT} = 100 mV_{PP}

Figure 6-6. Small-Signal Response vs Load Capacitance

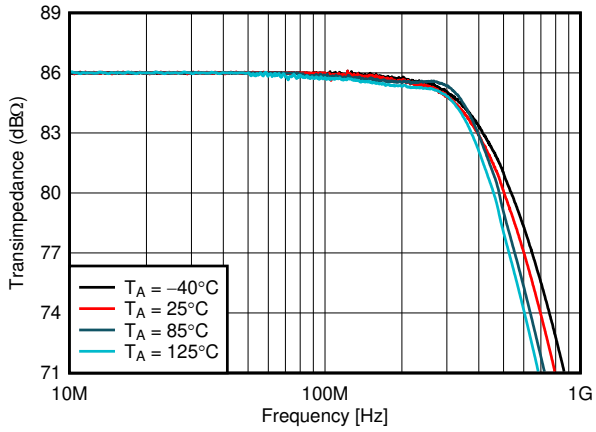
6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



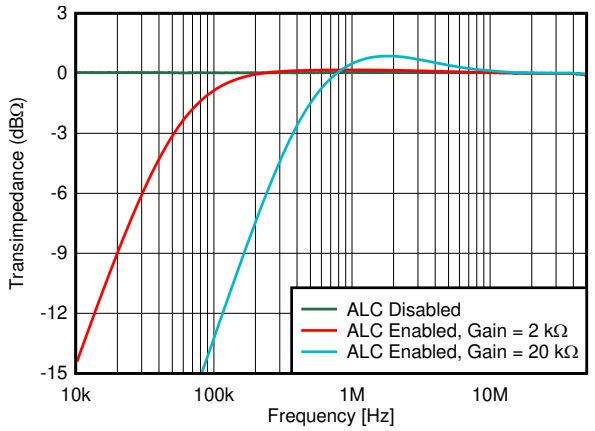
Gain = 2 kΩ, C_{IN} = PCB

Figure 6-7. Small-Signal Response vs Ambient Temperature



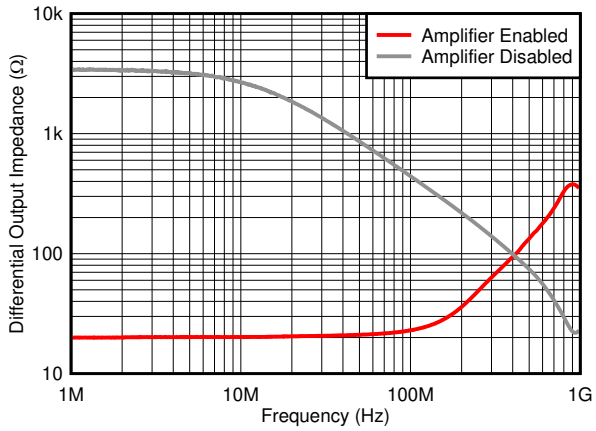
Gain = 20 kΩ, C_{IN} = PCB

Figure 6-8. Small-Signal Response vs Ambient Temperature



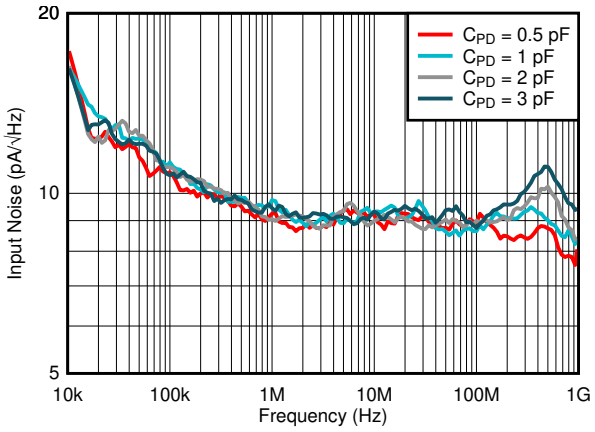
I_{DC_IN} = 100 µA

Figure 6-9. Low-side Frequency Response vs Ambient-Light Cancellation



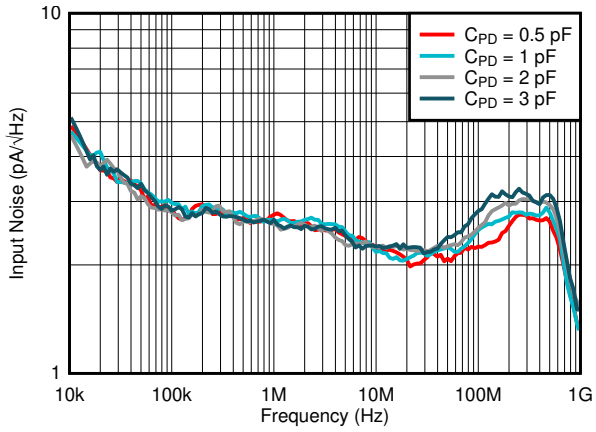
Gain = 2 kΩ

Figure 6-10. Closed-Loop Output Impedance vs Frequency



Gain = 2 kΩ

Figure 6-11. Input Noise Density vs Input Capacitance



Gain = 20 kΩ

Figure 6-12. Input Noise Density vs Input Capacitance

6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)

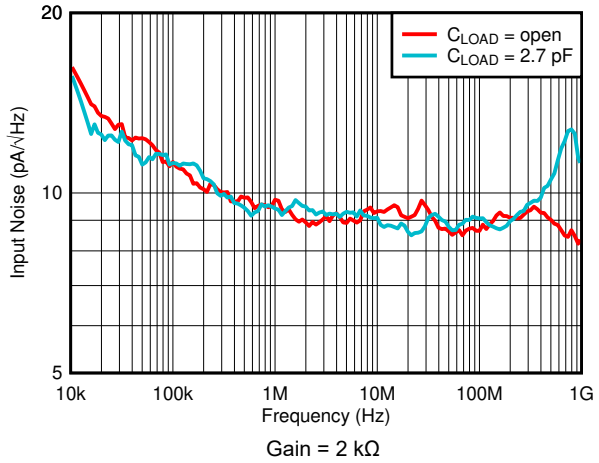


Figure 6-13. Input Noise Density vs Load Capacitance

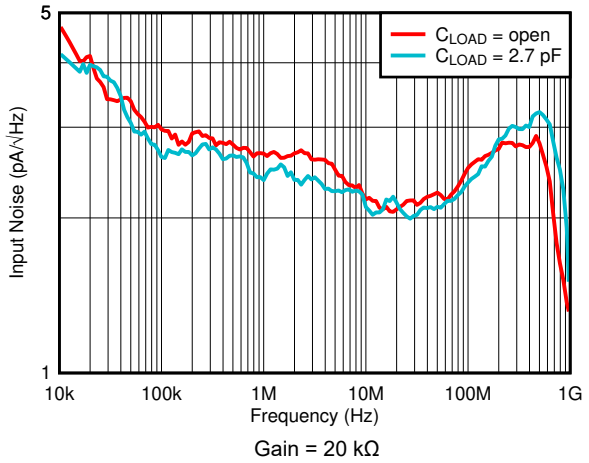


Figure 6-14. Input Noise Density vs Load Capacitance

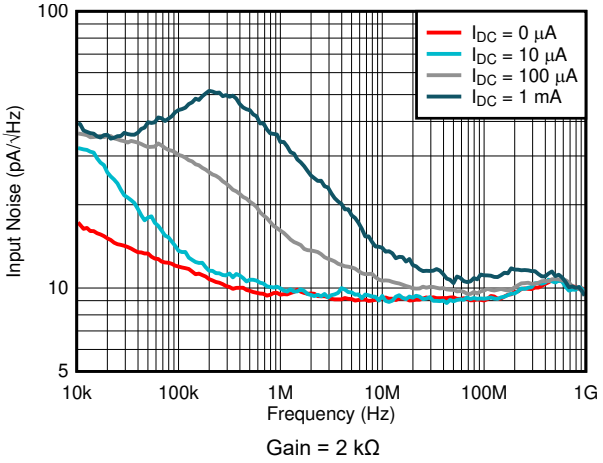


Figure 6-15. Input Noise Density vs Ambient-Light DC Current

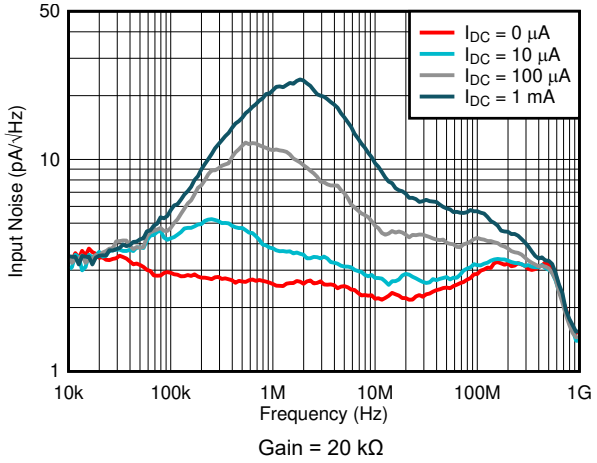


Figure 6-16. Input Noise Density vs Ambient-Light DC Current

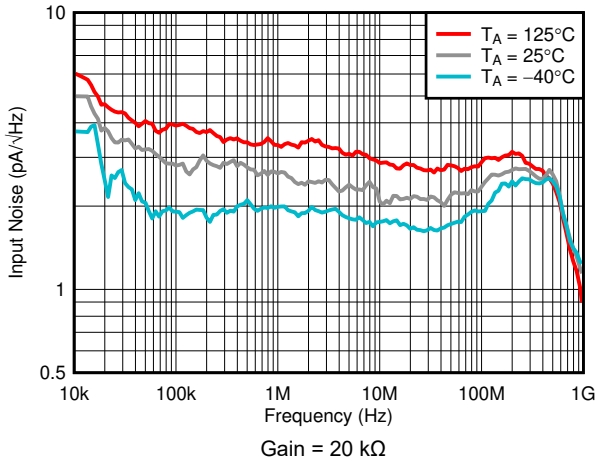


Figure 6-17. Input Noise Density vs Ambient Temperature

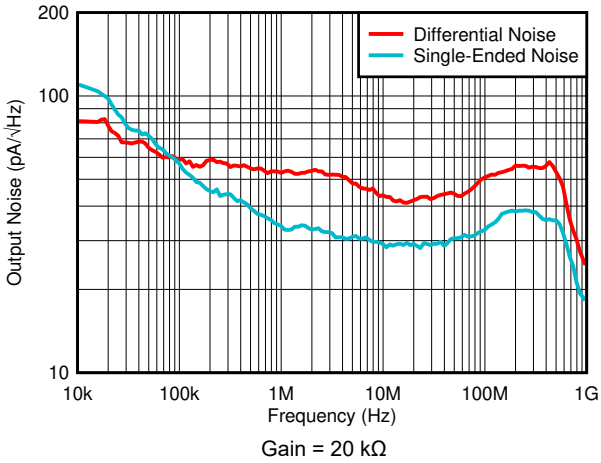
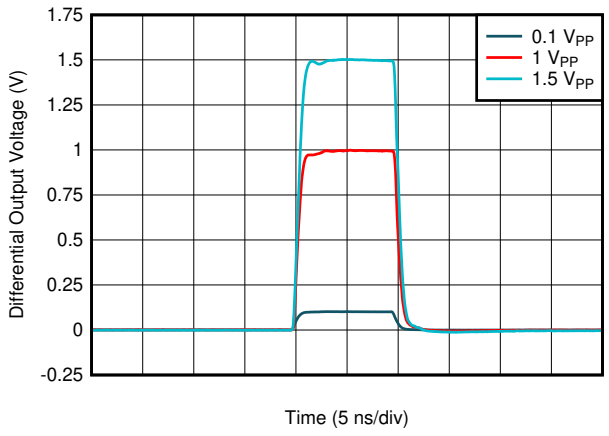


Figure 6-18. Output Noise Density vs Output Configuration

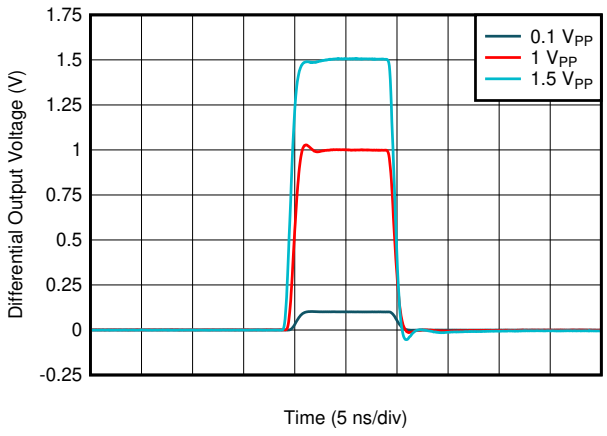
6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



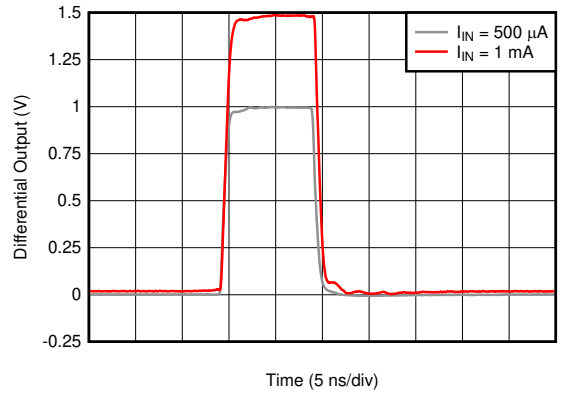
Gain = 2 kΩ

Figure 6-19. Pulse Response vs Output Swing



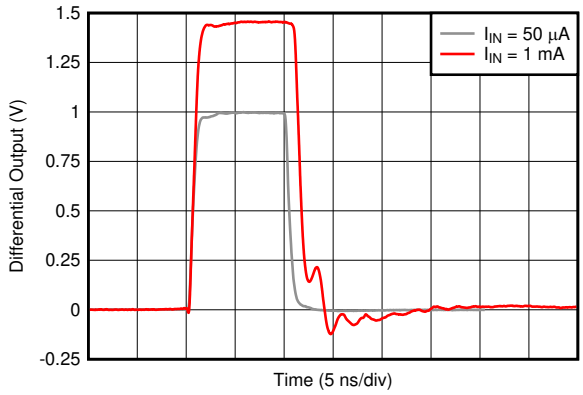
Gain = 20 kΩ

Figure 6-20. Pulse Response vs Output Swing



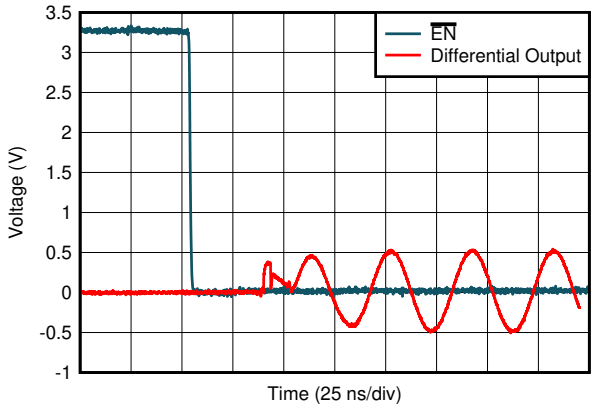
Gain = 2 kΩ

Figure 6-21. Overloaded Pulse Response



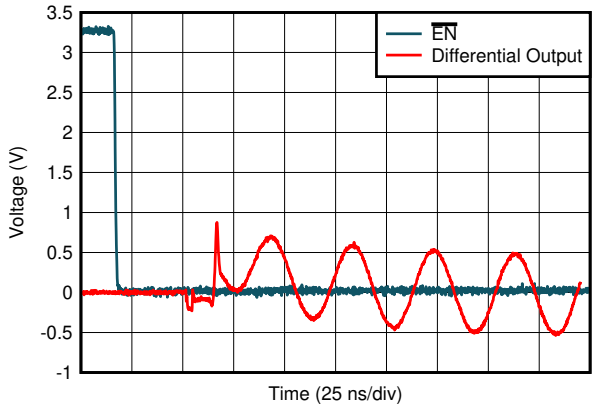
Gain = 20 kΩ

Figure 6-22. Overloaded Pulse Response



Gain = 2 kΩ

Figure 6-23. Turn-On Time

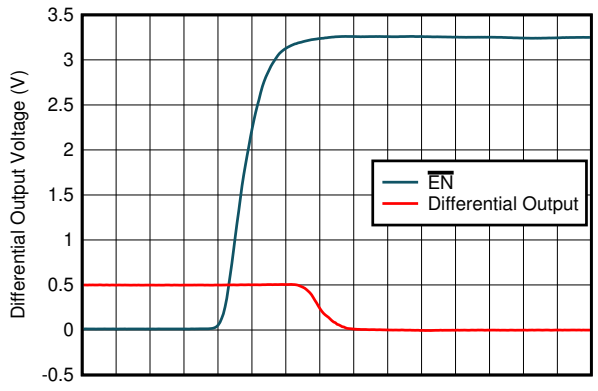


Gain = 20 kΩ

Figure 6-24. Turn-On Time

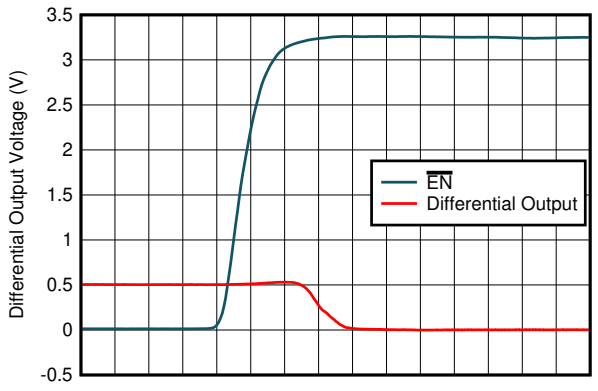
6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



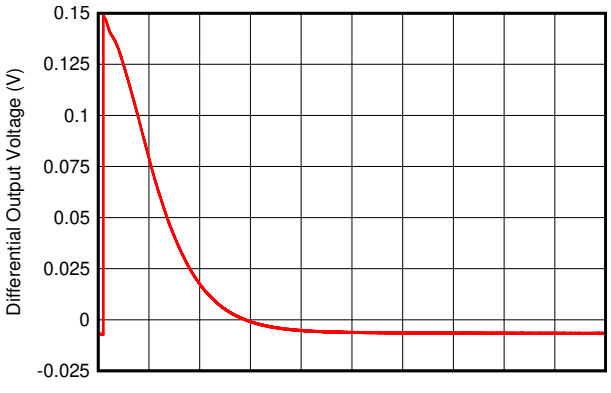
Gain = 2 kΩ, V_{VOD} = 0.5 V

Figure 6-25. Turn-Off Time



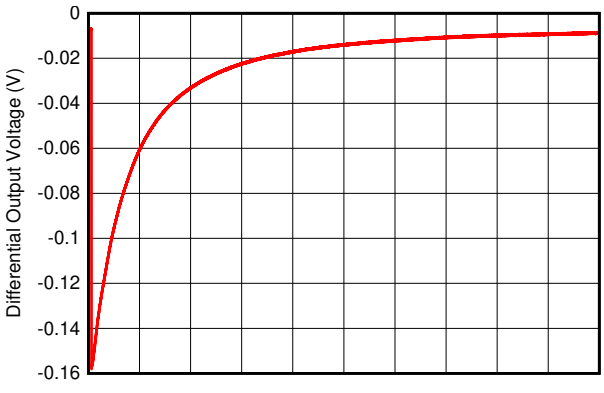
Gain = 20 kΩ, V_{VOD} = 0.5 V

Figure 6-26. Turn-Off Time



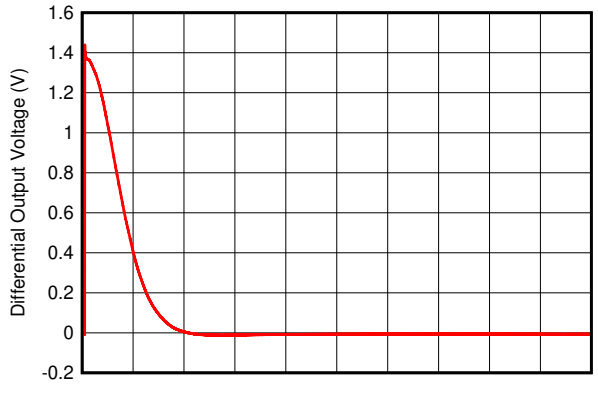
Gain = 2 kΩ, I_{DC_IN} = 0 µA → 100 µA (current due to ambient light transitions at the lowest displayed value of the time axis)

Figure 6-27. Ambient Loop Cancellation Settling Time



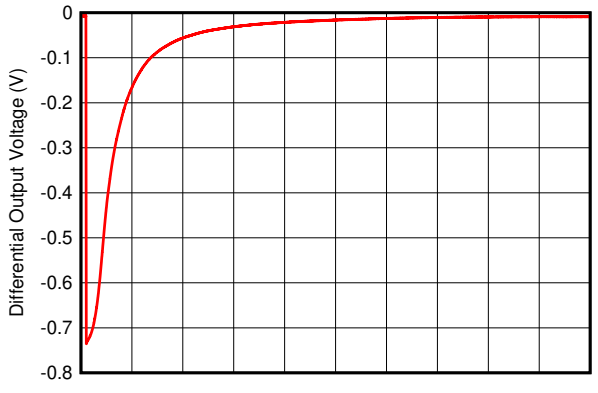
Gain = 2 kΩ, I_{DC_IN} = 100 µA → 0 µA (current due to ambient light transitions at the lowest displayed value of the time axis)

Figure 6-28. Ambient Loop-Cancellation Settling Time



Gain = 20 kΩ, I_{DC_IN} = 0 µA → 100 µA (current due to ambient light transitions at the lowest displayed value of the time axis)

Figure 6-29. Ambient Loop-Cancellation Settling Time

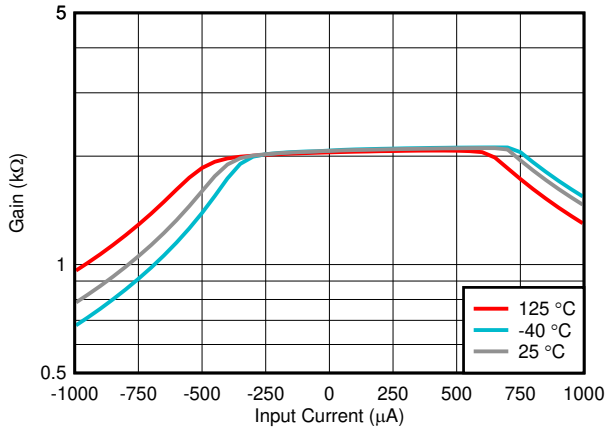


Gain = 20 kΩ, I_{DC_IN} = 100 µA → 0 µA (current due to ambient light transitions at the lowest displayed value of the time axis)

Figure 6-30. Ambient Loop-Cancellation Settling Time

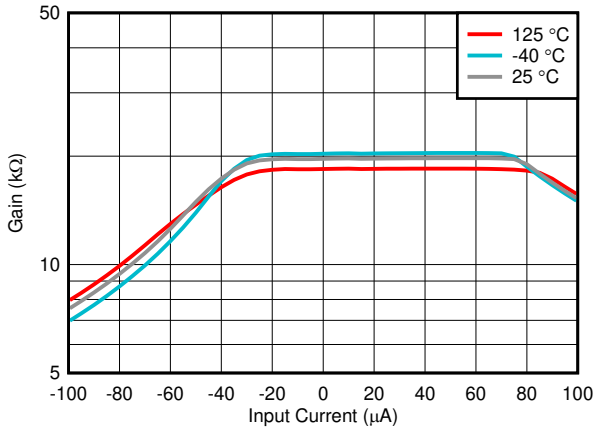
6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



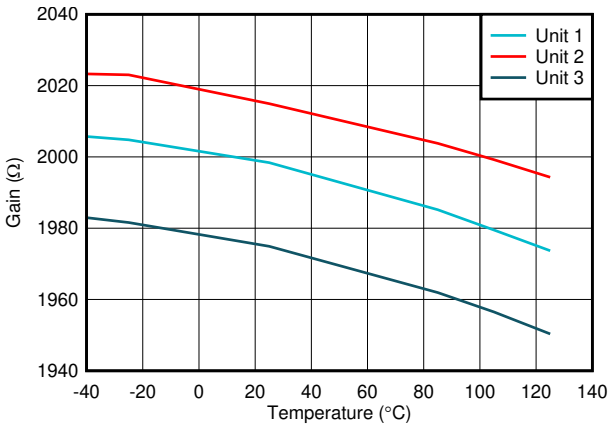
Gain = 2 kΩ, positive current is sinking current into the photodiode cathode

Figure 6-31. Transimpedance Gain vs Input Current



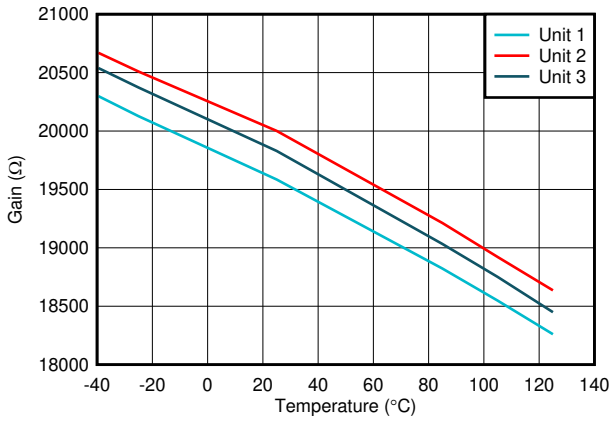
Gain = 20 kΩ, positive current is sinking current into the photodiode cathode

Figure 6-32. Transimpedance Gain vs Input Current



Gain = 2 kΩ

Figure 6-33. Transimpedance Gain vs Ambient Temperature



Gain = 20 kΩ

Figure 6-34. Transimpedance Gain vs Ambient Temperature

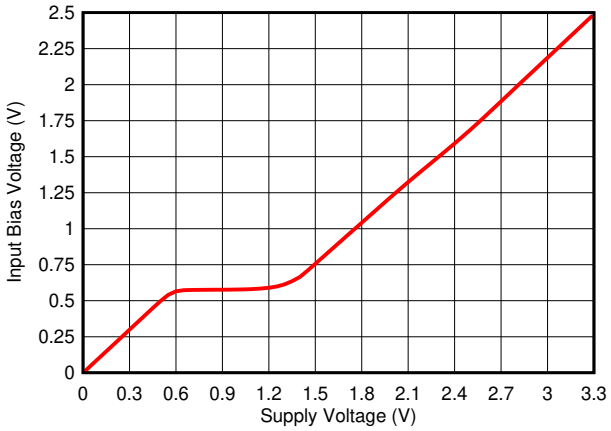
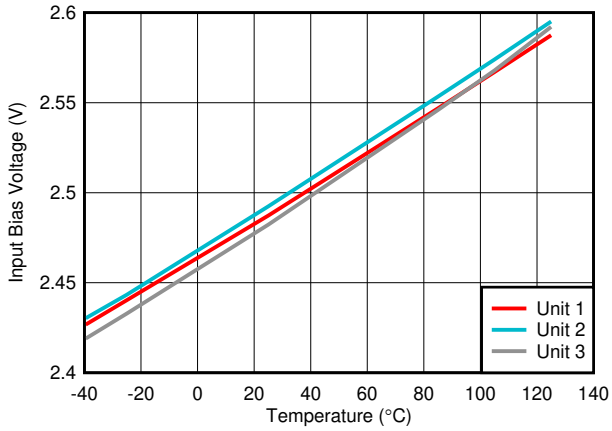


Figure 6-35. Input Bias Voltage vs Supply Voltage



Gain = 20 kΩ

Figure 6-36. Input Bias Voltage vs Ambient Temperature

6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)

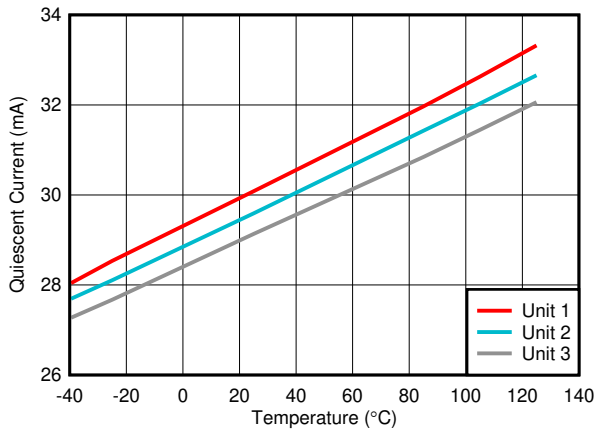


Figure 6-37. Quiescent Current vs Ambient Temperature

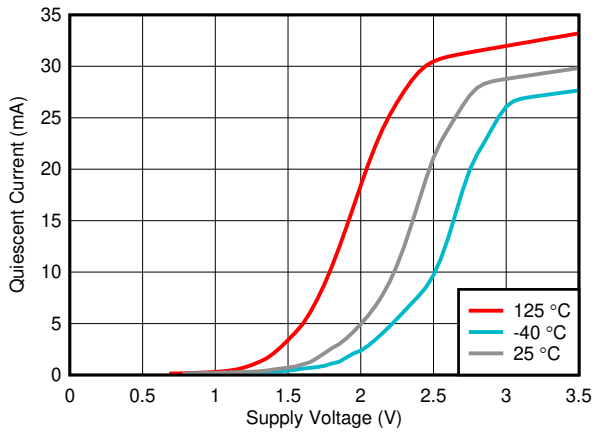
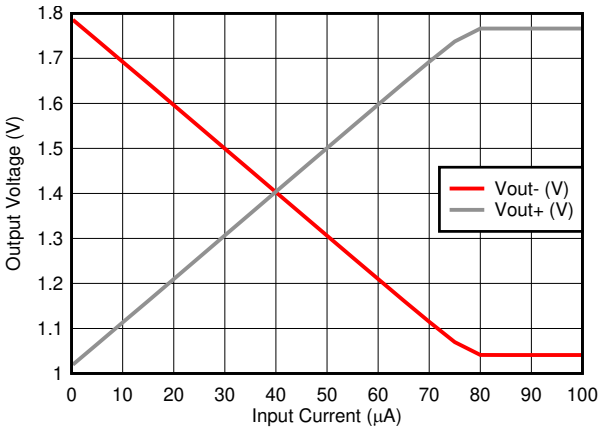
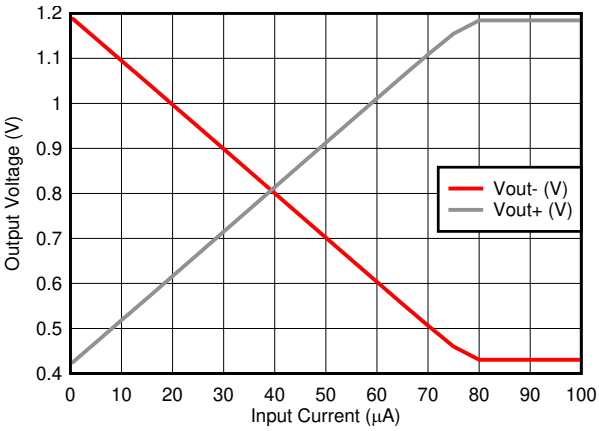


Figure 6-38. Quiescent Current vs Supply Voltage



V_{VOD} = 0.75 V, V_{VOCM} = 1.4 V

Figure 6-39. High-side Swing vs Input Current



V_{VOD} = 0.75 V, V_{VOCM} = 0.8 V

Figure 6-40. Low-side Swing vs Input Current

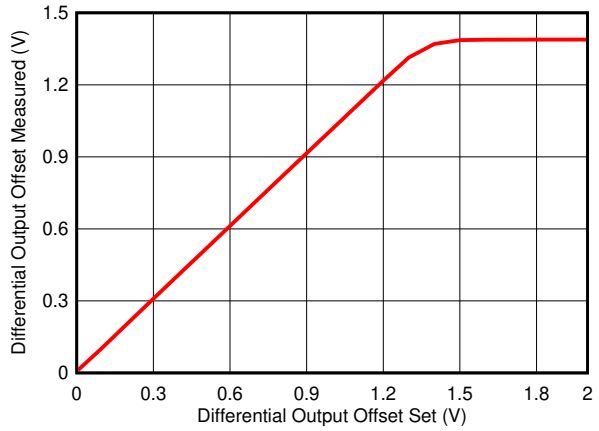


Figure 6-41. Differential Output Offset Gain

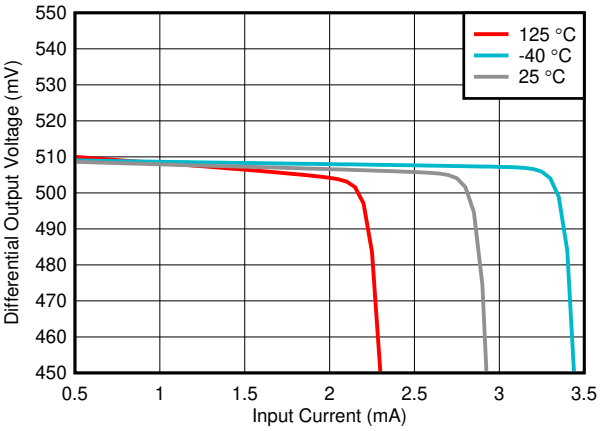
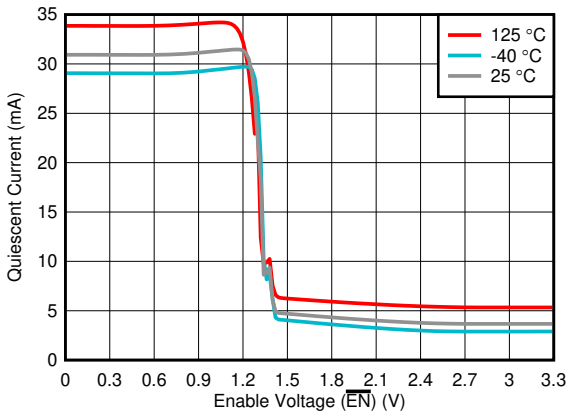


Figure 6-42. Ambient Light Cancellation Range vs Ambient Temperature

6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)



Logic switching demonstrated using $\overline{EN}$ pin.
$\overline{IDC\_EN}$ and gain pins behave similarly.

Figure 6-43. Logic Threshold vs Ambient Temperature

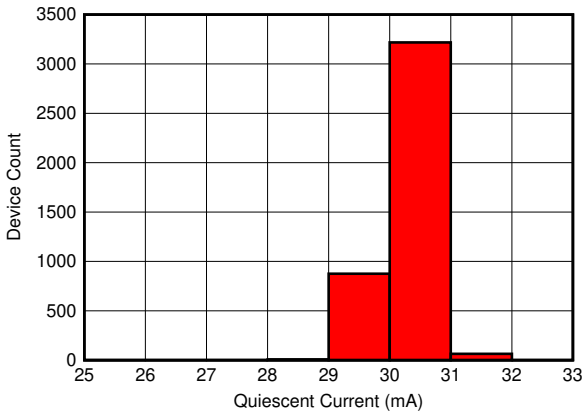


Figure 6-44. Quiescent Current Distribution

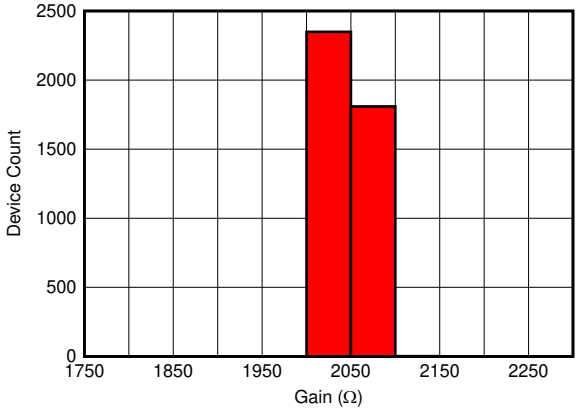
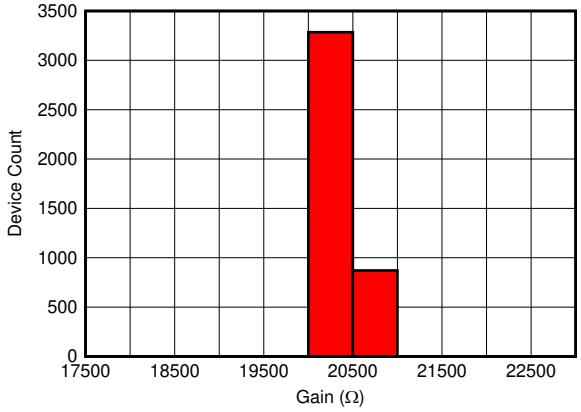


Figure 6-45. Transimpedance Gain (Low) Distribution



Gain = 20 kΩ

Figure 6-46. Transimpedance Gain (High) Distribution

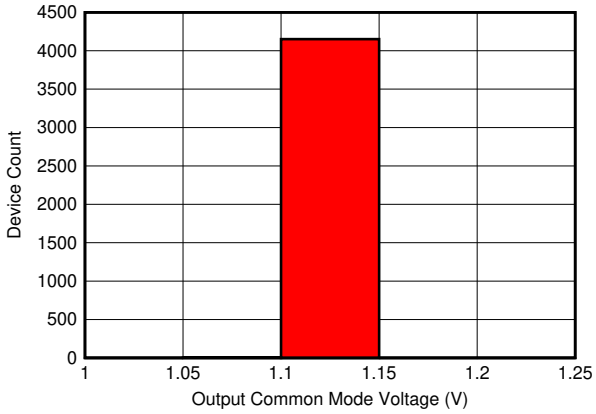


Figure 6-47. Output Common-Mode Voltage (V_{OCM}) Distribution

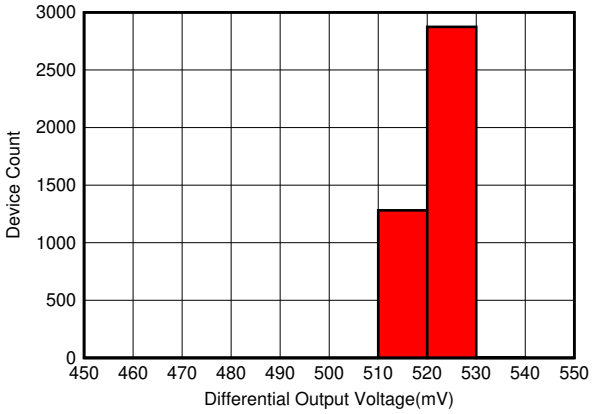


Figure 6-48. Differential Output Offset Voltage (V_{OD}) Distribution

6.9 Typical Characteristics (continued)

at V_{DD} = 3.3 V, V_{OCM} = open, V_{OD} = 0 V, C_{PD} = 1 pF, $\overline{EN}$ = 0 V (enabled), $\overline{IDC\_EN}$ = 3.3 V (disabled), R_L = 100 Ω (differential load between OUT+ and OUT–), and T_A = 25°C (unless otherwise noted)

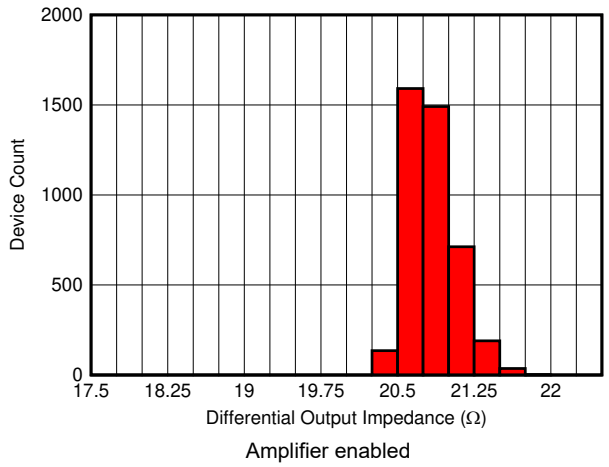


Figure 6-49. Differential Output Impedance (Z_{OUT}) Distribution

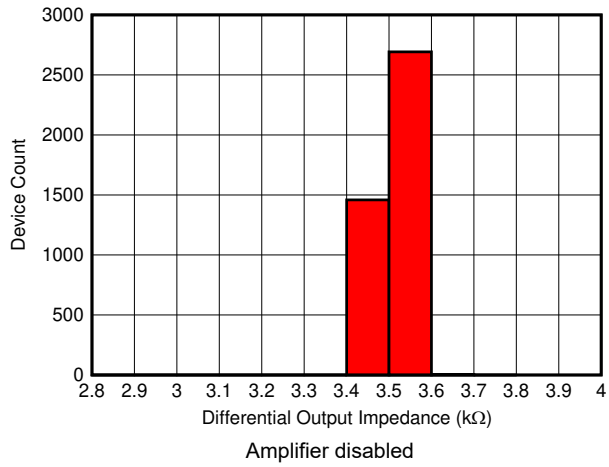


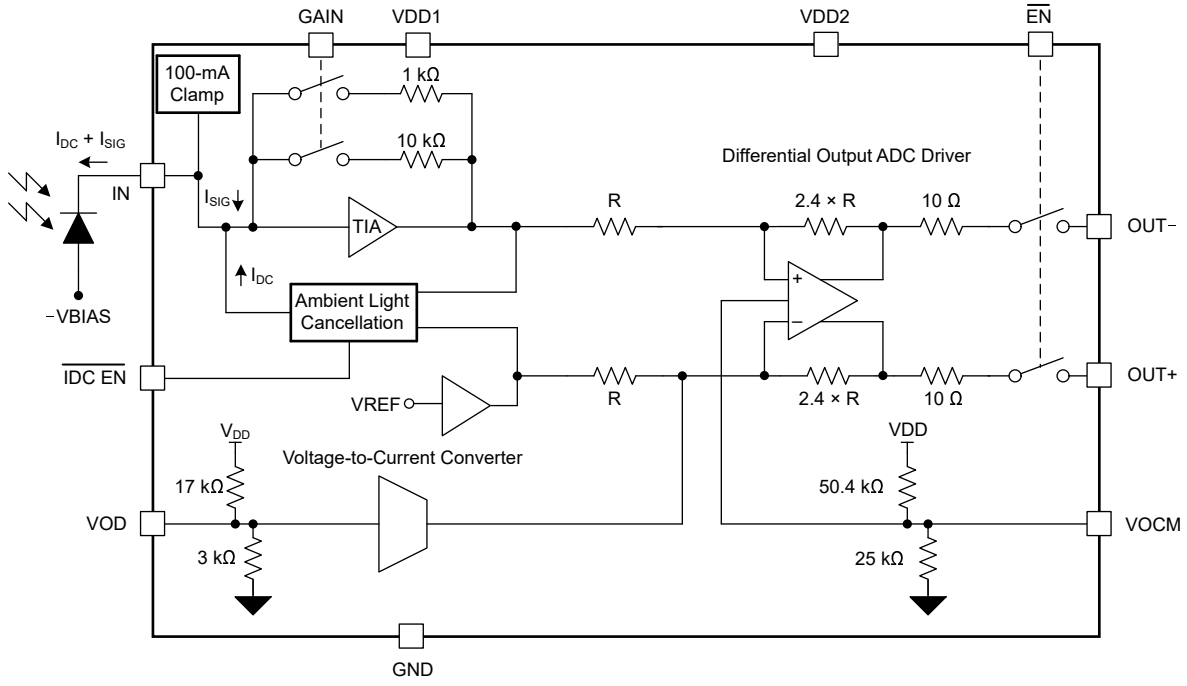
Figure 6-50. Differential Output Impedance (Z_{OUT}) Distribution

7 Detailed Description

7.1 Overview

The LMH32401-Q1 device is a single-channel, differential output, high-speed transimpedance amplifier (TIA) that features several integrated functions geared towards light detection and ranging (LIDAR) and pulsed time-of-flight (ToF) systems. The LMH32401-Q1 is designed to work with photodiode (PD) configurations that can source or sink current. When the photodiode sinks the photocurrent (the anode is biased to a negative voltage and the cathode is tied to the amplifier input), the fast recovery clamp activates when the amplifier input is overloaded. When the photodiode sources the photocurrent (the cathode is biased to a positive voltage and the anode is tied to the amplifier input), a soft clamp activates when the amplifier input is overloaded. When the soft clamp activates, the amplifier requires more time to recover. The recovery time depends on the level of input overload. The LMH32401-Q1 is offered in a space-saving 3-mm × 3-mm, 16-pin VQFN package and is rated over the temperature range of –40°C to +125°C.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Switched Gain Transimpedance Amplifier

The LMH32401-Q1 features a programmable gain transimpedance amplifier (TIA) stage followed by a fixed-gain, single-ended input to differential output amplifier stage. The closed-loop bandwidth and noise of a TIA are affected by the transimpedance gain and photodiode capacitance. For a given value of photodiode capacitance, the LMH32401-Q1 has higher bandwidth in the device low-gain configuration compared to the high-gain configuration. Increasing the gain of the TIA stage by a factor of X increases the output signal by a factor X, but the noise contribution from the resistor only increases by $\sqrt{X}$. The input-referred noise density of the low-gain configuration is therefore higher than the input-referred noise density of the high-gain configuration.

The gain of the TIA stage is controlled by the GAIN pin. Setting this pin low places the TIA in the low-gain configuration; whereas, setting the pin high places the TIA in a high-gain configuration. The LMH32401-Q1 defaults to the low-gain configuration when the GAIN pin is left floating.

7.3.2 Clamping and Input Protection

The LMH32401-Q1 is designed to work with photodiode (PD) configurations that can source or sink current; however, the LMH32401-Q1 is optimized for a sinking-current configuration. The LMH32401-Q1 is usually used with a PD that is configured with the device cathode tied to the amplifier input and the device anode tied to a negative supply voltage.

The LMH32401-Q1 features two internal clamps: fast-recovery and soft. The fast-recovery clamp is the active clamp when the photodiode is sinking a photocurrent. The soft clamp is the active clamp when the photodiode is sourcing a photocurrent. Stray reflections from nearby objects with high reflectivity can produce large output current pulses from the PD. The linear input range of the LMH32401-Q1 is approximately 65 µA in the high-gain configuration and 650 µA in the low-gain configuration (PD sinking the photocurrent).

Input currents in excess of the linear current range cause the internal nodes of the amplifier to saturate, which increases the amplifier recovery time. The end result is a broadening of the output pulse, leading to blind zones in the system response. To protect against this condition, the LMH32401-Q1 features an integrated clamp that absorbs and diverts the excess current to the positive supply (V_{DD1}) when the amplifier detects the device nodes entering a saturated condition. The integrated clamp minimizes the pulse extension to less than a few ns for input pulses up to 100 mA. The power-supply pins (VDD1 and VDD2) must each have bypass capacitors to prevent large input pulses from affecting the differential output stage. When the amplifier is in low-power mode, the clamp circuitry is still active, thereby protecting the TIA input.

7.3.3 ESD Protection

All LMH32401-Q1 pins have an internal electrostatic discharge (ESD) protection diode to the positive and negative supply rails to protect the amplifier from ESD events.

7.3.4 Differential Output Stage

The differential output stage of the LMH32401-Q1 performs the following two functions, which are common across all differential amplifiers:

1. Converts the single-ended output from the TIA stage to a differential output.
2. Performs a common-mode output shift to match the specified ADC input common-mode voltage.

The differential output stage has two 10-Ω series resistors on the output to isolate the amplifier output stage transistors from the package bond-wire inductance and printed circuit board (PCB) capacitance. The net gain of the LMH32401-Q1 (TIA + output stage) is 2 kΩ (low gain) and 20 kΩ (high gain) when driving an external 100-Ω resistor. When the external load resistor is increased above 100 Ω, the effective gain from the IN pin to the differential output pin increases. Conversely, when the external load resistor is decreased to less than 100 Ω, the effective gain from the IN pin to the differential output pin decreases as a result of the larger voltage drop across the two internal 10-Ω resistors. When there is no load resistor between the OUT+ and OUT– pins, the effective gain of the LMH32401-Q1 in the low-gain configuration is 2.4 kΩ, and in the high-gain configuration is 24 kΩ.

The output common-mode voltage of the LMH32401-Q1 is set externally through the VOCM pin. A resistor divider internal to the amplifier (between VDD2 and ground) sets the default voltage to 1.1 V. The internal resistors generate common-mode noise that is typically rejected by the CMRR of the subsequent ADC stage. To maximize the amplifier signal-to-noise ratio (SNR), place an external noise bypass capacitor to ground on the VOCM pin. In single-ended signal chains, such as ToF systems that use time-to-digital converters (TDCs), only a single output of the LMH32401-Q1 is required. In such situations, terminate the unused differential output in the same manner as the used output to maintain balance and symmetry. The signal swing of the single-ended output is half of the available differential output swing. Additionally, the common-mode noise of the output stage, which is typically rejected by the differential input ADC, is now added to the total noise, and further degrades SNR.

The output stage of the LMH32401-Q1 has an additional VOD input that sets the differential output between OUT– and OUT+. Figure 7-1 shows how each output pin of the LMH32401-Q1 is at the voltage set by the VOCM pin (default = 1.1 V) when the photodiode output current is zero and the VOD input is set to 0 V. When the VOD pin is driven to a voltage of *X* volts, the two output pins are separated by *X* volts when the photodiode current is zero. The average voltage is still equal to VOCM. For example, Figure 7-2 shows that if VOCM is set to 1.1 V and VOD is set to 0.4 V, then OUT– = 1.1 V + 0.2 V = 1.3 V and OUT+ = 1.1 V – 0.2 V = 0.9 V.

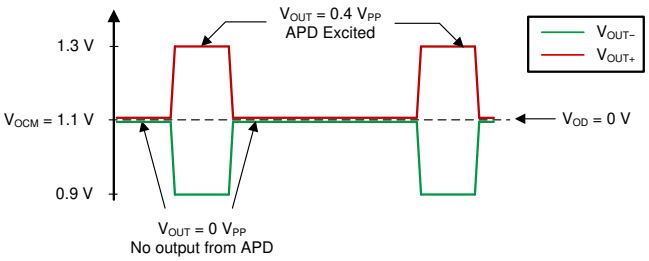


Figure 7-1. Individual Single-ended Outputs With VOD = 0 V

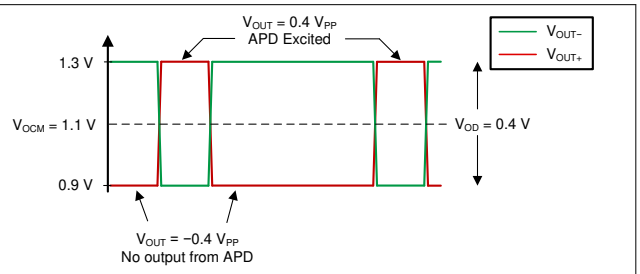


Figure 7-2. Individual Single-Ended Outputs With VOD = 0.4 V

The VOD pin is functional only when the LMH32401-Q1 is used with a PD that sinks the photocurrent. Set VOD = 0 V when the LMH32401-Q1 is interfaced with a PD that sources the photocurrent. The VOD output offset feature is included in the LMH32401-Q1 because the output current of a photodiode is unipolar. Depending on the reverse bias configuration, the photodiode can either sink or source current, but cannot do both simultaneously. With the anode connected to a negative bias and the cathode connected to the TIA stage input, the photodiode can only sink current, which implies that the TIA stage output swings in a positive direction greater than the default input bias voltage (2.47 V). Subsequently, OUT– only swings less than VOCM, and OUT+ only swings greater than VOCM. Figure 7-1 shows how the LMH32401-Q1 device only uses half of the output swing range ($V_{OUT} = V_{OUT+} – V_{OUT–}$) when VOD = 0 V because one output never swings less than VOCM and the other output never exceeds VOCM. The signal dynamic range in this case is 0.4 V_{PP} – 0 V = 0.4 V_{PP}.

Figure 7-2 shows how the VOD pin voltage allows OUT– to be level-shifted to greater than VOCM, and OUT+ to be level-shifted below VOCM to maximize the output swing capabilities of the amplifier. The signal dynamic range in this case is 0.4 V_{PP} – (–0.4 V_{PP}) = 0.8 V_{PP}.

When the LMH32401-Q1 device drives a 100-Ω load, the voltage set at the VOD pin is equal to the differential output offset ($V_{OUT} = V_{OUT+} – V_{OUT–}$) when the input signal current is zero. Use Equation 1 to calculate the differential output offset under other load conditions.

$$V_{OD} = 1.2 \times V_{VOD} \times \frac{R_L}{R_L + 20\Omega} \quad (1)$$

where

- V_{VOD} = Voltage applied at pin 9
- $V_{OD} = (V_{OUT–}) – (V_{OUT+})$
- R_L = External load resistance

7.4 Device Functional Modes

7.4.1 Ambient Light Cancellation (ALC) Mode

The LMH32401-Q1 has an integrated, dc, ambient light cancellation (ALC) loop that cancels any voltage offsets as a result of incidental ambient light. ALC mode only works when the PD is sinking the photocurrent. To enable ALC mode, set $\overline{\text{IDC\_EN}}$ low. Incidental ambient light on a photodiode produces a dc current that results in an offset voltage at the output of the LMH32401-Q1 TIA stage. *Section 7.2* shows how the ALC loop senses the low-frequency dc offset at the output of the TIA stage and compares the offset against the internal reference voltage (V_{REF}). The ALC loop then outputs an opposing dc current (I_{DC}) to compensate for the differential offset voltage at the device input. The ALC loop has a high-pass cutoff frequency of 100 kHz. ALC mode is disabled when the amplifier is placed in power-down mode.

The shot noise current introduced by the ALC loop increases the overall amplifier noise; therefore, if the ambient-light level is negligible, disable the loop to improve SNR. The ALC loop helps save PCB space and system costs by eliminating the need for external ac-coupling, passive components. Additionally, the extra trace inductance and PCB capacitance introduced by using external ac-coupling components degrade the LMH32401-Q1 dynamic performance.

7.4.2 Power-Down Mode (Multiplexer Mode)

To place the LMH32401-Q1 into a power-down mode, and thus help save system power, set $\overline{\text{EN}}$ high. Power-down mode puts the outputs of the LMH32401-Q1 internal amplifiers, including the differential outputs, into a high-impedance state. If a system consists of several photodiode and amplifier channels multiplexed to a single ADC channel, Figure 7-3 shows how this device feature can further save board space and cost by eliminating the need for a discrete high-speed multiplexer. The disabled channel outputs are not an ideal open circuit; therefore, as the number of multiplexed channels increases, the disabled channels begin to load the enabled channel. Multiplexing more than four channels in parallel degrades the performance of the enabled channel. When the amplifier is in power-down mode, the clamp circuitry is still active, thereby protecting the TIA input. The ALC loop is disabled when the amplifier is placed in power-down mode. When the LMH32401-Q1 is brought out of power-down operation, the ALC loop requires several time constants to settle. Figure 6-9 shows the low-frequency loop response, which in turn determines the time constant required for the loop to settle.

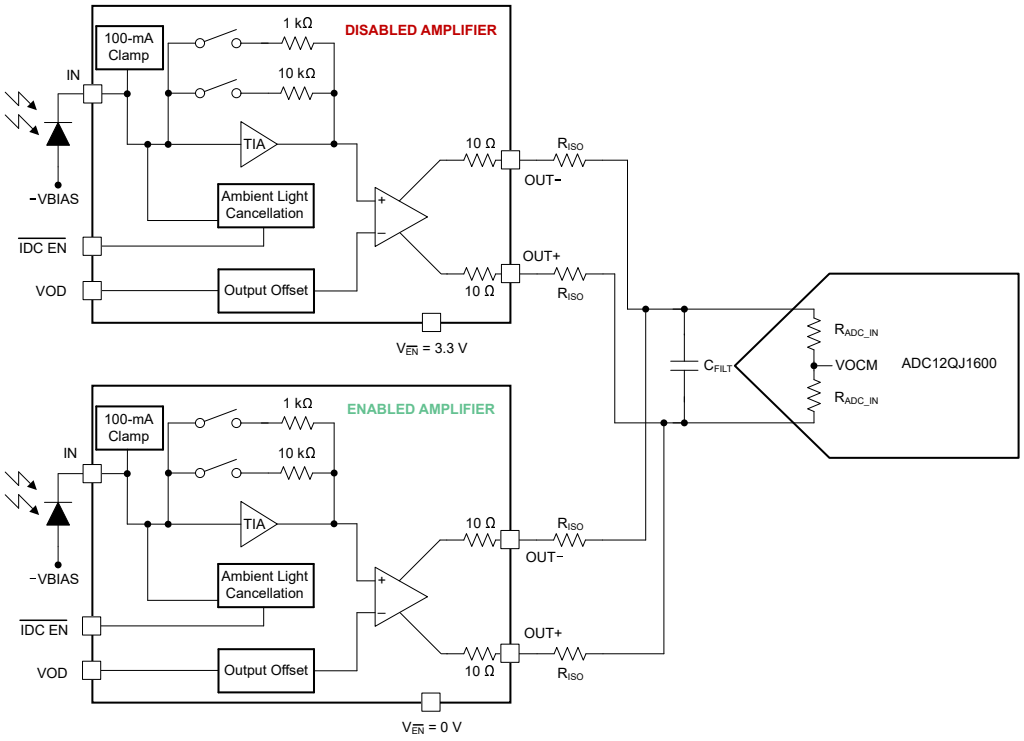


Figure 7-3. Configuring Two LMH32401-Q1 Devices in Multiplexer Mode to Drive a Single ADC

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, as well as validating and testing their design implementation to confirm system functionality.

8.1 Application Information

The differential outputs of the LMH32401-Q1 can directly drive a high-speed differential input ADC. Figure 8-1 shows the LMH32401-Q1 differential outputs directly driving the ADC12QJ1600. The effective signal gain between the TIA input and the ADC input is 2 kΩ or 20 kΩ when driving an ADC with a 100-Ω differential input impedance (R_{ADC_IN} = 50 Ω). Equation 2 gives the effective signal gain between the TIA input and the ADC input when driving an ADC with any other value of differential input impedance (R_{ADC_IN} ≠ 50 Ω).

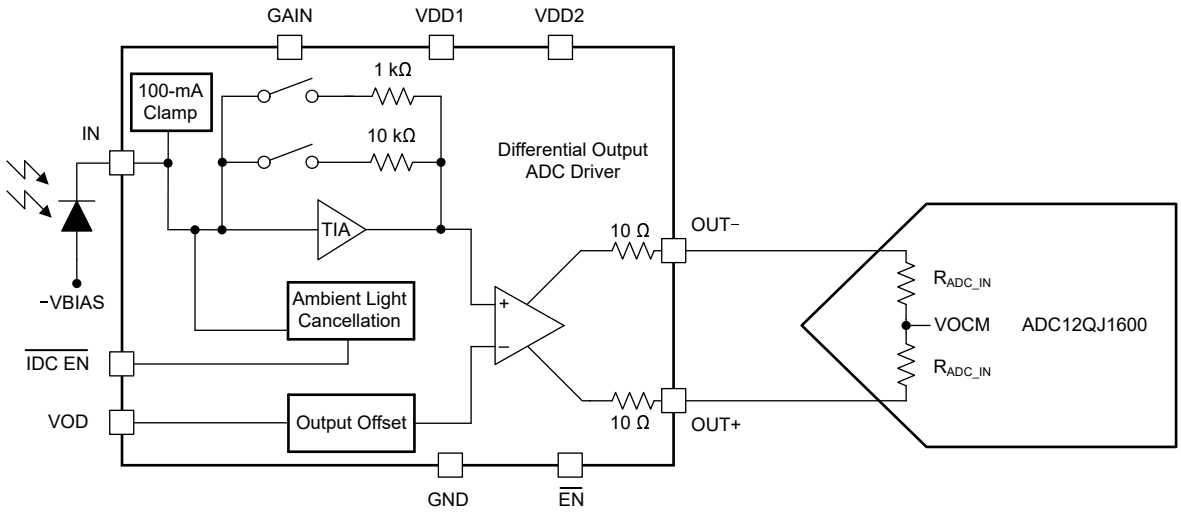


Figure 8-1. LMH32401-Q1 to ADC Interface

$$A_Z = 2\ k\Omega \left(\text{or } 20\ k\Omega \right) \times 1.2 \times \frac{2 \times R_{ADC\_IN}}{\left(2 \times R_{ADC_{IN}} + 20\ \Omega \right)} \quad (2)$$

where

- A_Z = Differential gain from the TIA input to the ADC input
- R_{ADC_IN} = Input resistance of the ADC

Figure 8-2 shows a matching resistor network between the LMH32401-Q1 output and the ADC12QJ1600 input. The matching network is needed to prevent signal reflections when the signal path between the LMH32401-Q1 and ADC is very long. Equation 3 gives the effective gain from the TIA input to the ADC input when using a matching resistor network.

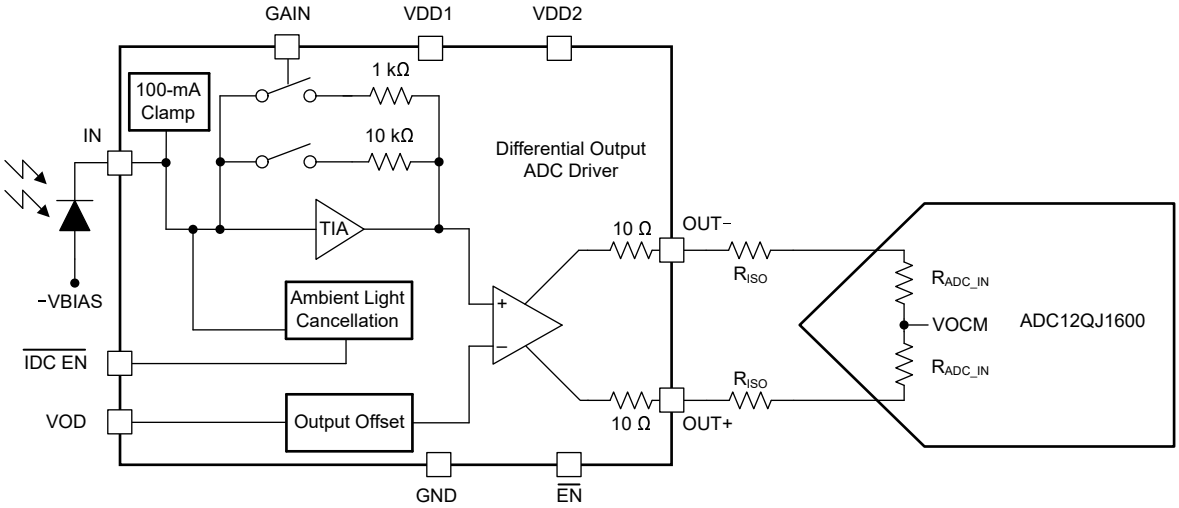


Figure 8-2. LMH32401-Q1 to ADC Interface With a Matching Resistor Network

$$A_Z = 2\ k\Omega \left(\text{or } 20\ k\Omega \right) \times 1.2 \times \frac{2 \times R_{ADC\_IN}}{\left(2 \times R_{ADC\_IN} + 2 \times R_{ISO} + 20\ \Omega\right)} \quad (3)$$

where

- A_Z = Gain from the TIA input to the ADC input
- R_{ADC_IN} = Differential input resistance of the ADC
- R_{ISO} = Series resistance between the TIA and ADC

Equation 4 gives the voltage to be applied at VOD (pin 9) if a certain differential offset voltage (V_{OD}) is needed at the ADC input for the circuit in Figure 8-2.

$$V_{VOD} = V_{OD} \times \left(\frac{1}{1.2}\right) \times \frac{\left(2 \times R_{ADC\_IN} + 2 \times R_{ISO} + 20\ \Omega\right)}{\left(2 \times R_{ADC\_IN}\right)} \quad (4)$$

where

- V_{VOD} = Voltage applied at pin 9
- V_{OD} = Desired differential offset voltage at the ADC input
- R_{ADC_IN} = Differential input resistance of the ADC
- R_{ISO} = Series resistance between the TIA and ADC

8.2 Typical Application

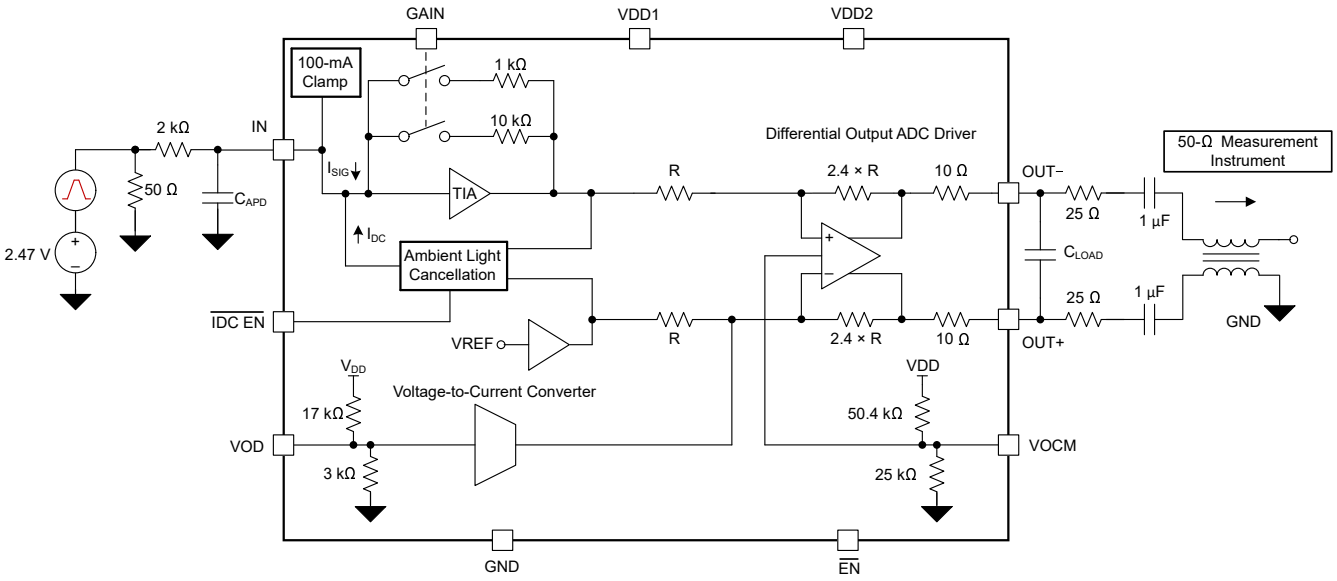


Figure 8-3. LMH32401-Q1 Test Circuit

This section demonstrates the performance of the LMH32401-Q1 device when the input current flows into the IN pin. Figure 8-3 shows the circuit used to test the LMH32401-Q1 device with a voltage source. This configuration demonstrates the use case when the photodiode anode is tied to the amplifier input and the photodiode cathode is tied to a positive voltage greater than 2.47 V.

8.2.1 Design Requirements

The objective is to design a low-noise, wideband differential output transimpedance amplifier. The design requirements are as follows:

- Amplifier supply voltage: 3.3 V
- Transimpedance gain: 2 kΩ and 20 kΩ
- Input capacitance: C_{PCB} ≅ 1 pF
- Target bandwidth: > 250 MHz
- Differential output offset (VOD): 0 V
- Ambient light cancellation ($\overline{IDC\_EN}$): 3.3 V (disabled)

8.2.2 Detailed Design Procedure

Figure 8-3 shows the test circuit used to measure the LMH32401-Q1 bandwidth and transient pulse response. The voltage source is dc biased close to the input bias voltage of the LMH32401-Q1 (approximately 2.47 V). The internal design of the LMH32401-Q1 is optimized to only source current out of the input pin (pin 3), and all the data shown previously are with the current flowing out of the pin. When the voltage input from the source exceeds 2.47 V, the LMH32401-Q1 input sinks the current. Set V_{VOD} = 0 V when the input must sink the current from the photodiode, or in this case, the voltage source. Set the dc bias so that sum of the input ac and dc component is always greater than the input voltage (2.47 V) when testing the LMH32401-Q1 with a network analyzer or sinusoidal source.

Figure 8-4 and Figure 8-5 shows the bandwidth of the LMH32401-Q1 when the device input is sinking the current. The input current range of the LMH32401-Q1 is reduced when the device input is sinking the current. This effect is seen by the decrease in bandwidth as the output swing increases and is more pronounced in a gain configuration of 20 kΩ. Compare Figure 8-4 with Figure 6-1 and Figure 6-3 to see the effect of current direction and input range in a 2-kΩ gain configuration. In a similar way, compare Figure 8-5 with Figure 6-2 and Figure 6-4 to see the effect of current direction and input range in a gain of 20 kΩ.

Figure 8-6 and Figure 8-7 show the pulsed-output response of the LMH32401-Q1 when the input current is increased past the amplifier linear input range. When the input is sinking current, a soft clamp aids in fast recovery; however, the pulse stretches slightly as the input current overrange increases. Compare Figure 8-6 with Figure 6-21 to see the pulse extension effect in a gain of 2 kΩ. Compare Figure 8-7 with Figure 6-22 to see the pulse extension effect in a gain of 20 kΩ. Knowledge of the pulse extension is used to determine the approximate input current, even under overrange situations that can occur because of the presence of retro-reflectors in the environment. As Figure 7-1 shows, each half of the differential output pulse swings greater than or less than the VOCM voltage, and the resulting maximum differential output swing is 0.75 V_{PP} because VOD is set to 0 V. Consequently, only half of the total ADC range is used in this photodiode configuration.

8.2.3 Application Curves

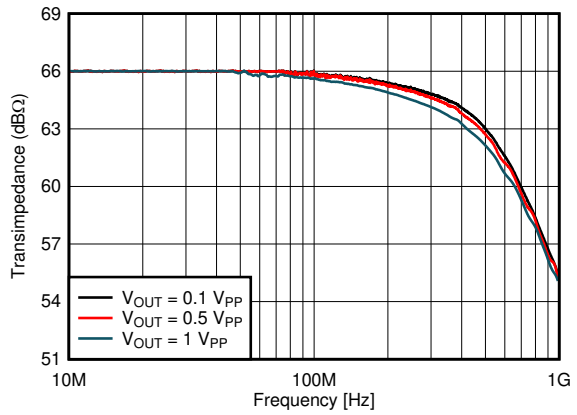


Figure 8-4. Bandwidth vs Output Swing (Gain = 2 kΩ)

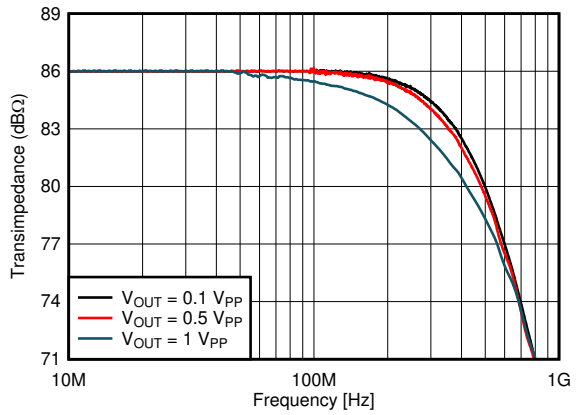


Figure 8-5. Bandwidth vs Output Swing (Gain = 20 kΩ)

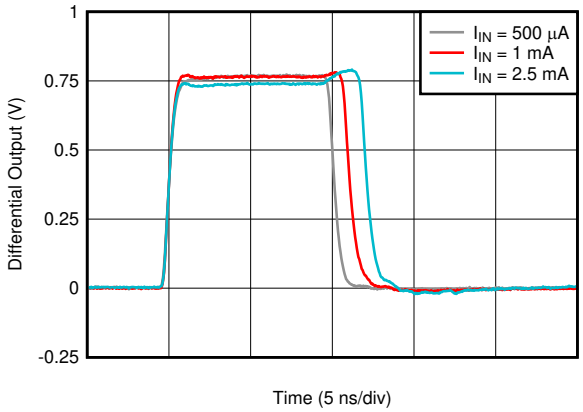


Figure 8-6. Pulse Response vs Input Current (Gain = 2 kΩ)

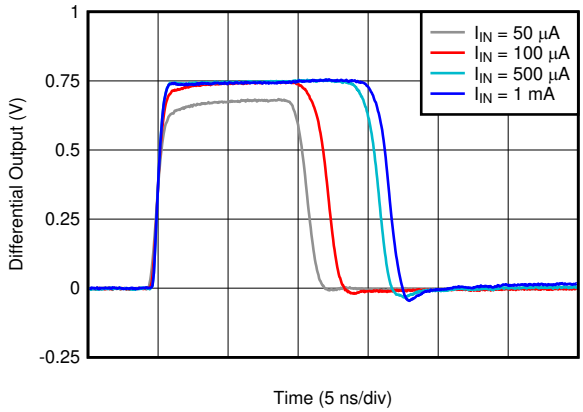


Figure 8-7. Pulse Response vs Input Current (Gain = 20 kΩ)

8.3 Power Supply Recommendations

The LMH32401-Q1 operates on 3.3-V supplies. Always drive the VDD1 and VDD2 pins from the same supply source, and individually bypass these two pins. Always maintain a low power-supply source impedance across frequency; therefore, use multiple bypass capacitors in parallel. Place the bypass capacitors as close as possible to the supply pins. Place the smallest capacitor on the same side of the PCB as the LMH32401-Q1 device. If possible, place the larger-valued bypass capacitors on the same side of the PCB. However, if space constraints are an issue, then move the capacitors to the opposite side of the PCB using multiple vias to reduce the series inductance resulting from the vias. To operate the LMH32401-Q1 on bipolar supplies, connect pins 1 and 7 to the negative supply. Always connect the thermal pad to the most negative supply. Appropriately level shift the digital pin threshold voltages because the pins are connected to voltages at pins 1 and 7.

8.4 Layout

8.4.1 Layout Guidelines

Achieving the best performance with a high-frequency amplifier, such as the LMH32401-Q1, requires careful attention to board layout parasitics and external component types. Recommendations that optimize performance include the following:

- **Minimize parasitic capacitance from the signal I/O pins to ac ground.** Parasitic capacitance on the output pins can cause instability; whereas, parasitic capacitance on the input pin reduces the amplifier bandwidth. To reduce unwanted capacitance, cut out the power and ground traces under the signal input and output pins. Otherwise, ground and power planes must be unbroken elsewhere on the board.
- **Minimize the distance from the power-supply pins to high-frequency bypass 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. Place the smallest-value capacitors on the same side as the DUT. If space constraints force the larger-value bypass capacitors to be placed on the opposite side of the PCB, then use multiple vias on the supply and ground side of the capacitors. This configuration provides a low-impedance path to the amplifiers power-supply pins across the amplifiers gain bandwidth specification. Avoid narrow power and ground traces to minimize inductance between the pins and the decoupling capacitors. Larger (2.2-µF to 6.8-µF) decoupling capacitors that are effective at lower frequency must be used on the supply pins. Place these decoupling capacitors further from the device. Share the decoupling capacitors among several devices in the same area of the printed circuit board (PCB).

8.4.2 Layout Example

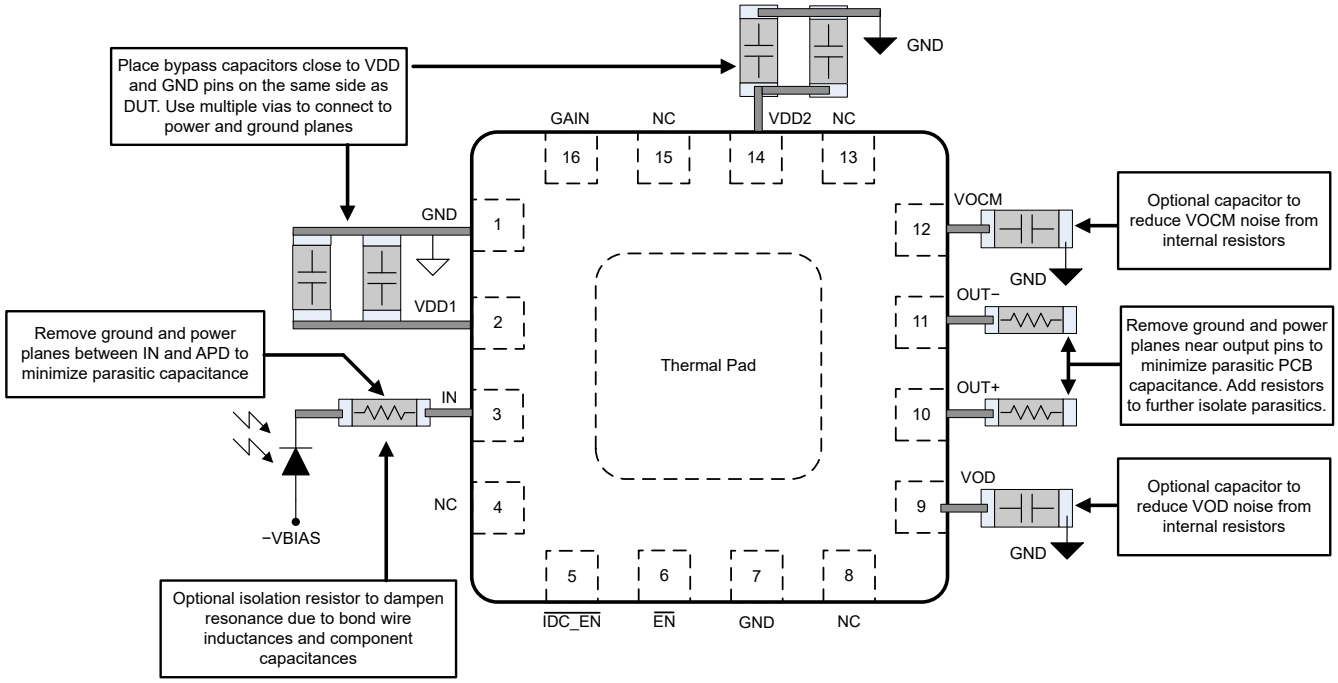


Figure 8-8. Layout Recommendation

9 Device and Documentation Support

9.1 Device Support

9.1.1 Development Support

For development support on this product, see the following:

- Texas Instruments, *LMH32401 Transimpedance Amplifier Evaluation Module*.
- Texas Instruments, *Optical Front-End System Reference Design* design guide.
- Texas Instruments, *LIDAR-Pulsed Time-of-Flight Reference Design Using High-Speed Data Converters* design guide.
- Texas Instruments, *LIDAR Pulsed Time of Flight Reference Design* design guide.

9.2 Documentation Support

9.2.1 Related Documentation

- Texas Instruments, *LMH32401IRGT Evaluation Module* user's guide.
- Texas Instruments, *Transimpedance Considerations for High-Speed Amplifiers* application report.
- Texas Instruments, *What You Need To Know About Transimpedance Amplifiers – Part 1* blog.
- Texas Instruments, *An Introduction to Automotive LIDAR*.
- Texas Instruments, *Maximizing the Dynamic Range of Analog Front Ends Having a Transimpedance Amplifier*.
- Texas Instruments, *Time of Flight and LIDAR – Optical Front End Design*.
- Texas Instruments, *What You Need To Know About Transimpedance Amplifiers – Part 2* blog.
- Texas Instruments, *Training Video: How to Design Transimpedance Amplifier Circuits*.
- Texas Instruments, *Training Video: High-Speed Transimpedance Amplifier Design Flow*.
- Texas Instruments, *Training Video: How to Convert a TINA-TI Model into a Generic SPICE Model*.

9.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* 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.

9.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is 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.

9.5 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

9.6 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.

9.7 Glossary

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

10 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.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LMH32401QWRGTRQ1	ACTIVE	VQFN	RGT	16	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	L401Q	Samples

(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.

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

OTHER QUALIFIED VERSIONS OF LMH32401-Q1 :

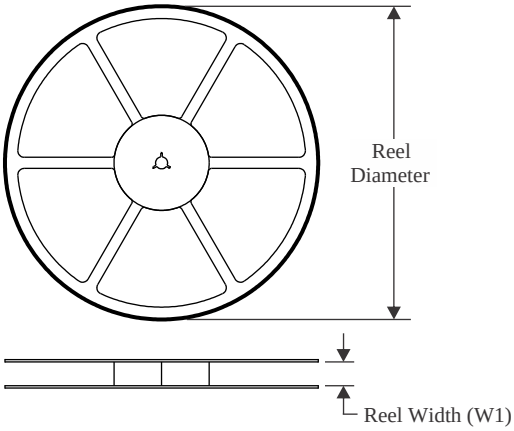
- Catalog : LMH32401

NOTE: Qualified Version Definitions:

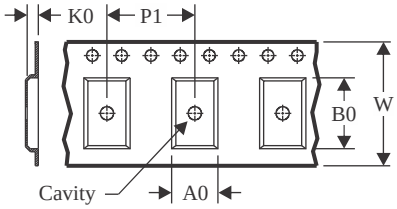
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

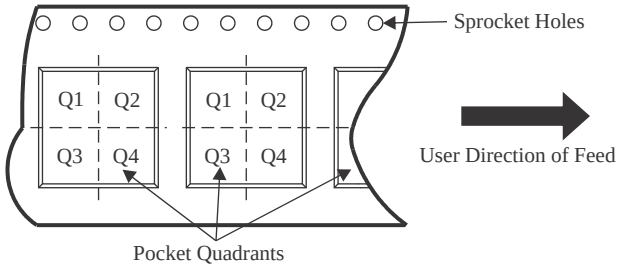


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

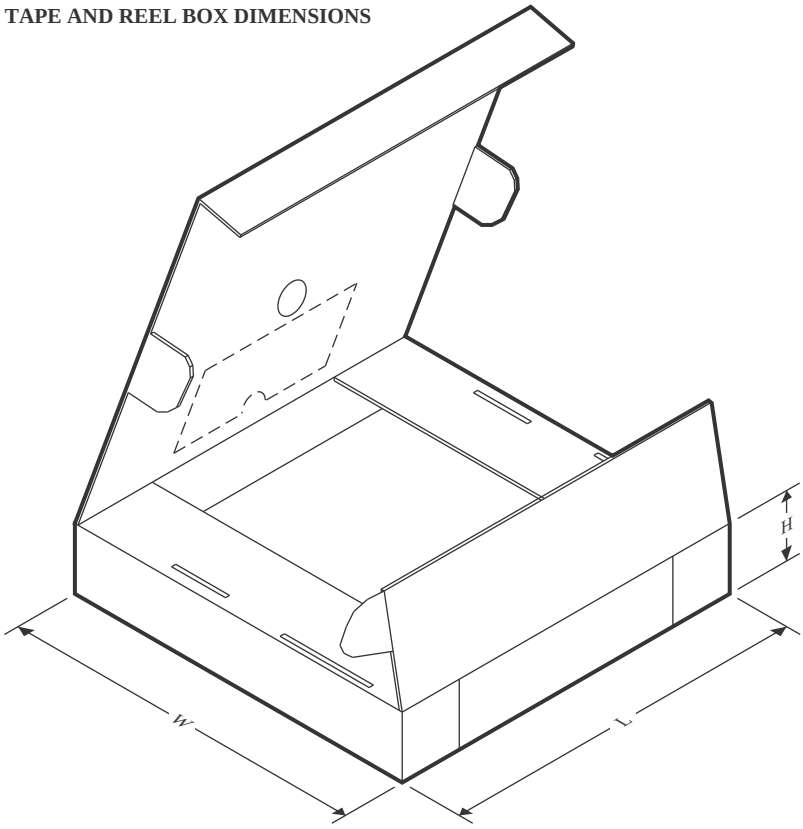
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LMH32401QWRGTRQ1	VQFN	RGT	16	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS

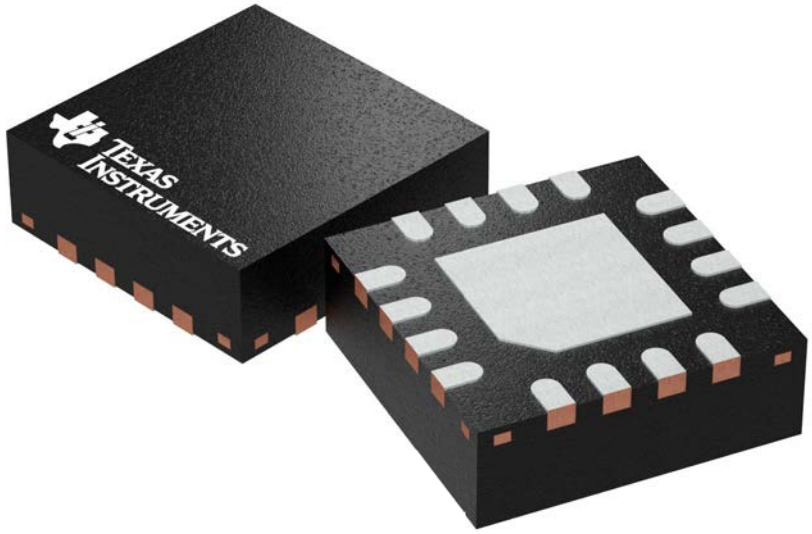


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LMH32401QWRGTRQ1	VQFN	RGT	16	3000	367.0	367.0	35.0

RGT 16 VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



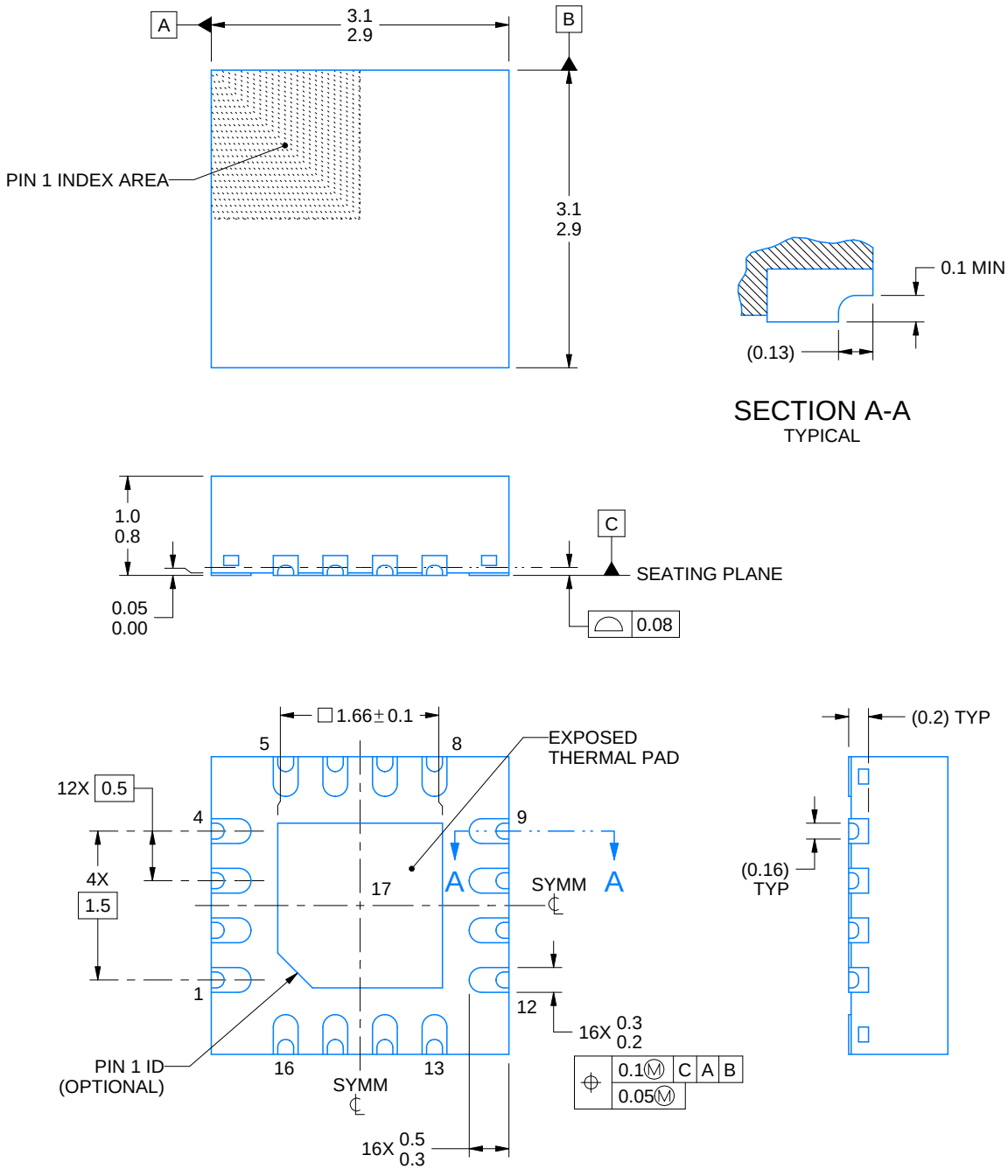
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

RGT0016K

PACKAGE OUTLINE

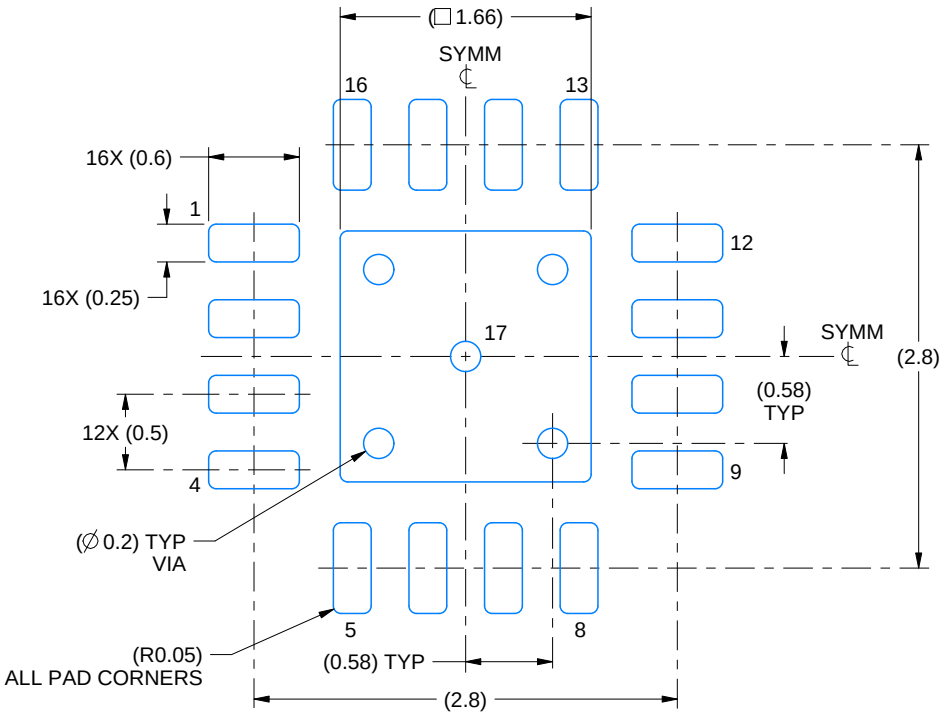
VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

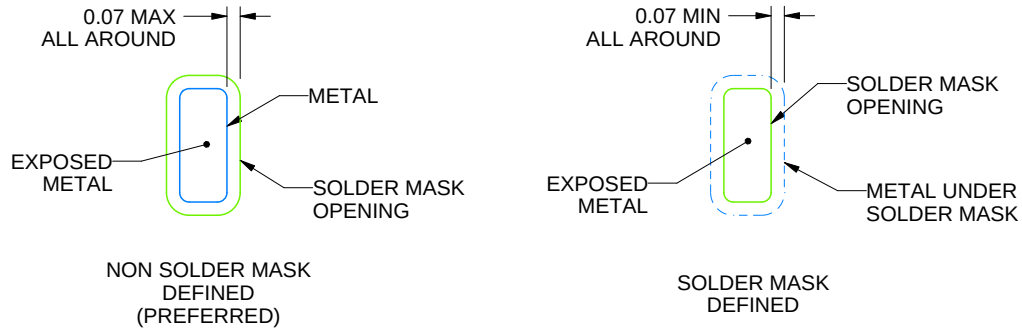


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X



SOLDER MASK DETAILS

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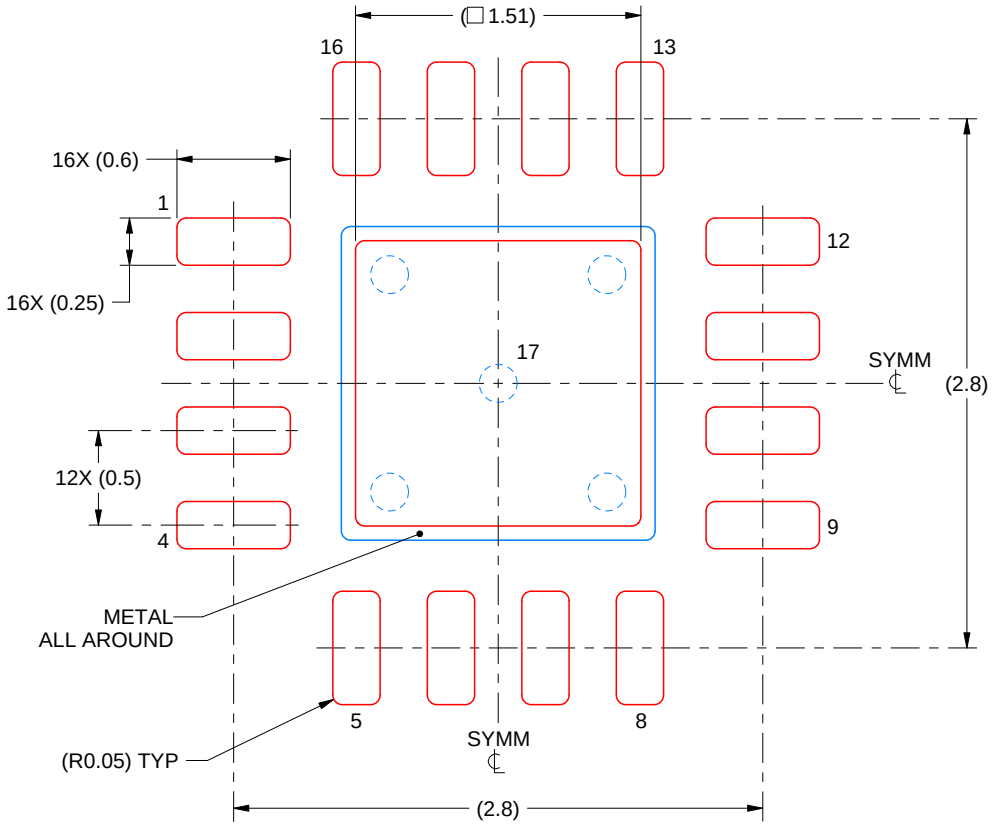
NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 17:
84% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:25X

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NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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