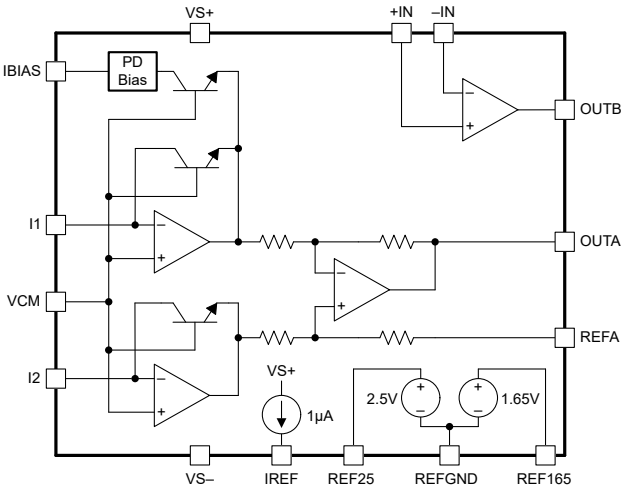
LOG200 Precision, High-Speed Logarithmic Amplifier With Integrated Photodiode Bias

1 Features

- Ultra-fast transient response to low current levels:
  - Settling time for 10nA to 100nA step: 240ns rising, 620ns falling (typ)
  - Settling time for 100nA to 1µA step: 60ns rising, 150ns falling (typ)
- Wide dynamic range: 10pA to 10mA (180dB)
  - Specified from 100pA to 10mA (160dB)
- High signal bandwidth:
  - 20MHz at 10µA to 10mA
  - 6.3MHz at 1µA
  - 90kHz at 1nA
- High-accuracy transfer function:
  - 0.2% max log conformity error (10nA to 100µA)
- Integrated reference current (1µA) and reference voltages (2.5V and 1.65V)
- Additional auxiliary high-speed op amp for differential ADC drive, single-ended gain or filter blocks, and other peripheral functions
- Single supply (4.5V to 12.6V) or dual supply (±2.25V to ±6.3V) operation
- Specified temperature range: –40°C to +125°C
- Small package options:
  - 3mm × 3mm VQFN
  - 1.6mm × 1.6mm DSBGA

2 Applications

- Optical modules
- Inter-DC interconnect
- Optical network terminal unit
- Chemistry/gas analyzer
- Erbium-doped fiber optic amplifier (EDFA)



LOG200 Device Schematic

3 Description

The LOG200 is a wide-dynamic-range current-to-voltage amplifier specifically designed to optimize current measurements across 160dB of dynamic range with unparalleled accuracy and speed for optical communications, medical diagnostics, and industrial process-control measurements. The LOG200 features two logarithmic amplifiers followed by a high-accuracy differential amplifier that convert current signals into a voltage representing the log-compressed ratio of the two currents. The current inputs are designed to feature a high-speed response from one input, and a highly accurate reference signal on the other input, allowing for a unique combination of fast transient response and high logarithmic conformity.

The LOG200 ratio is internally set to 250mV/decade of current-to-voltage conversion. The device integrates an uncommitted high-speed amplifier to allow the output to be configured for differential or filtered responses, with a fast settling time to drive successive approximation analog-to-digital converters (SAR ADCs). The LOG200 also features a separate reference current and reference voltage designed to configure the device for optimized input current and common-mode voltages.

The LOG200 can be powered in a single-supply (4.5V to 12.6V) or dual-supply (±2.25V to ±6.3V) configuration and is specified from –40°C to +125°C.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
LOG200	RGT (VQFN, 16)	3mm × 3mm
	YBH (DSBGA, 16)	1.6mm × 1.6mm

(1) For more information, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Pin Configuration and Functions

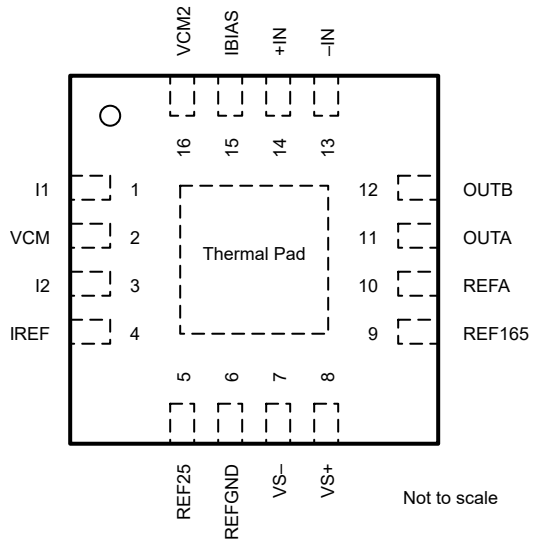


Figure 4-1. RGT Package, 16-Pin VQFN (Top View)

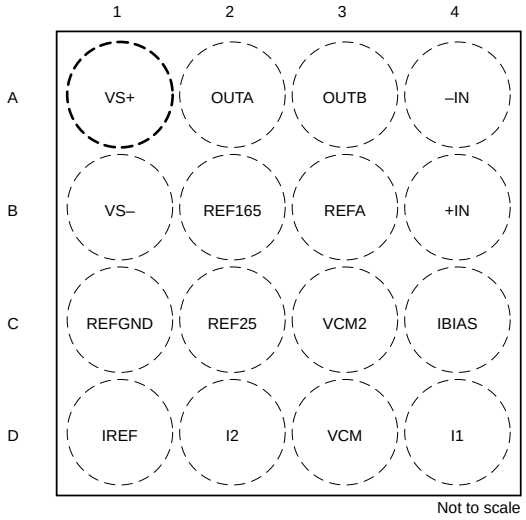


Figure 4-2. YBH Package, 16-Pin DSBGA (Top View)

Table 4-1. Pin Functions

PIN			TYPE	DESCRIPTION
NAME	NO.			
	RGT (VQFN)	YBH (DSBGA)		
+IN	14	B4	Input	Auxiliary op-amp voltage non-inverting input
–IN	13	A4	Input	Auxiliary op-amp voltage inverting input
I1	1	D4	Input	Current input for logarithm numerator
I2	3	D2	Input	Current input for logarithm denominator
IBIAS	15	C4	Output	Photodiode adaptive biasing current output
IREF	4	D1	Output	Reference current output
REFA	10	B3	Input	Logarithmic difference amplifier reference input
OUTA	11	A2	Output	Logarithmic difference amplifier output
OUTB	12	A3	Output	Auxiliary op-amp voltage output
REF165	9	B2	Output	1.65V voltage reference output
REF25	5	C2	Output	2.5V voltage reference output
REFGND	6	C1	Power	Voltage reference negative potential
VCM	2	D3	Input	Input common-mode voltage
VCM2	16	C3	Input	Input common-mode voltage. Connect to VCM.
VS+	8	A1	Power	Positive supply voltage
VS–	7	B1	Power	Negative supply voltage
Thermal Pad	PAD	N/A	—	Thermal Pad. Connect to VCM to minimize leakage on I1 pin.

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5 Specifications

5.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V_S	Supply voltage, $V_S = (V_{S+}) - (V_{S-})$		–0.3	13	V
	I1 or I2 to VCM		–5.5	5.5	V
	I1, I2, and VCM	Voltage	$(V_{S-}) - 0.3$	$(V_{S+}) + 0.3$	V
		Current		20	mA
	Auxiliary amplifier input voltage	Single-ended	$(V_{S-}) - 0.3$	$(V_{S+}) + 0.3$	V
		Differential $(V_{+IN}) - (V_{-IN})$	–0.3	0.3	
	Auxiliary amplifier input current		–10	10	mA
	Output short-circuit (2)			Continuous	mA
	Operating temperature		–40	125	°C
T_J	Junction temperature		–55	150	°C
T_{stg}	Storage temperature, T_{stg}		–60	160	°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) Short-circuit to ground, one amplifier per package.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±2500	V
		Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002 (2)	±1000	

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

5.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_S	Supply voltage	4.5		12.6	V
V_{REFGND}	REFGND compliance voltage	(V_{S-})		$(V_{S+}) - 4.5$	V
V_{IBIAS}	IBIAS compliance voltage	(V_{S-})		$(V_{S+}) - 1.0$	V
I_{VREF}	Output current of REF165 or REF25 reference	–2		5	mA
I_{I2}	I2 input current			1	mA
T_A	Specified temperature	–40		125	°C

5.4 Thermal Information

THERMAL METRIC (1)		LOG200		UNIT
		16 PINS		
		RGT (VQFN)	YBH (DSBGA)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	66.7	80.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	61.8	0.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	39.8	18.8	°C/W
ψ_{JT}	Junction-to-top characterization parameter	3.8	0.2	°C/W
ψ_{JB}	Junction-to-board characterization parameter	39.8	18.8	°C/W

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THERMAL METRIC (1)		LOG200		UNIT
		16 PINS		
		RGT (VQFN)	YBH (DSBGA)	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	31.2	N/A	°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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5.5 Electrical Characteristics

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
LOG CONFORMITY ERROR								
	Logarithmic conformity error	I_{I1} = 10nA to 100µA				0.004	0.017	dB
						0.05	±0.2	%
			T_A = 0°C to 85°C			0.004	0.026	dB
						0.05	±0.3	%
		I_{I1} = 10nA to 1mA				0.007	0.044	dB
						0.08	±0.5	%
			T_A = 0°C to 85°C			0.007	0.087	dB
						0.08	±1	%
		I_{I1} = 1nA to 10mA				0.022	0.065	dB
						0.25	±0.75	%
			T_A = 0°C to 85°C			0.022	0.131	dB
						0.25	±1.5	%
			T_A = –40°C to +125°C, V_S = 5V (1)			0.030	0.265	dB
						0.35	±3	%
			T_A = –40°C to +125°C, V_S = 10V (1)			0.044	0.265	dB
						0.5	±3	%
TRANSFER FUNCTION (GAIN)								
	Initial scaling factor	I_{I1} = 100pA to 10mA				250		mV/decade
	Scaling factor error	I_{I1} = 1nA to 100µA		LOG200RGT	–1	0.15	1	%
				LOG200YBH	–1.5		1.5	
			T_A = 0°C to 85°C	LOG200RGT	–1.1		1.1	
				LOG200YBH	–1.5		1.5	
		I_{I1} = 100pA to 10mA				0.4		
			T_A = 0°C to 85°C, V_S = 5V			0.5		
			T_A = 0°C to 85°C, V_S = 10V			0.7		
			T_A = –40°C to +125°C, V_S = 5V (1)			3.8		
			T_A = –40°C to +125°C, V_S = 10V (1)			6.3		
LOGARITHMIC AMPLIFIER INPUT								
V_{OS}	Offset voltage	V_{I1} – V_{CM}	I_{I1} = 10nA, V_S = 5V	LOG200RGT	–3	–0.84	3	mV
			I_{I1} = 10nA, V_S = 5V	LOG200YBH	–5	–0.84	4.5	
			I_{I1} = 10nA, V_S = 10V	LOG200RGT	–4	–1.6	2	
			I_{I1} = 10nA, V_S = 10V	LOG200YBH	–5.75	–1	3.75	
			I_{I1} = 100µA			32	50	
			I_{I1} = 100µA, T_A = –40°C to +125°C			42		
		V_{I2} – V_{CM}	I_{I2} = 10nA, V_S = 5V		–3	–0.89	3	
			I_{I2} = 10nA, V_S = 10V		–4	–1.4	2	
			I_{I2} = 100µA, V_S = 5V			–0.66	3	
			I_{I2} = 100µA, V_S = 10V			–1.2	2	
			I_{I2} = 100µA, T_A = –40°C to +125°C			–1.5		

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5.5 Electrical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
dV_{OS}/dT		$V_{I1} – V_{CM}$				22		µV/°C
		$V_{I2} – V_{CM}$				–7		
V_{CM}	Input common mode voltage				$(V_{S–})$ + 2.3		(V_{S+}) – 2.0	V
	I_{BIAS} ratio	$V_{IBIAS} = (V_{S+}) – 1.0V$, V_S = 5V	I_{I1} = 100µA		1.069	1.127	1.185	A/A
		$V_{IBIAS} = (V_{S+}) – 1.0V$, V_S = 5V	I_{I1} = 10mA	LOG200RGT	1.094	1.128	1.161	
				LOG200YBH	1.058	1.128	1.176	
		$V_{IBIAS} = (V_{S+}) – 1.0V$, V_S = 10V	I_{I1} = 100µA		1.069	1.127	1.184	
		$V_{IBIAS} = (V_{S+}) – 1.0V$, V_S = 10V	I_{I1} = 10mA	LOG200RGT	1.128	1.162	1.195	
				LOG200YBH	1.109	1.162	1.209	

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5.5 Electrical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
LOGARITHMIC AMPLIFIER OUTPUT							
V_{OSO}	Output offset voltage				1.3	±7.5	mV
		T_A = –40°C to +125°C			2.5	±10	mV
PSRR	Power supply rejection ratio	I_{I1} = I_{I2} = 1µA			±0.1		mV/V
CMRR	Common-mode rejection ratio (2)	($V_{S–}$) + 2.3V < V_{CM} < (V_{S+}) – 2.0V, I_{I1} = I_{I2} = 1µA			60		dB
	Voltage output swing			($V_{S–}$) + 0.3		(V_{S+}) – 0.3	V
	Short-circuit current				±20		mA
	Capacitive load				100		pF
AUXILIARY OPERATIONAL AMPLIFIER							
	Offset voltage				46	±700	µV
		T_A = –40°C to +125°C			0.07	±1	mV
	Offset voltage drift				0.53	±3	µV/°C
	Input bias current				–0.84	±3	µA
		T_A = –40°C to +125°C			–1.2		
	Input offset current				18	±100	nA
		T_A = –40°C to +125°C			45	±300	
	Input common mode voltage			($V_{S–}$) + 1.0		(V_{S+}) – 1.0	V
	Input voltage noise density	f = 0.1Hz to 10kHz			50		nV_{RMS}
		f = 1kHz			4.1		nV/√Hz
	Input current noise	f = 1kHz			1.2		pA/√Hz
A_{OL}	Open-loop voltage gain	($V_{S–}$) + 200mV < V_O < (V_{S+}) – 200mV, R_L = 10kΩ	LOG200RGT	126	150		dB
			LOG200YBH	124	150		
			T_A = –40°C to +125°C		126		
		($V_{S–}$) + 200mV < V_O < (V_{S+}) – 200mV, R_L = 2kΩ		124	140		
			T_A = –40°C to +125°C		124		
PSRR	Power supply rejection ratio				–1		µV/V
CMRR	Common-mode rejection ratio	($V_{S–}$) + 1.0 < V_{CM} < (V_{S+}) – 1.0			130		dB
GBW	Gain-bandwidth product	C_L = 28pF			60		MHz
	Unity-gain bandwidth				42		MHz
SR	Slew rate	2V step, G = 1			22		V/µs
t_S	Settling time	To 0.1%, 2V step, G = 1	Rising		110		ns
			Falling		400		
		To 0.01%, 2V step, G = 1	Rising		550		
			Falling		1100		
C_{IN}	Input capacitance	Differential			2.6		pF
		Common-mode			0.7		
Z_O	Open-loop output impedance	f = 1MHz			7.5		Ω
CURRENT REFERENCE							
I_{IREF}	IREF initial current			0.98	1	1.02	µA
	IREF initial accuracy			–2	0.3	2	%
	Temperature coefficient				35		ppm/°C
V_{IREF}	IREF compliance voltage			($V_{S–}$)		(V_{S+}) – 1.0	V
	Output impedance	ΔV_{IREF} / ΔI_{IREF}			3		GΩ

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5.5 Electrical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
VOLTAGE REFERENCE							
V_{REF165}	REF165 initial voltage			1.645	1.65	1.655	V
	REF165 initial accuracy			–0.3	0.06	0.3	%
V_{REF25}	REF25 initial voltage			2.494	2.5	2.506	V
	REF25 initial accuracy			–0.24	0.05	0.24	%
	Temperature coefficient	REF165 reference, REF25 reference			20		ppm/°C
	Load regulation	REF165 reference, –2mA < I_{REF165} < 5mA			–360		µV/mA
		REF25 reference, –2mA < I_{REF25} < 5mA			–475		
	Line regulation	5V < V_S < 10V	REF165 reference		16		µV/V
			REF25 reference		30		
	Short-circuit current				–14		mA
	Noise				4.2		μV_{RMS}
NOISE							
	Voltage noise (2) (3)	f = 1kHz, I_{I2} = I_{REF}	I_{I1} = 1nA		2000		nV/√Hz
			I_{I1} = 10nA		650		
			I_{I1} = 100nA		210		
			I_{I1} = 1µA		110		
FREQUENCY RESPONSE							
BW	–3dB bandwidth (4) (3)	I1 input	I_{I2} = I_{REF}, I_{I1} = 100pA		12		kHz
			I_{I2} = I_{REF}, I_{I1} = 1nA		90		
			I_{I2} = I_{REF}, I_{I1} = 10nA		0.5		MHz
			I_{I2} = I_{REF}, I_{I1} = 100nA		2.3		
			I_{I2} = I_{REF}, I_{I1} = 1µA		6.3		
			I_{I2} = I_{REF}, I_{I1} = 10µA to 10mA		20		
		I2 input	I_{I1} = I_{REF}, I_{I2} = 100pA		0.05		kHz
			I_{I1} = I_{REF}, I_{I2} = 1nA		0.5		
			I_{I1} = I_{REF}, I_{I2} = 10nA		5.2		
			I_{I1} = I_{REF}, I_{I2} = 100nA		55		
			I_{I1} = I_{REF}, I_{I2} = 1µA		0.55		MHz
			I_{I1} = I_{REF}, I_{I2} = 10µA to 10mA		6		MHz
	Step response, I1 (5) (3)	I_{I2} = I_{REF}, I_{I1} = 100pA to 1nA	Rising		9		µs
			Falling		30		
		I_{I2} = I_{REF}, I_{I1} = 1nA to 10nA	Rising		1.2		
			Falling		5		
		I_{I2} = I_{REF}, I_{I1} = 10nA to 100nA	Rising		0.24		
			Falling		0.62		
		I_{I2} = I_{REF}, I_{I1} = 100nA to 1µA	Rising		0.06		
			Falling		0.15		
		I_{I2} = I_{REF}, I_{I1} = 100µA to 1mA	Rising		0.02		
			Falling		0.03		
POWER SUPPLY							
I_Q	Quiescent current	I_{OUTA} = I_{OUTB} = 0mA			9.5	10	mA
			T_A = –40°C to +125°C			13	

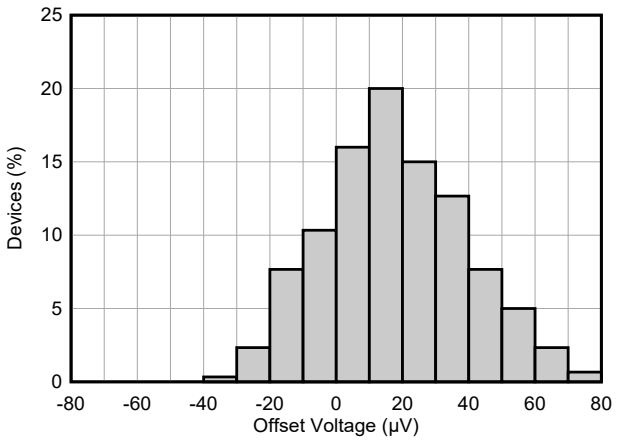
(1) The result of this calculation is dominated by the error from T_A = 95°C to 125°C.
(2) Output referred.
(3) Measurement parasitic C_{IN} of 3pF nominal.
(4) Assumes parasitic C_{IN} of 3pF or less.

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(5) Step response is defined as 10% to 90%.

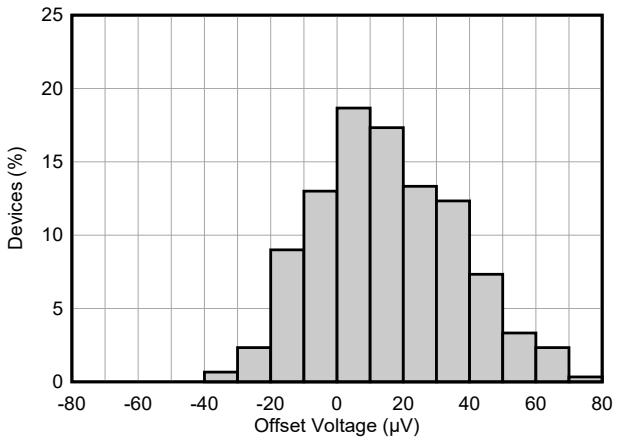
5.6 Typical Characteristics

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



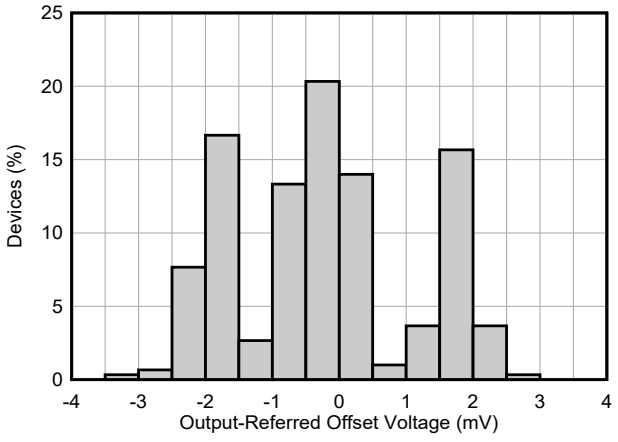
V_S = 5V (±2.5V), n = 300, 10µV bin width

Figure 5-1. Auxiliary-Amplifier Offset-Voltage Distribution



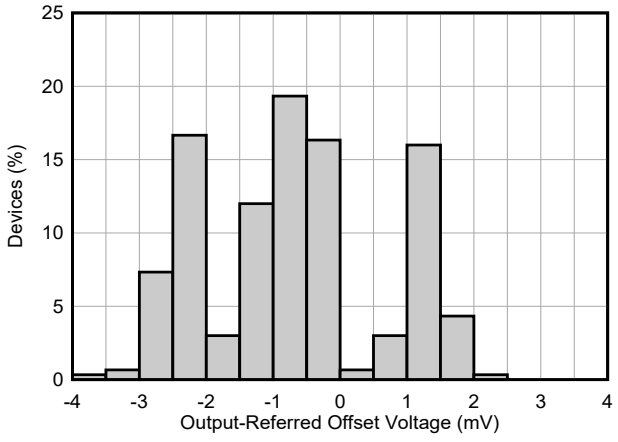
V_S = 10V (±5V), n = 300, 10µV bin width

Figure 5-2. Auxiliary-Amplifier Offset-Voltage Distribution



V_S = 5V (±2.5V), n = 300, 0.5mV bin width

Figure 5-3. Difference-Amplifier Output-Offset Voltage Distribution



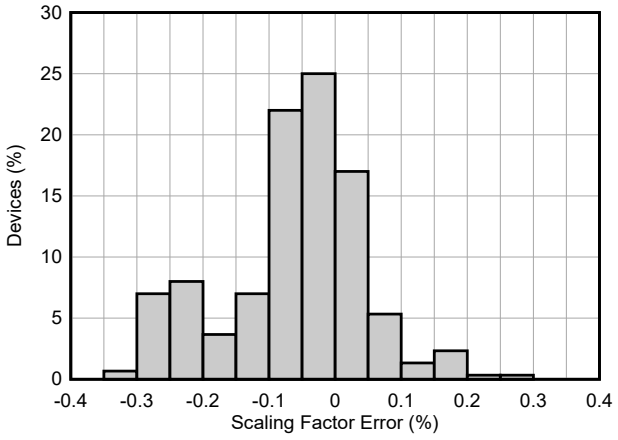
V_S = 10V (±5V), n = 300, 0.5mV bin width

Figure 5-4. Difference-Amplifier Output-Offset Voltage Distribution

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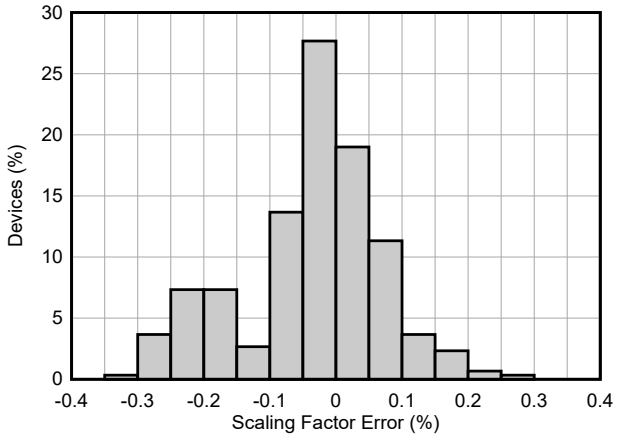
5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



V_S = 5V (±2.5V), n = 300, 0.05% bin width

Figure 5-5. Scaling-Factor Error Distribution



V_S = 10V (±5V), n = 300, 0.05% bin width

Figure 5-6. Scaling-Factor Error Distribution

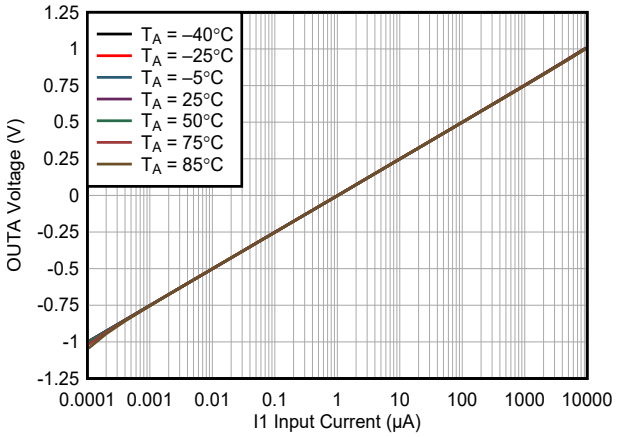


Figure 5-7. Output Voltage vs I1 Current

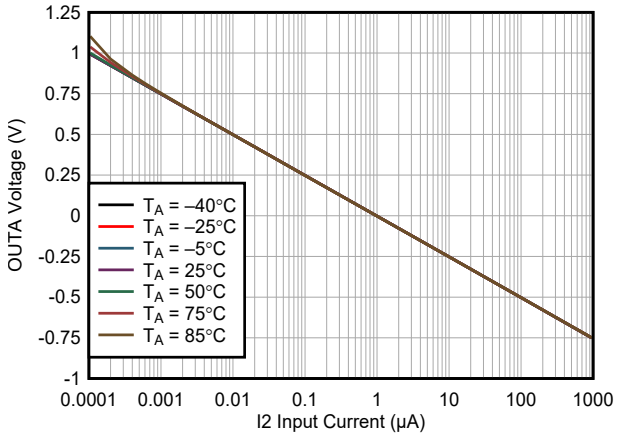


Figure 5-8. Output Voltage vs I2 Current

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

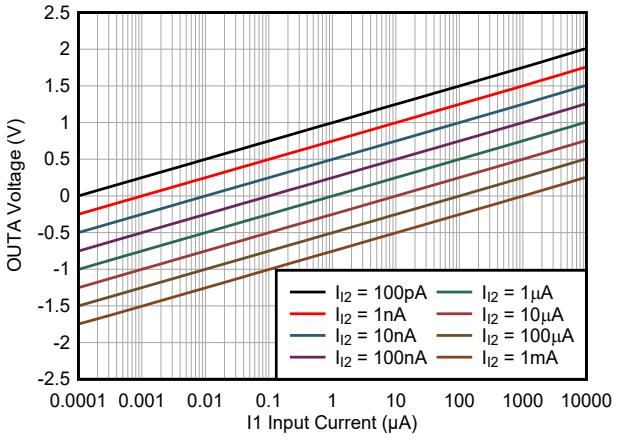


Figure 5-9. Output Voltage vs Input Currents

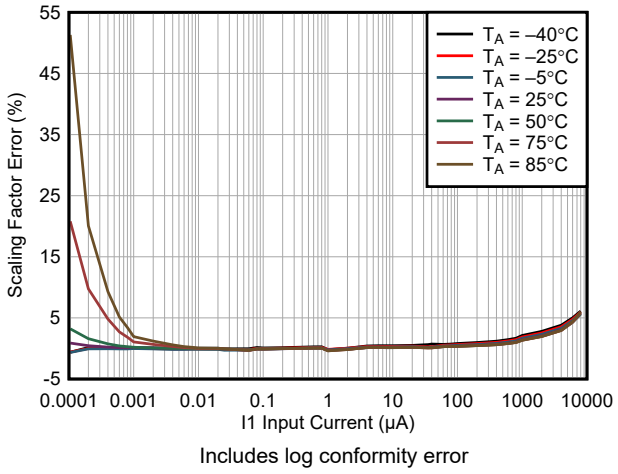


Figure 5-10. Scaling Factor Error vs I1 Current

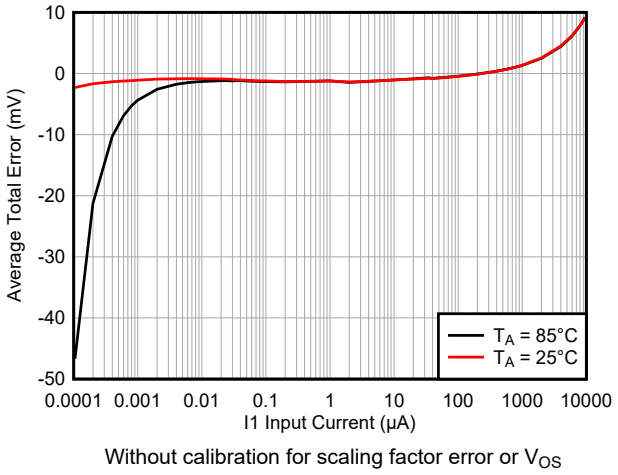


Figure 5-11. Average Total Error vs I1 Current

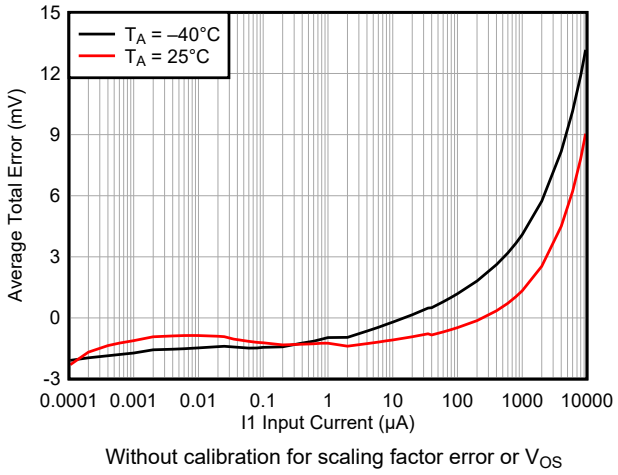


Figure 5-12. Average Total Error vs I1 Current

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

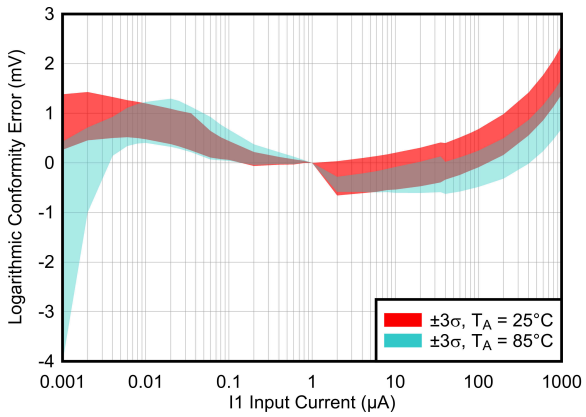


Figure 5-13. Logarithmic-Conformity Error Distribution vs I1 Current

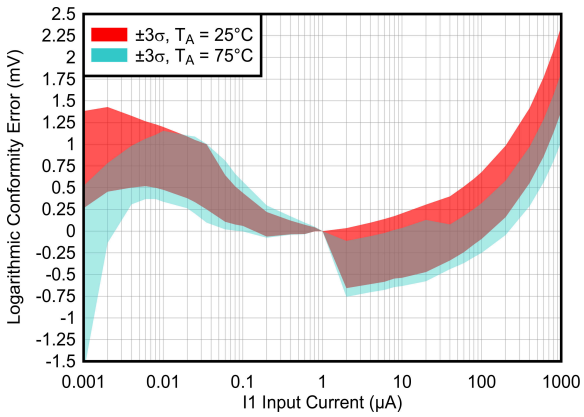


Figure 5-14. Logarithmic-Conformity Error Distribution vs I1 Current

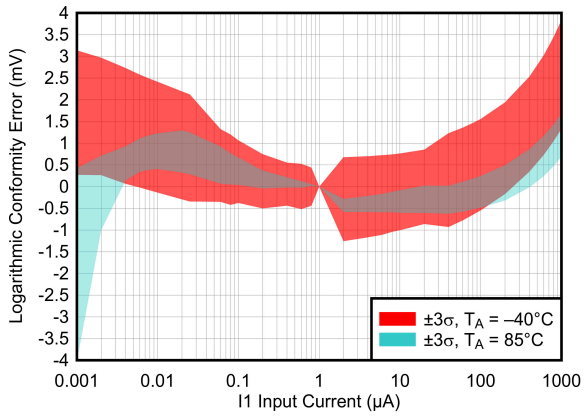


Figure 5-15. Logarithmic-Conformity Error Distribution vs Input Current

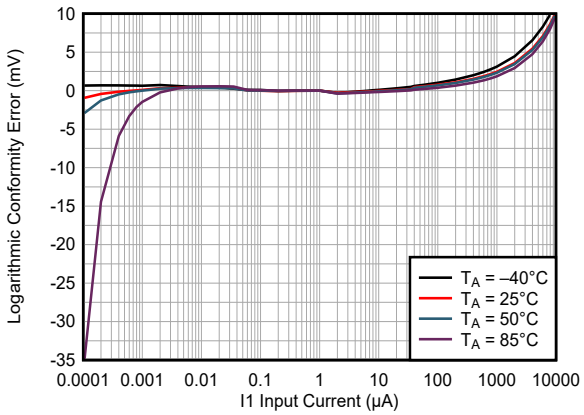
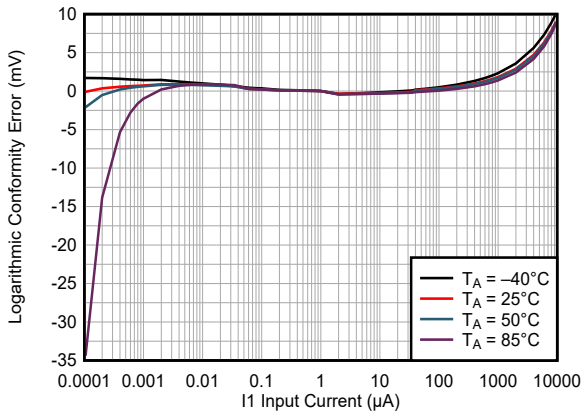


Figure 5-16. Six-Decade Logarithmic Conformity Error vs I1 Current

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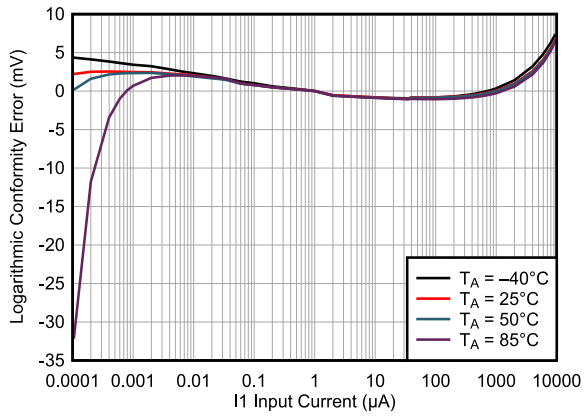
5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



Using 1nA–1mA best-fit line for scaling-factor error correction

Figure 5-17. Seven-Decade Logarithmic Conformity Error vs I1 Current



Using 1nA–10mA best-fit line for scaling-factor error correction

Figure 5-18. Eight-Decade Logarithmic Conformity Error vs I1 Current

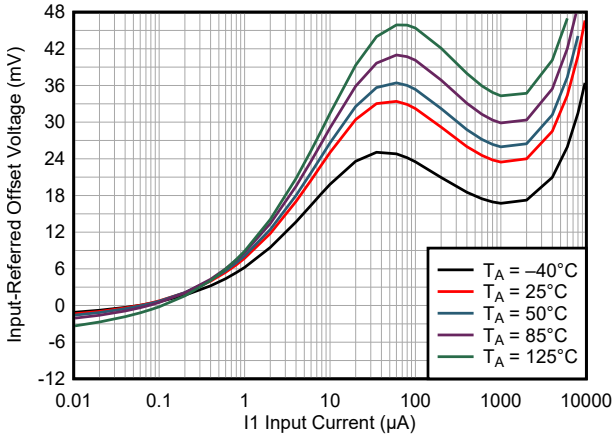


Figure 5-19. Logarithmic-Amplifier Offset vs I1 Current

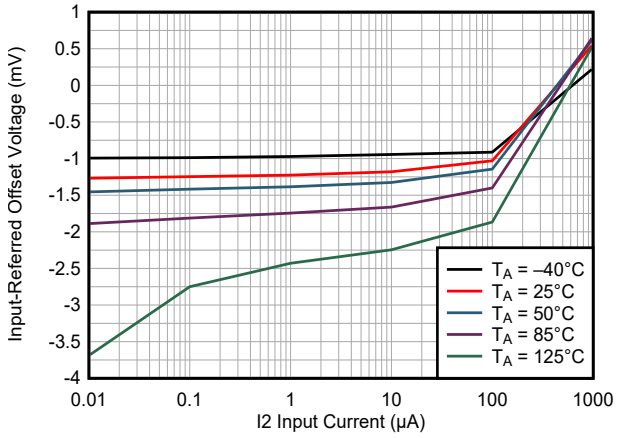


Figure 5-20. Logarithmic-Amplifier Offset vs I2 Current

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

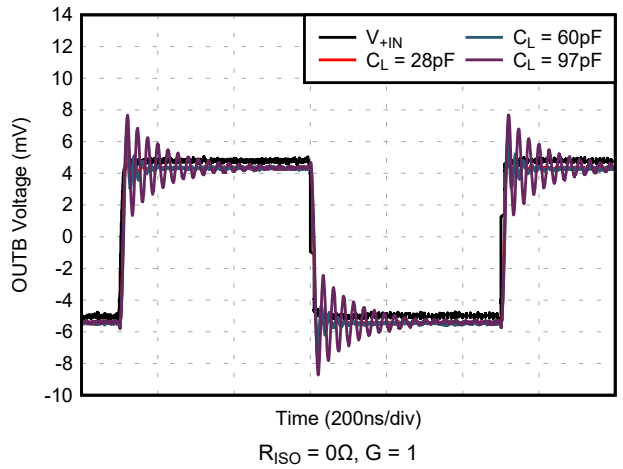


Figure 5-21. Auxiliary-Amplifier Small-Signal Step Response

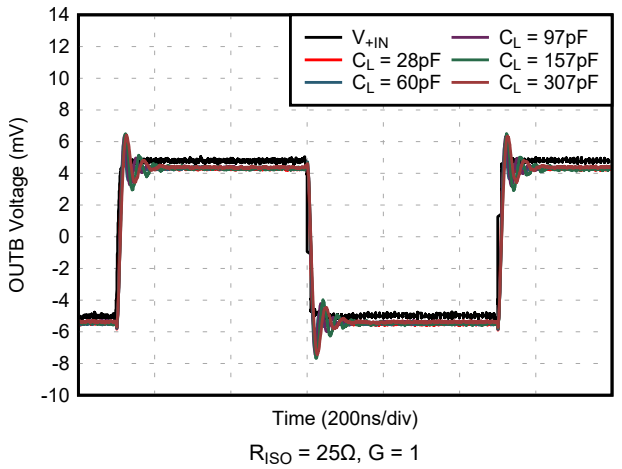


Figure 5-22. Auxiliary-Amplifier Small-Signal Step Response

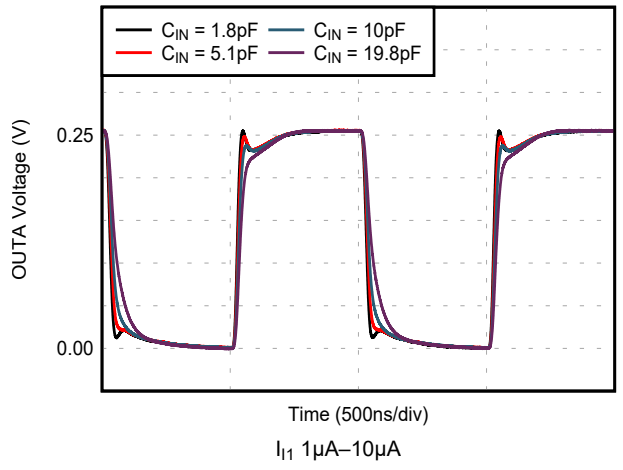


Figure 5-23. Step Response for Various C_{IN}

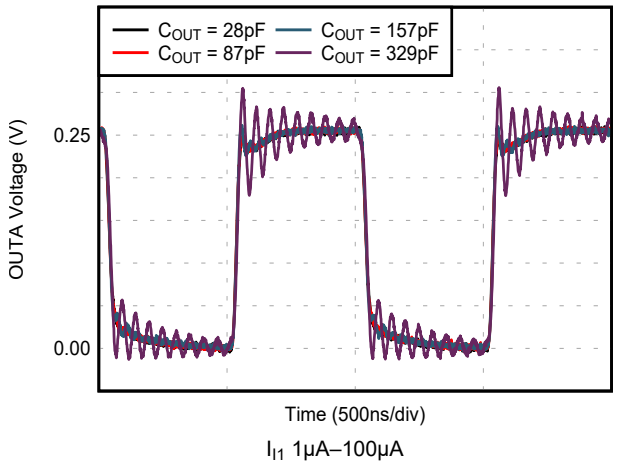


Figure 5-24. Step Response for Various C_{OUT}

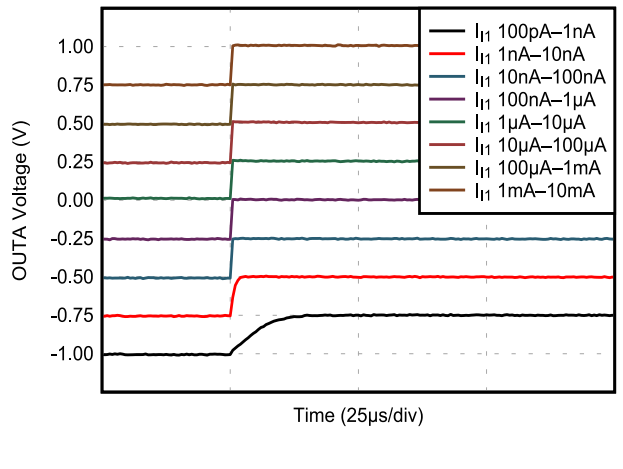


Figure 5-25. Step Response for Decade Steps, Rising

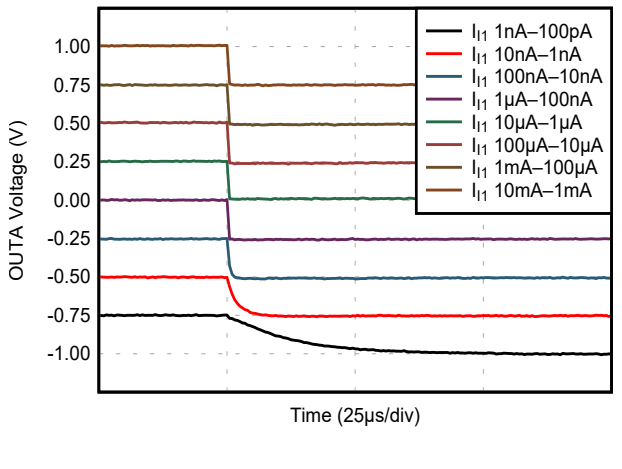


Figure 5-26. Step Response for Decade Steps, Falling

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

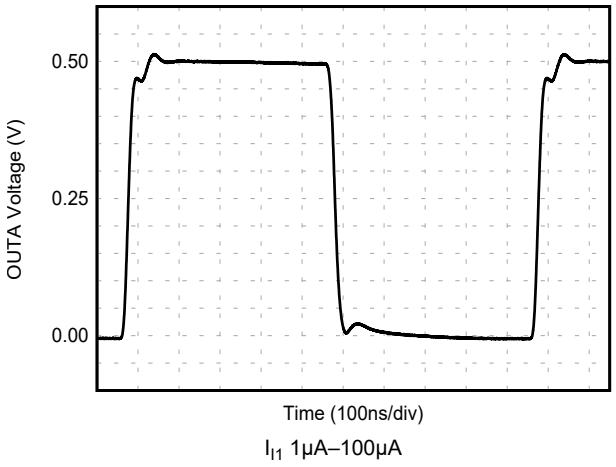


Figure 5-27. Step Response for Two-Decade Step

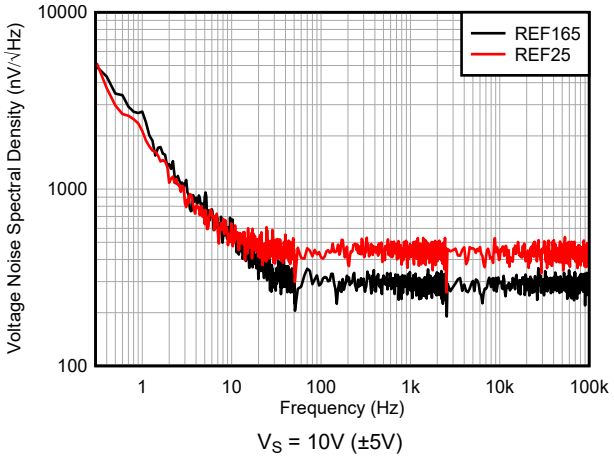


Figure 5-28. Voltage-Reference-Noise Spectral Density

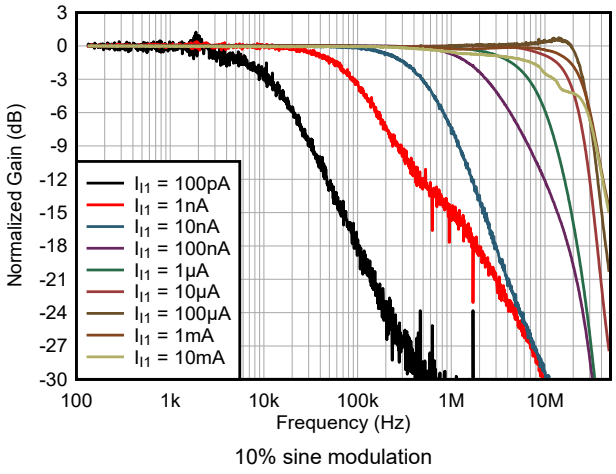


Figure 5-29. Small-Signal I_{I1} AC Response

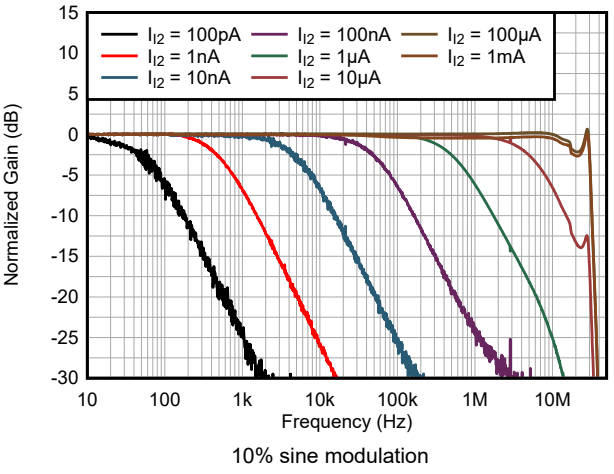


Figure 5-30. Small-Signal I_{I2} AC Response

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

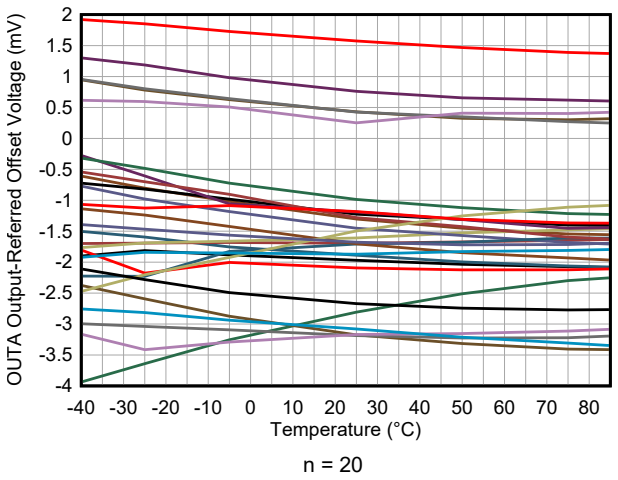


Figure 5-31. Difference-Amplifier Offset vs Temperature

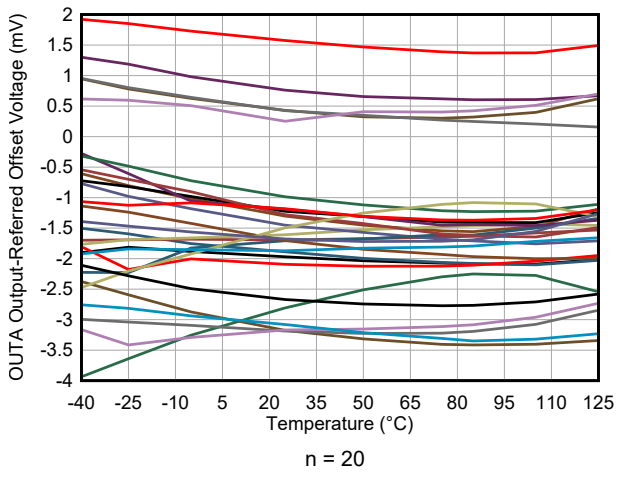


Figure 5-32. Difference-Amplifier Offset vs Temperature

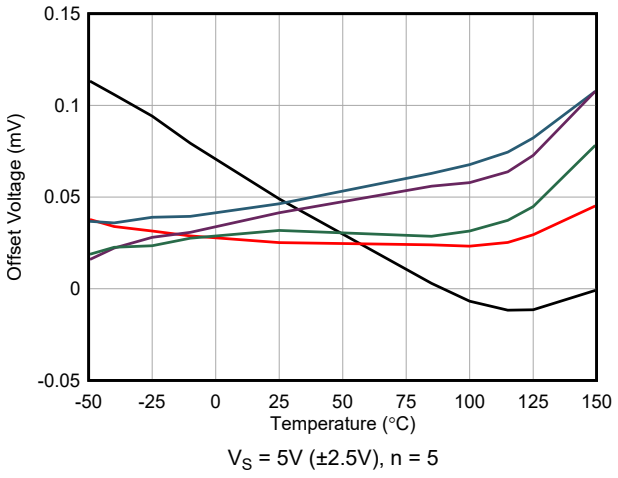


Figure 5-33. Auxiliary-Amplifier Offset vs Temperature

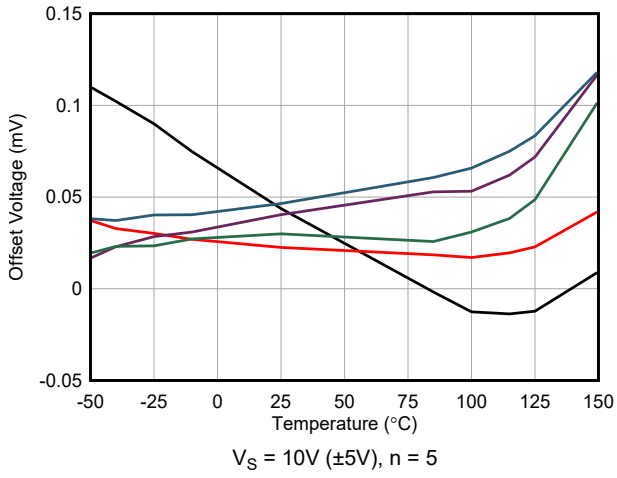
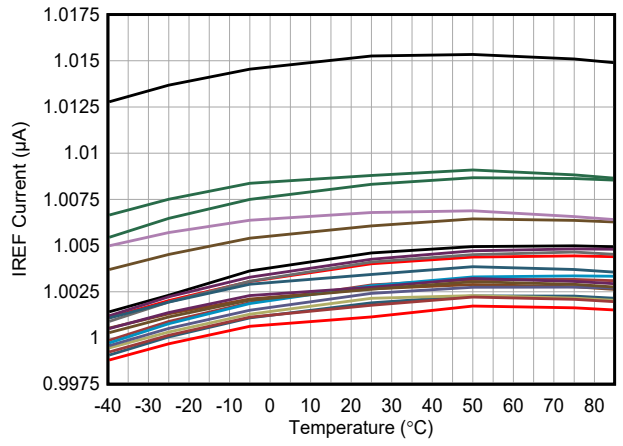


Figure 5-34. Auxiliary-Amplifier Offset vs Temperature

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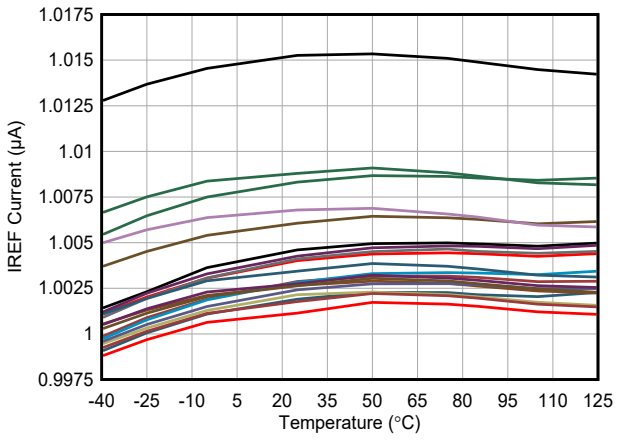
5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



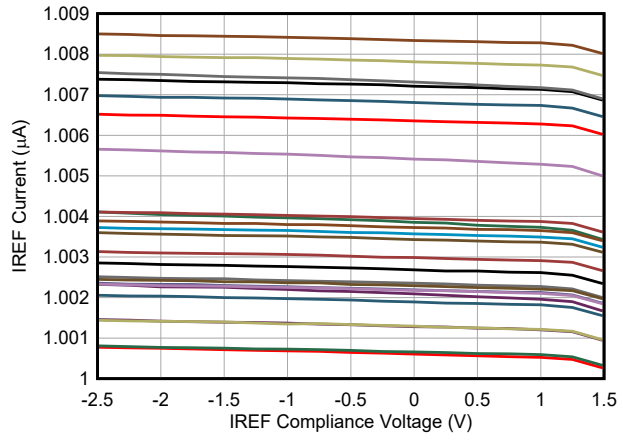
V_{IREF} = V_{CM}, n = 20

Figure 5-35. I_{REF} vs Temperature



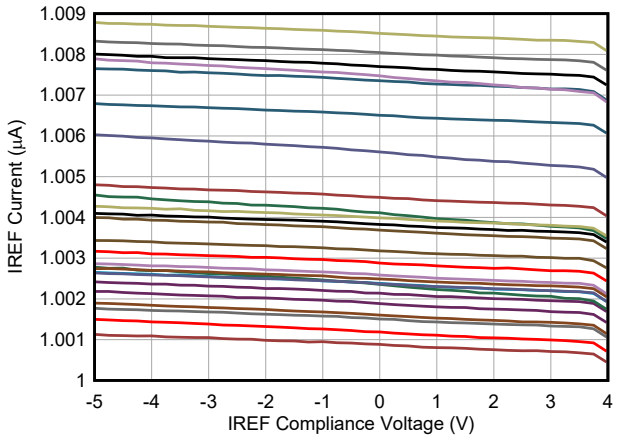
V_{IREF} = V_{CM}, n = 20

Figure 5-36. I_{REF} vs Temperature



V_S = 5V (±2.5V), n = 24

Figure 5-37. I_{REF} Line Regulation



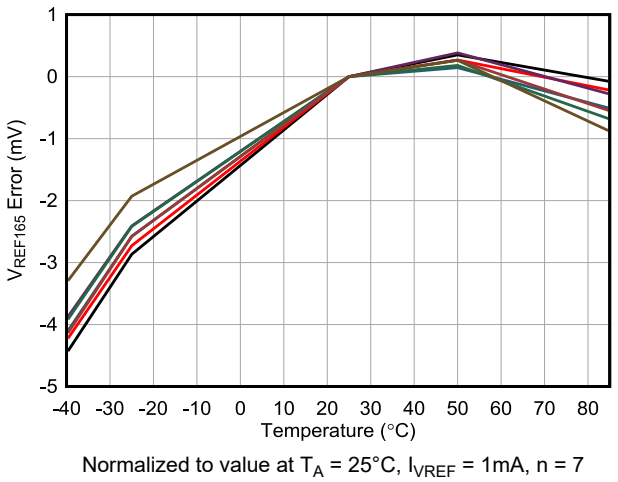
V_S = 10V (±5V), n = 25

Figure 5-38. I_{REF} Line Regulation

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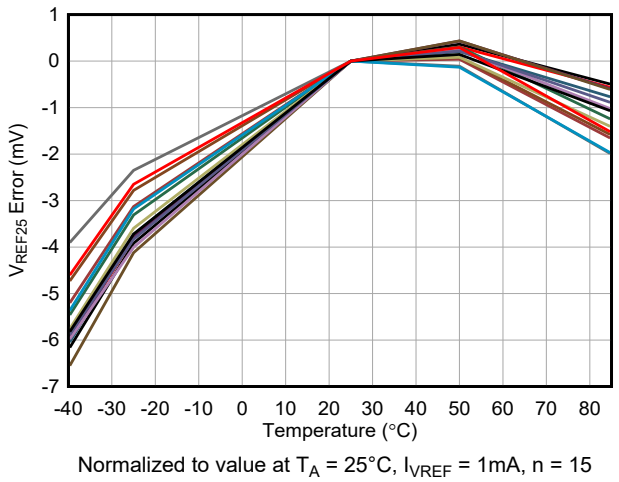
5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



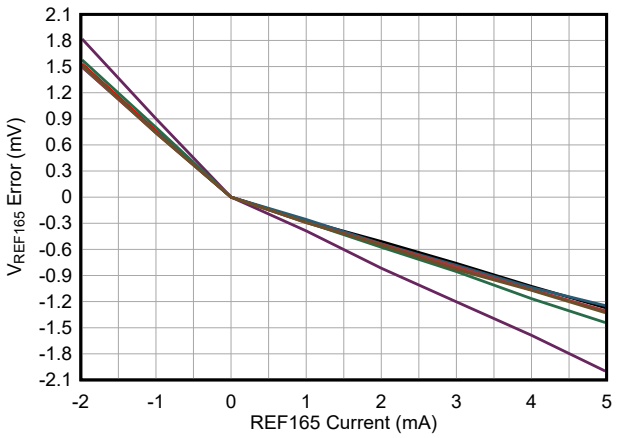
Normalized to value at T_A = 25°C, I_{VREF} = 1mA, n = 7

Figure 5-39. V_{REF165} vs Temperature



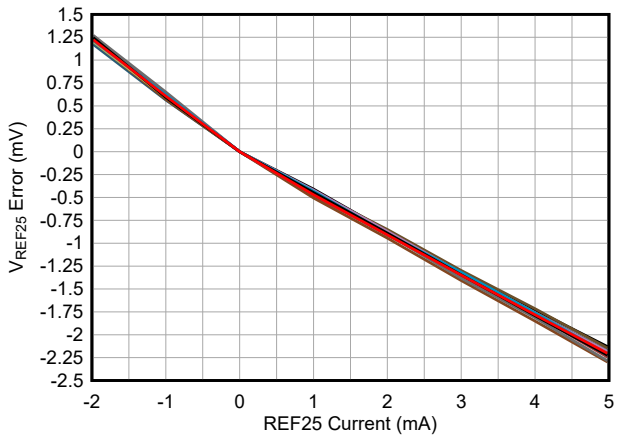
Normalized to value at T_A = 25°C, I_{VREF} = 1mA, n = 15

Figure 5-40. V_{REF25} vs Temperature



n = 7

Figure 5-41. V_{REF165} Load Regulation



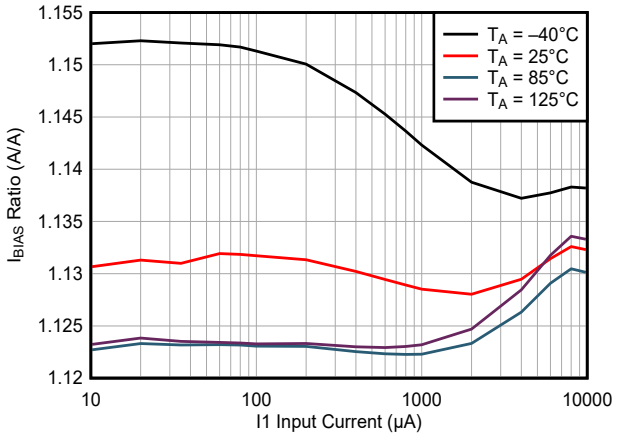
n = 15

Figure 5-42. V_{REF25} Load Regulation

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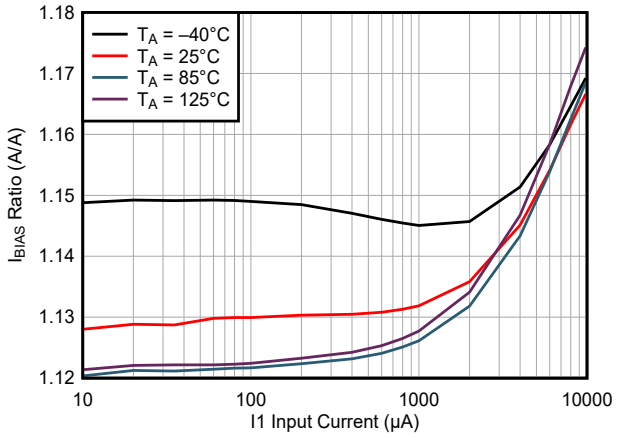
5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



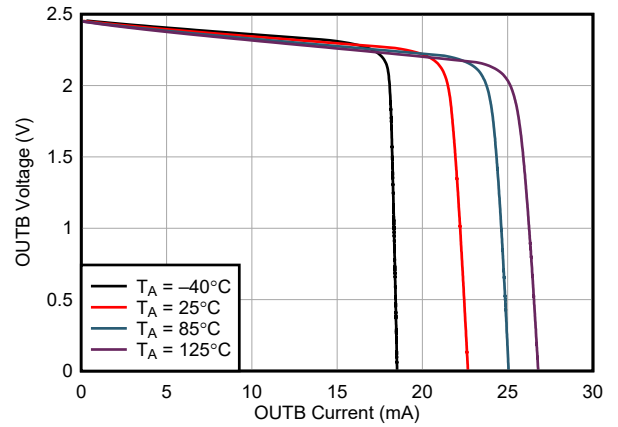
V_S = 5V (±2.5V), V_{IBIAS} = (V_{S+}) – 1V, mean of n = 32 samples

Figure 5-43. I_{BIAS} Ratio vs I1 Current



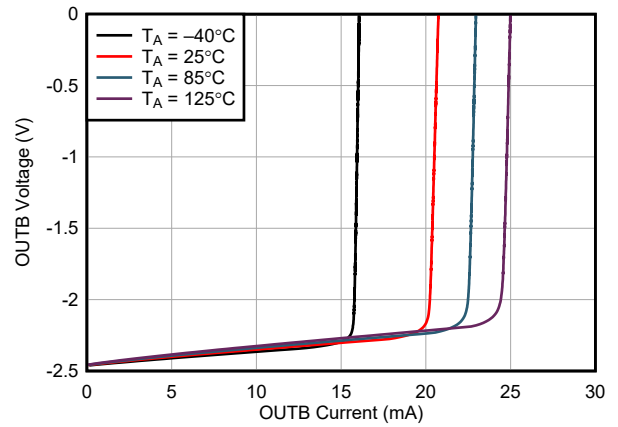
V_S = 10V (±5V), V_{IBIAS} = (V_{S+}) – 1V, mean of n = 32 samples

Figure 5-44. I_{BIAS} Ratio vs I1 Current



V_S = 5V (±2.5V), sourcing

Figure 5-45. Auxiliary-Amplifier Output Voltage vs Output Current



V_S = 5V (±2.5V), sinking

Figure 5-46. Auxiliary-Amplifier Output Voltage vs Output Current

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)

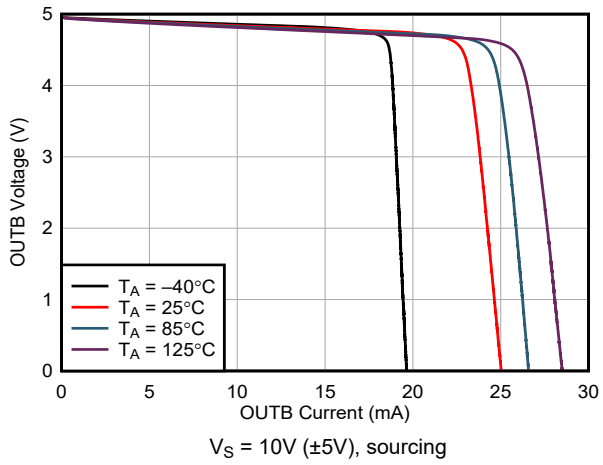


Figure 5-47. Auxiliary-Amplifier Output Voltage vs Output Current

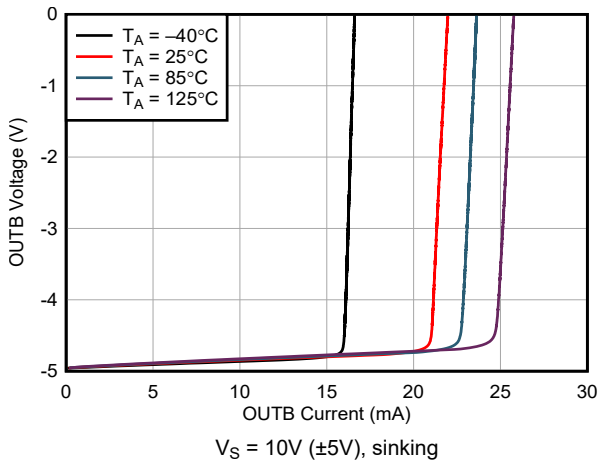


Figure 5-48. Auxiliary-Amplifier Output Voltage vs Output Current

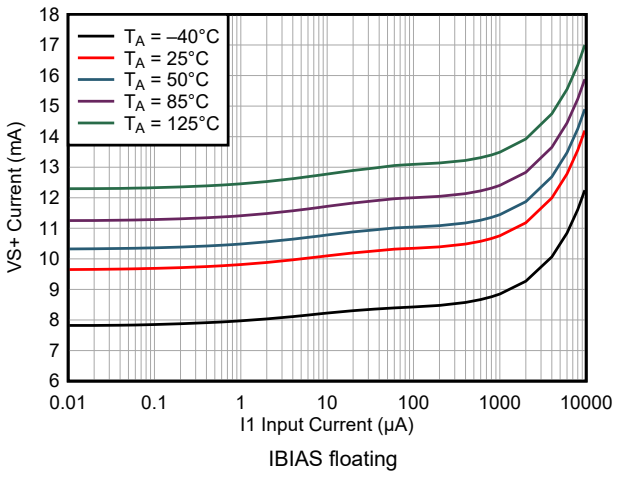


Figure 5-49. VS+ Current vs I1 Current

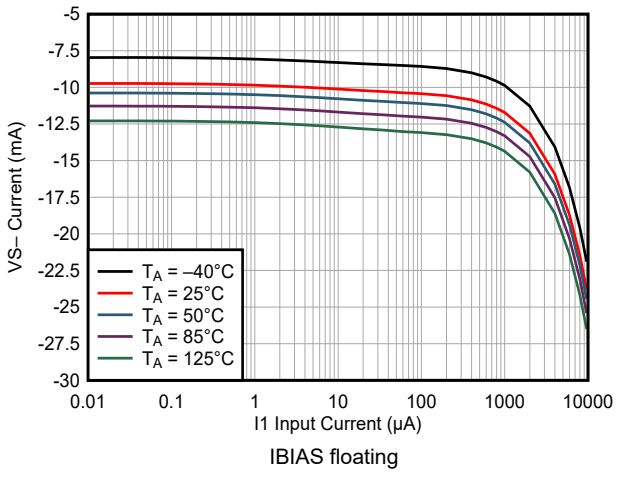
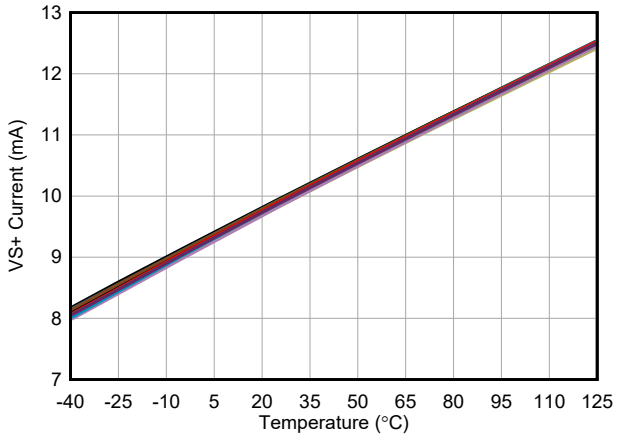


Figure 5-50. VS– Current vs I1 Current

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5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V (±2.5V) to 10V (±5V), OUTA R_L = 10kΩ connected to V_S / 2, OUTB R_L = 2kΩ connected to V_S / 2, V_{CM} = V_{REFA} = V_S / 2, V_{REFGND} = $V_{S–}$, I_{I1} = 1µA, and I_{I2} = 1µA (unless otherwise noted)



I_{OUTA} = I_{OUTB} = 0mA, IBIAS floating, n = 30

Figure 5-51. VS+ Current vs Temperature

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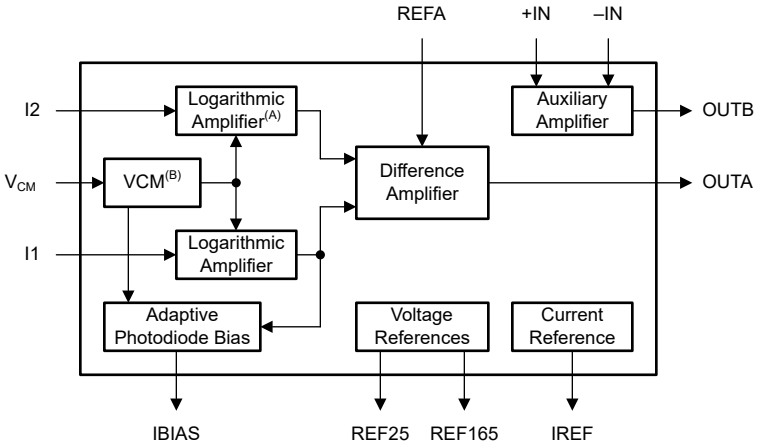
6 Detailed Description

6.1 Overview

The LOG200 is a wide-dynamic-range current-to-voltage amplifier specifically designed to optimize current measurements across 160dB of dynamic range with unparalleled accuracy and speed for optical communications, medical diagnostics, and industrial process control measurements. The LOG200 features two logarithmic amplifiers followed by a high-accuracy differential amplifier to convert current signals into a single-ended voltage that represents the log-compressed ratio of the two currents. The current inputs are designed to feature a high-speed response from one input, and a highly accurate reference signal on the other input, allowing for a unique combination of fast transient response and high logarithmic conformity.

The LOG200 ratio is internally set to 250mV/decade of current-to-voltage conversion. The device integrates an uncommitted high-speed amplifier to allow the output to be configured for differential or filtered responses, with a fast settling time to drive successive approximation analog-to-digital converters (SAR ADCs). The LOG200 also features an integrated reference current and reference voltages, simplifying configuration of the device for common input current ranges and common-mode voltages.

6.2 Functional Block Diagram



A. Either IREF or an external source drive I2.

B. Either REF25, REF165, or an external source drive VCM. Comply with the input common-mode voltage constraints so that the input logarithmic amplifiers have sufficient headroom.

6.3 Feature Description

6.3.1 High Speed, Logarithmic Current-to-Voltage Conversion

The LOG200 converts current into voltage using an advanced, high-speed-amplifier architecture. By dynamically controlling the amplifier open-loop gain, the LOG200 achieves transient response from low-to-high current and high-to-low current measurements significantly faster than previous-generation logarithmic amplifiers.

The LOG200 features two current inputs, I1 and I2. The I1 input is optimized for speed, facilitating the excellent transient response of the device to changes in the measured current. The I2 input is optimized for precision and accuracy, intended for use with a current reference, such as the onboard 1µA reference. If an external current in excess of 100µA is used for I2, implement a snubber network to improve device stability.

The effective capacitance at a current input pin establishes the effective bandwidth of the corresponding feedback loop, and thus the effective device bandwidth. Photodiode capacitance and system parasitics both play a role and must be considered for stability and transient performance analyses.

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6.3.2 Voltage and Current References

The LOG200 integrates two separate voltage references (2.5V and 1.65V) and a current reference (1µA). The voltage references are designed to be used as the input common-mode reference (2.5V) and output reference (1.65V); however, the references can also be used for other functions requiring precise voltages within the system, as long as the maximum current limitations are observed. These voltage references are established relative to the voltage applied to the REFGND pin; therefore, establish the current return path to the REFGND pin rather than to VS–. A snubber circuit improves stability when driving larger capacitive loads, and can improve noise filtering. If not using a voltage reference, place a 33pF capacitor between the corresponding pin and REFGND.

The current reference is designed to be used as the input to the I2 pin. If the current reference is instead used for another function in the system, establish the corresponding current return path to the $V_{S–}$ supply potential. If the current reference is unused, float the corresponding pin.

6.3.3 Adaptive Photodiode Bias

The LOG200 includes an IBIAS current output feature that can be used to bias a photodiode with a voltage that is proportional to the photocurrent. The current from the IBIAS pin is nominally 1.1 times the input current of the I1 pin. When an R_{BIAS} resistance is placed in parallel with the photodiode, 1.0 times the input current is drawn through the photodiode and the remaining 0.1 times the input current flows through R_{BIAS}. This configuration establishes a bias voltage across that resistance. As the anode end of the photodiode (connected to the I1 input) is held at V_{CM}, the cathode voltage effectively rises by $0.1 \times R_{BIAS} \times I_1$, thus providing a current-dependent reverse bias voltage for the photodiode.

This feature creates very small bias voltages for applications with low photodiode currents, reducing the dark current of the photodiode. In applications with high photodiode currents (which often require larger photodiodes), higher reverse-bias voltages are developed, thus reducing the effective capacitance of the photodiode and increasing the effective device bandwidth. If this feature is not used, float the IBIAS pin.

6.3.4 Auxiliary Operational Amplifier

The LOG200 features an additional wide bandwidth amplifier to support functions such as single-ended to differential conversion, or single-ended gain or filter blocks. Do not use this additional amplifier as a comparator, as the amplifier is not mux-friendly and is not intended to withstand a continuous differential voltage between the input pins.

6.4 Device Functional Modes

The LOG200 has a maximum supply voltage of 12.6V (±6.3V) and a minimum supply voltage of 4.5V (±2.25V). The device has two VCM pins (not internally connected to each other). Drive both VCM pins to the same potential by one of the two onboard voltage references, or by an external source. Likewise, drive the reference input of the difference amplifier by a reference or other low-impedance source. For proper operation, do not float the VCM, VCM2, and REFA pins.

Typically, apply the test current to be measured through the I1 input. Apply a fixed reference current, whether external or provided by the onboard IREF, through the I2 input. Two external currents can be applied through I1 and I2, but only the logarithmic ratio of the two currents can be measured, rather than the absolute values of either. The IBIAS feature is used to provide a reverse voltage bias for an input photodiode. If not used, float the IBIAS pin or connect the pin to the positive supply voltage V_{S+}.

The LOG200 also features an auxiliary amplifier that is used to create a differential output voltage or for any other purpose in the system (provided the amplifier input common-mode limitations and other conditions are met). If the auxiliary amplifier is not needed, apply a midsupply voltage or one of the onboard reference voltages to the noninverting input to keep the auxiliary amplifier fixed within the input common-mode range. Short the output and inverting input together, which causes the amplifier to act as a buffer in a known state, rather than float the pins, which can lead to erratic behavior in noisy environments. Do not use the auxiliary amplifier as a comparator, as the amplifier does not support a high differential voltage between the input pins.

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7 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.

7.1 Application Information

The LOG200 is a wide-dynamic-range current-to-voltage amplifier specifically designed to optimize current measurements across 160dB of dynamic range with unparalleled accuracy and speed. The LOG200 features two logarithmic amplifiers, followed by a high-accuracy differential amplifier to convert current signals into a single-ended voltage that represents the log-compressed ratio of the two currents. The current inputs are designed to feature a high-speed response from one input, and a highly accurate reference signal on the other input, allowing for a unique combination of fast transient response and high logarithmic conformity. The LOG200 ratio is internally set to 250mV/decade of current-to-voltage conversion.

The LOG200 integrates an uncommitted high-speed amplifier to allow the output to be configured for a differential- or filtered-response output. The device also features a precise reference current and reference voltages designed to configure the device for optimized input current and common-mode voltages. The LOG200 operates with a single-ended 5V supply or bipolar ±5V supplies, with a total supply range from 4.5V to 12.6V. VCM can be driven by either of the onboard voltage references (REF25 or REF165), or by an external source. I2 can be driven by an external source but is typically driven by the onboard current reference, IREF.

7.1.1 Logarithmic Transfer Function

The LOG200 uses a differential amplifier to compare the voltage outputs of two logarithmic amplifiers. Logarithmic amplifiers rely on the feedback transistor relation of the base-emitter voltage (V_{BE}) to the collector current I_C, according to the principle:

$$V_{BE} = \left(\frac{kT}{q}\right) \ln\left(\frac{I_C}{I_S}\right) \quad (1)$$

where

- k = the Boltzmann constant, 1.381 × 10^{-23}J/K
- T = absolute temperature in kelvins (K)
- q = the elementary charge, 1.602 × 10^{-19}C
- I_S = the transistor reverse saturation current

For the basic logarithmic amplifier implementation shown in Figure 7-1, the following expression holds:

$$V_{OUT} = -V_{BE} = -\left(\frac{kT}{q}\right) \ln\left(\frac{I_{IN}}{I_S}\right) \quad (2)$$

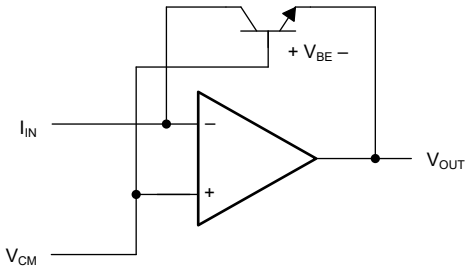


Figure 7-1. Basic Logarithmic Amplifier

When a difference amplifier with reference voltage V_{REF} is implemented to compare the outputs of two logarithmic amplifiers with input currents I_1 and I_2,

$$V_{OUT2} - V_{OUT1} = \left(\frac{kT}{q}\right)\ln\left(\frac{I_1}{I_{S1}}\right) - \left(\frac{kT}{q}\right)\ln\left(\frac{I_2}{I_{S2}}\right) \quad (3)$$

As I_{S1} is approximately equivalent to I_{S2} by design, this equation is equivalent to:

$$V_{OUT2} - V_{OUT1} = \left(\frac{kT}{q}\right)\ln\left(\frac{I_1}{I_2}\right) = \left(\frac{kT}{0.434q}\right)\log_{10}\left(\frac{I_1}{I_2}\right) \quad (4)$$

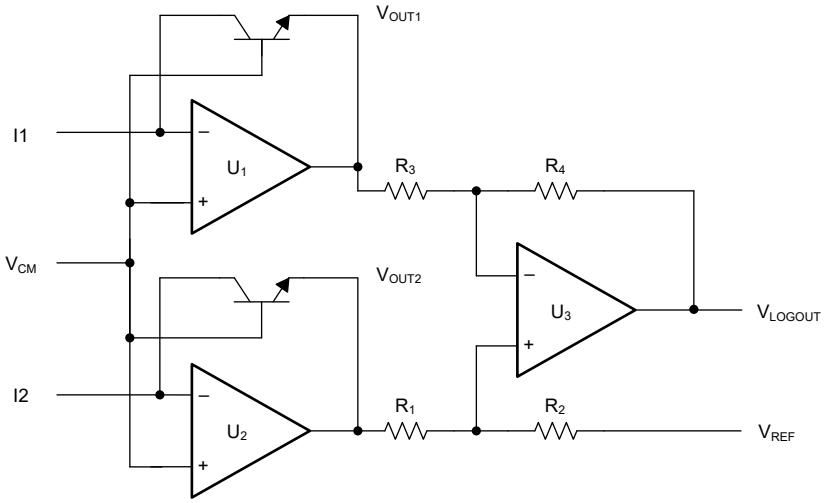


Figure 7-2. LOG200 Difference Amplifier

In the LOG200, the internal input resistors of the difference amplifier have a positive temperature coefficient to compensate for the temperature dependence of the above expression. The difference amplifier also gains up the nominal output, such that the output of the LOG200 is:

$$V_{LOGOUT} = K \times \log_{10}\left(\frac{I_1}{I_2}\right) + V_{REF} \quad (5)$$

where *K* is the device scaling factor, nominally 250mV/decade. Thus, for each decade or order of magnitude shift in the difference of I_1 and I_2, the device output is correspondingly shifted by 250mV (such as by 250mV for I_1 = 10µA and I_2 = 1µA, or by –500mV for I_1 = 10nA and I_2 = 1µA).

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7.1.1.1 Logarithmic Conformity Error

The LOG200 current-input logarithmic conversions, as well as the input and gain resistors of the LOG200 output-stage difference amplifier, have some inherent mismatches (both initially and across temperature) that appear as errors at the system level. These errors are subdivided into three categories: offset error, gain or scaling factor error, and logarithmic or log conformity error (LCE). The LCE is a nonlinear error that is measured after the offset and gain errors have been calibrated, and is similar in many ways to the integrated nonlinearity error of an ADC or DAC. The LCE describes the difference between the expected value and measured value due to random nonideal behavior within the device. The LCE is defined in one of two possible ways: either as an immediate error (with units of volts) or as a maximum error envelope (expressed as a percentage). Typically, a plot of input current or logarithmic current (logarithmic scale) vs output voltage (linear scale) is used for the data set, as in Figure 7-3.

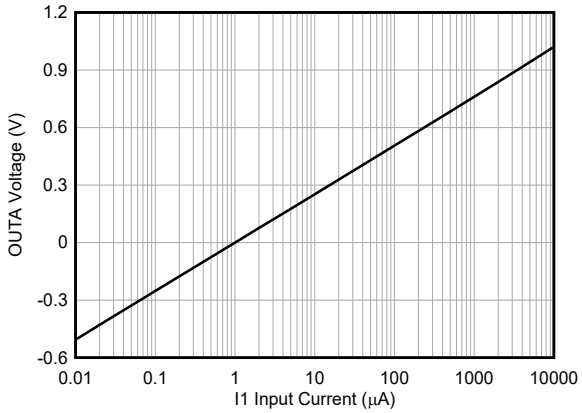


Figure 7-3. OUTA Voltage vs I1 Input Current

First, a best-fit line is established to describe the device transfer function. The slope of this line as compared to the nominal scaling factor, *K*, establishes the scaling factor error, and the intercept of the line establishes the offset error. Next, the difference of the measured device output as compared to the point on the best-fit line is calculated for a given input condition (point on the X axis). For any given point, the result is the immediate logarithmic conformity error, and the value differs depending on the data range across that the best-fit line was established. For example, at high input currents, the LOG200 experiences self-heating due to the increased power dissipation through parasitic resistances, and these thermal effects result in higher apparent LCE within the 100µA to 10mA current range than is measured within the 10nA to 100µA current range.

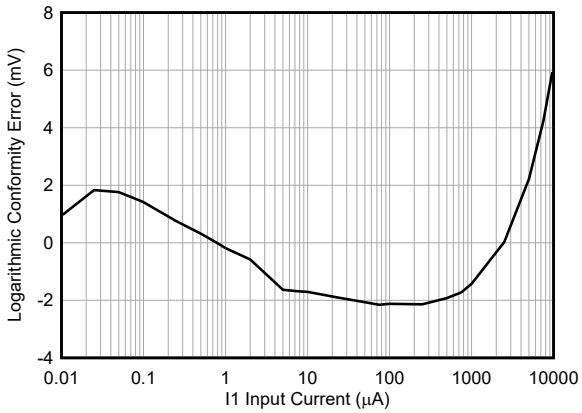


Figure 7-4. Logarithmic Conformity Error vs I1 Input Current

Individually calculating the LCE for every possible input condition is not practical. The LCE expressed as an error envelope is more useful to circuit designers. This calculation conveys the maximum LCE expected across a given input range as a percentage of the expected full-scale output voltage. The calculation involves iterating

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across a set of all measured immediate LCE values for a given range. The difference of the maximum and minimum values is then halved and normalized with a division by the output voltage span of the measurement (the difference of the maximum output voltage and minimum output voltage, typically at the two endpoints of the data set), to express LCE as a percentage of the full-scale range:

$$\mathrm{LCE_{\%}} = \frac{\mathrm{LCE_{max}} - \mathrm{LCE_{min}}}{2 \times (\mathrm{V_{LOGOUTmax}} - \mathrm{V_{LOGOUTmin}})} \times 100\% \quad (6)$$

The LCE envelope can then be expressed in dB through the following relationship, where the factor of 20 is associated with amplitude. For expression in terms of optical power, this factor is 10.

$$\mathrm{LCE_{dB}} = 20\log\left(1 - \frac{\mathrm{LCE_{\%}}}{100\%}\right) \quad (7)$$

7.1.1.2 Error Analysis Example

For an illustration of typical system error for a LOG200 implementation, consider the example use case defined by the following conditions:

Table 7-1. Example Design Parameters

PARAMETER	SYMBOL	EXAMPLE VALUE
Maximum input current	I_{max}	200µA
Minimum input current	I_{min}	10nA
Output reference voltage	V_{REF}	REF165 (1.65V)
Input reference current	I_{I2}	IREF (1µA)
Supply voltage	V_S	10V (±5V)

Table 7-2lists the major error sources, and the typical values of each under the provided conditions. Typical values are generally the sum of the mean value and one standard deviation. Calculations using these typical values tend to be conservative, as the summation of uncorrelated errors tends to result in a larger compounded total predicted error than the actual total error observed in a real system.

Table 7-2. Example Error Sources

PARAMETER	SYMBOL	TYPICAL VALUE
IREF reference current error	I_{REF_error}	0.3%
REF165 reference error	$REF165_{error}$	0.06%
Scaling factor error	K_{error}	0.15%
Logarithmic conformity error	LCE	0.05%
Logarithmic amplifier output offset error	V_{OSO}	1.3mV

These error terms are used to calculate *actual* values, as per the following equations:

$$\mathrm{I_{REF_actual}} = \mathrm{I_{REF}} \times (1 - \mathrm{I_{REF_error}}) = 1\mu\mathrm{A} \times (1 - 0.003) = 0.997\mu\mathrm{A} \quad (8)$$

$$\mathrm{V_{REF_actual}} = \mathrm{V_{REF165}} \times (1 + \mathrm{REF165_{error}}) = 1.65\mathrm{V} \times (1 + 0.0006) = 1.65099\mathrm{V} \quad (9)$$

$$\mathrm{K_{actual}} = \mathrm{K} \times (1 + \mathrm{K_{error}}) = 250\frac{\mathrm{mV}}{\mathrm{dec}} \times (1 + 0.0015) = 250.375\frac{\mathrm{mV}}{\mathrm{dec}} \quad (10)$$

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Begin error analysis by solving for the nominal output voltage at the minimum and maximum currents, without considering error terms. The results are then used to approximate the contribution of the logarithmic conformity error, in mV.

$$V_{LOG_nominal_atImin} = K \times \log_{10}\left(\frac{I_{min}}{I_{REF}}\right) + V_{REF} = 250\frac{mV}{dec} \times \log_{10}\left(\frac{10nA}{1\mu A}\right) + 1.65V = 1.15V \quad (11)$$

$$V_{LOG_nominal_atImax} = K \times \log_{10}\left(\frac{I_{max}}{I_{REF}}\right) + V_{REF} = 250\frac{mV}{dec} \times \log_{10}\left(\frac{200\mu A}{1\mu A}\right) + 1.65V = 2.2253V \quad (12)$$

$$LCE_{atImin} = LCE \times \left(V_{LOG_nominal_atImin} - V_{REF}\right) = -0.0005 \times (1.15V - 1.65V) = 0.25mV \quad (13)$$

$$LCE_{atImax} = LCE \times \left(V_{LOG_nominal_atImax} - V_{REF}\right) = 0.0005 \times (2.2253V - 1.65V) = 0.288mV \quad (14)$$

Repeat this exercise, taking into account typical error values as previously calculated, and then determine the difference of the results to calculate the output error at each current level.

$$V_{LOG_actual_atImin} = K_{actual} \times \log_{10}\left(\frac{I_{min}}{I_{REF_actual}}\right) + V_{REF_actual} + V_{OSO} + LCE_{atImin} = 1.1521V \quad (15)$$

$$V_{LOG_actual_atImax} = K_{actual} \times \log_{10}\left(\frac{I_{max}}{I_{REF_actual}}\right) + V_{REF_actual} + V_{OSO} + LCE_{atImax} = 2.2290V \quad (16)$$

$$V_{LOG_error_atImin} = V_{LOG_actual_atImin} - V_{LOG_nominal_atImin} = 2.117mV \quad (17)$$

$$V_{LOG_error_atImax} = V_{LOG_actual_atImax} - V_{LOG_nominal_atImax} = 3.767mV \quad (18)$$

The output error at a given current level is then expressed as a percentage of the full-scale range as per Equation 19 and Equation 20:

$$ERROR_{full_scale_atImin} = \frac{V_{LOG_error_atImin}}{V_{LOG_nominal_atImax} - V_{LOG_nominal_atImin}} = 0.197\% \quad (19)$$

$$ERROR_{full_scale_atImax} = \frac{V_{LOG_error_atImax}}{V_{LOG_nominal_atImax} - V_{LOG_nominal_atImin}} = 0.350\% \quad (20)$$

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7.2 Typical Application

7.2.1 Optical Current Sensing

A common use case for the LOG200 is an optical current sense circuit, using an external photodiode. Figure 7-5 shows an implementation using an InGaAs, PIN photodiode for a λ = 1.31µm application. This design uses ±5V supplies, and is intended for use with input currents from 10nA to 100µA. Decoupling capacitors are not shown for brevity. The design can be easily implemented using the LOG200 Evaluation Module board. For additional information, bench measurements, and examples for interfacing the LOG200 with photodiodes, see the *Perform Accurate Optical Power Measurements With The LOG200* application note.

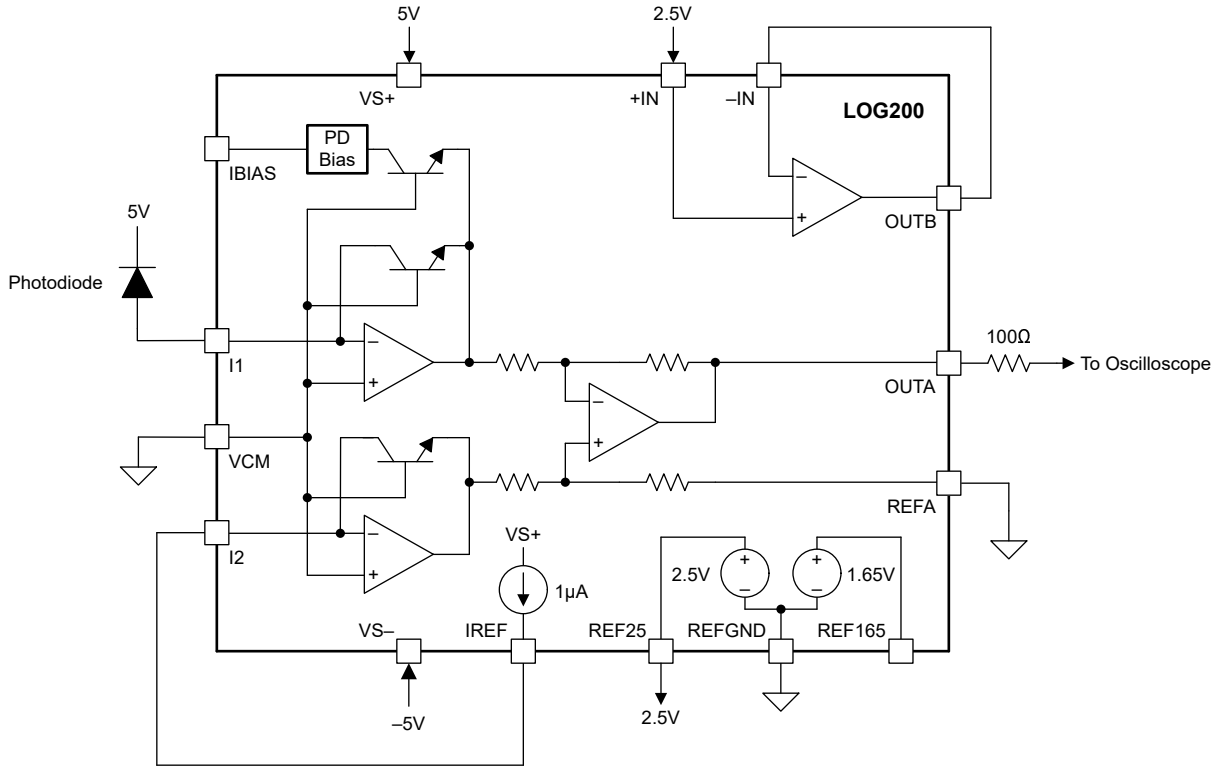


Figure 7-5. LOG200 Optical Current-Sensing Application

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7.2.1.1 Design Requirements

For this application, the design requirements are as follows:

- VS+ = 5V, VS– = –5V, VCM = GND, REFA = GND
- IREF (1µA) connected to I2
- Input current range: 10nA ≤ I_1 ≤ 100µA
- Photodiode: GP8195-12
  - V_R = 5V
  - 20pA dark current (typical)
  - 1pF typical capacitance (1.5pF maximum)
  - Spectral response range from λ = 0.9µm to λ = 1.7µm

For bench testing of the system, the following configuration is used:

- Laser diode: LPS-1310-FC
  - λ = 1.31µm
  - Threshold current 5mA to 20mA
  - Current control mode used
- Laser controller: THOR CLD1010
- Variable attenuator: VOA50-FC-SM 50dB in-line
- External modulation: Agilent 33500 30MHz waveform generator

7.2.1.2 Detailed Design Procedure

The G8195-12 photodiode was used with a fixed reverse bias voltage of 5V. The cathode was connected to the VS+ 5V supply, and the anode to the I1 pin. GND is used for the VCM potential. The IBIAS feature and REF165 voltage reference were not needed; therefore, the IBIAS and REF165 pins are left floating. The auxiliary amplifier was not needed; therefore, the auxiliary amplifier was placed in a buffer configuration and used to buffer the REF25 reference voltage.

GND was used for the REFA input of the logarithmic difference amplifier. The circuit output follows the expression

$$V_{LOGOUT} = 250mV \times \log_{10}\left(\frac{I_1}{1\mu A}\right) \quad (21)$$

such that the expected output for a 100nA input is –500mV, the expected output for a 10µA input is 250mV, and so on.

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7.2.1.3 Application Curves

The following figures show oscilloscope captures of the LOG200 output as the device responds to one-decade shifts in the input current. Rising and falling steps between 10nA and 100nA, and between 10µA and 100µA, were recorded. The oscilloscope was set to use the ac-coupled path.

For the current steps between 10nA and 100nA, a 10mA laser diode bias was used. A rise time of approximately 268ns and a fall time of approximately 626ns are observed.

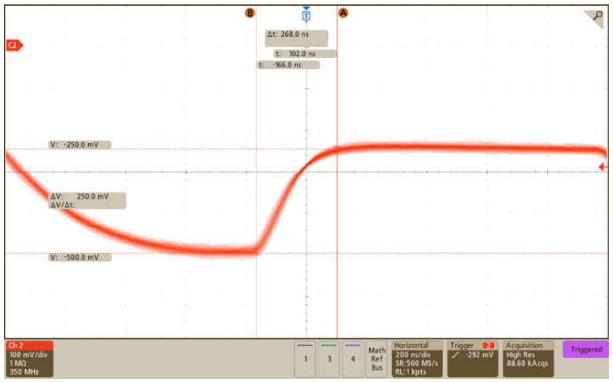


Figure 7-6. 10nA-to-100nA Current Step

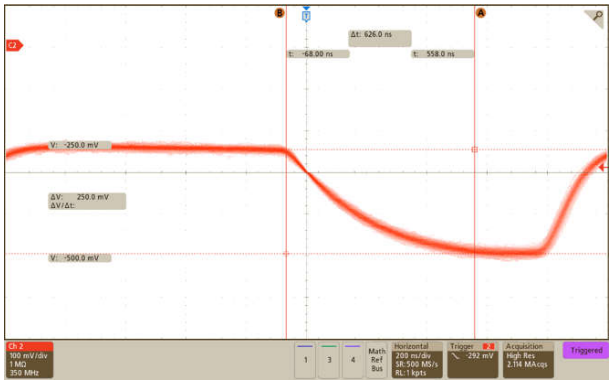


Figure 7-7. 100nA-to-10nA Current Step

For the current steps between 10µA and 100µA, a 13mA laser diode bias was used. A rise time of approximately 45.60ns and a fall time of approximately 55.60ns are observed.

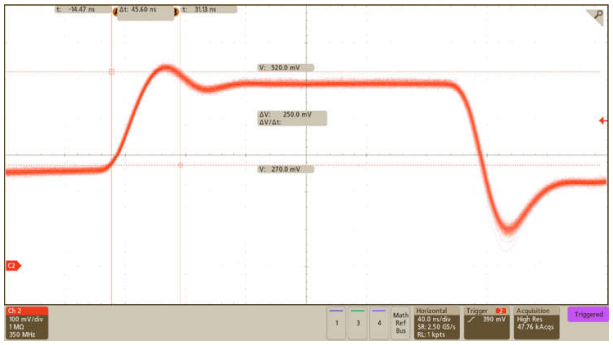


Figure 7-8. 10µA-to-100µA Current Step



Figure 7-9. 100µA-to-10µA Current Step

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7.3 Power Supply Recommendations

The LOG200 has a maximum supply voltage of 12.6V (±6.3V) and a minimum supply voltage of 4.5V (±2.25V). Decoupling capacitors must be used on the power supply and VCM pins.

In many cases, a 5V single-ended supply or ±5V bipolar supply is used. If the only power supply available in the system is a 3.3V single-ended supply, a boost converter is needed to achieve the 4.5V minimum operating voltage required by the LOG200. This approach can require larger decoupling capacitors to reduce the effects of power-supply ripple on the device.

7.4 Layout

7.4.1 Layout Guidelines

Attention to good layout practices is always recommended. For best operational performance of the device, use good printed circuit board (PCB) layout practices, including:

- Make sure that both input paths of the secondary amplifier are symmetrical and well-matched for source impedance and capacitance to avoid converting common-mode signals into differential signals and thermal electromotive forces (EMFs).
- Noise can propagate into analog circuitry through the power pins of the device and of the circuit as a whole. Bypass capacitors reduce the coupled noise by providing low-impedance power sources local to the analog circuitry. Connect low-ESR, 0.1µF X7R ceramic bypass capacitors between each supply pin and ground, placed as close as possible to the device. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Use a C0G (NP0) ceramic capacitor for the V_{CM} decoupling capacitance and place as close to the VCM pin as possible.
- Connect C0G (NP0) ceramic bypass capacitors to each of the REF165 and REF25 reference pins, as close to the pins as possible. Use a sum of 100pF to 330pF of capacitance per pin when using the reference, or 33pF if the reference is not used. When driving larger capacitive loads, use a snubber circuit, such as a 50Ω isolation resistance driving a 100nF decoupling capacitance to REFGND. A snubber circuit of 100Ω and 100µF can improve noise filtering.
- For photoelectric-sensing applications, place the photodiode as close as possible to the I1 pin to minimize parasitic inductance.
- Use ceramic C0G (NP0)-dielectric capacitors for any capacitance that is part of the input or output signal chain (C_3, C_4, C_5, and C_{BIAS} if implemented).
- Surround the current input traces with copper guard traces all the way from the source to the input pins of the LOG200. Remove all solder mask and silkscreen from the guard area to reduce surface-charge accumulation and prevent surface-level leakage paths. Use V_{CM} as the guard potential.
  - For ultra-low current measurements, the guard must be implemented in a three-dimensional scheme to prevent leakage currents originating in other layers from flowing into the signal path. Place additional guard copper on the next layer directly below the surface-level signal and guard traces to protect from vertical leakage paths. Surround the sensitive input traces with a via fence connecting the guard copper on different layers to complete the three-dimensional guard enclosure.
- To reduce parasitic coupling, run the input traces as far away as possible from the supply or output traces. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better than in parallel with the noisy trace.
- Minimize the number of thermal junctions. Preferably, the signal path is routed within a single layer without vias, with the traces as short as possible.
- Keep sufficient distance from major thermal energy sources (circuits with high power dissipation). If not possible, place the device so that the effects of the thermal energy source on the high and low sides of the differential signal path are evenly matched.
- Solder the thermal pad to the PCB. For the LOG200 to properly dissipate heat and minimize leakage, connect the thermal pad to a plane or large copper pour that is electrically connected to VCM, even for low-power applications.

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7.4.2 Layout Example

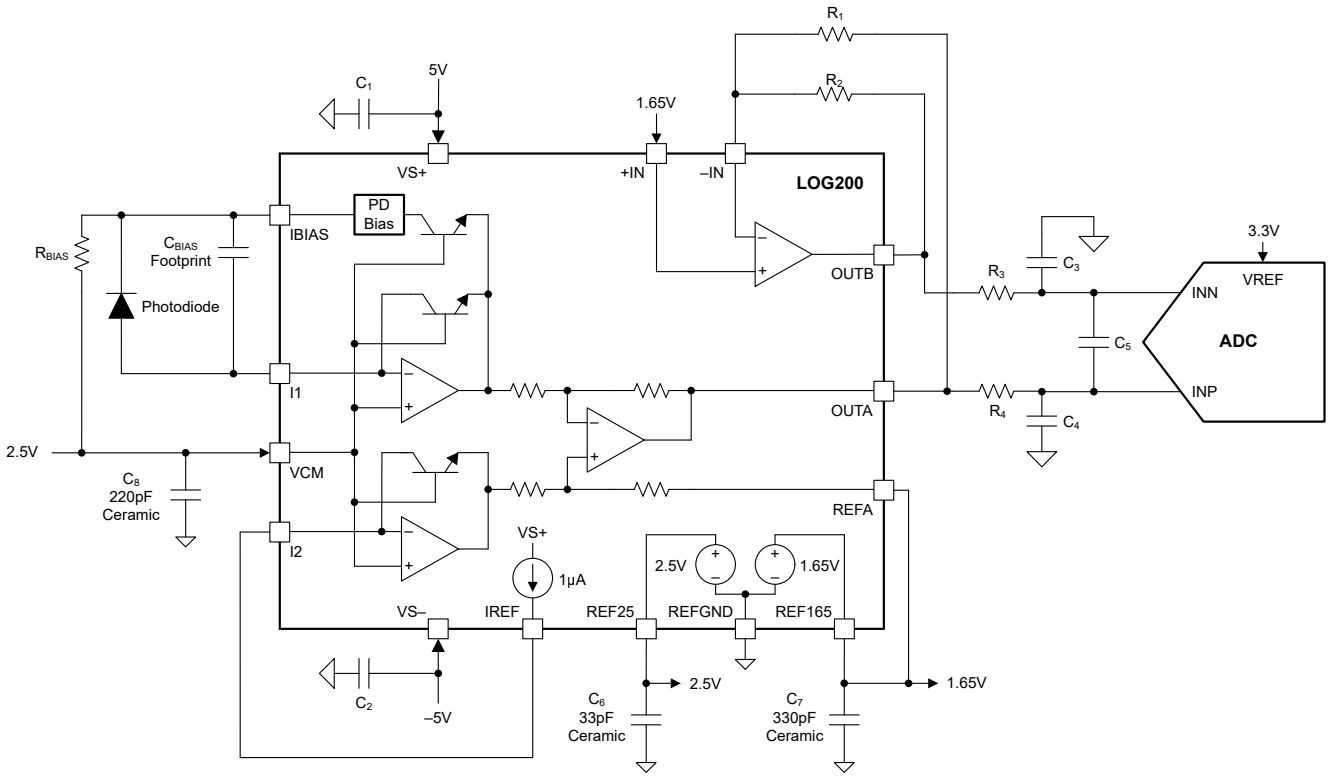


Figure 7-10. LOG200 Example Circuit

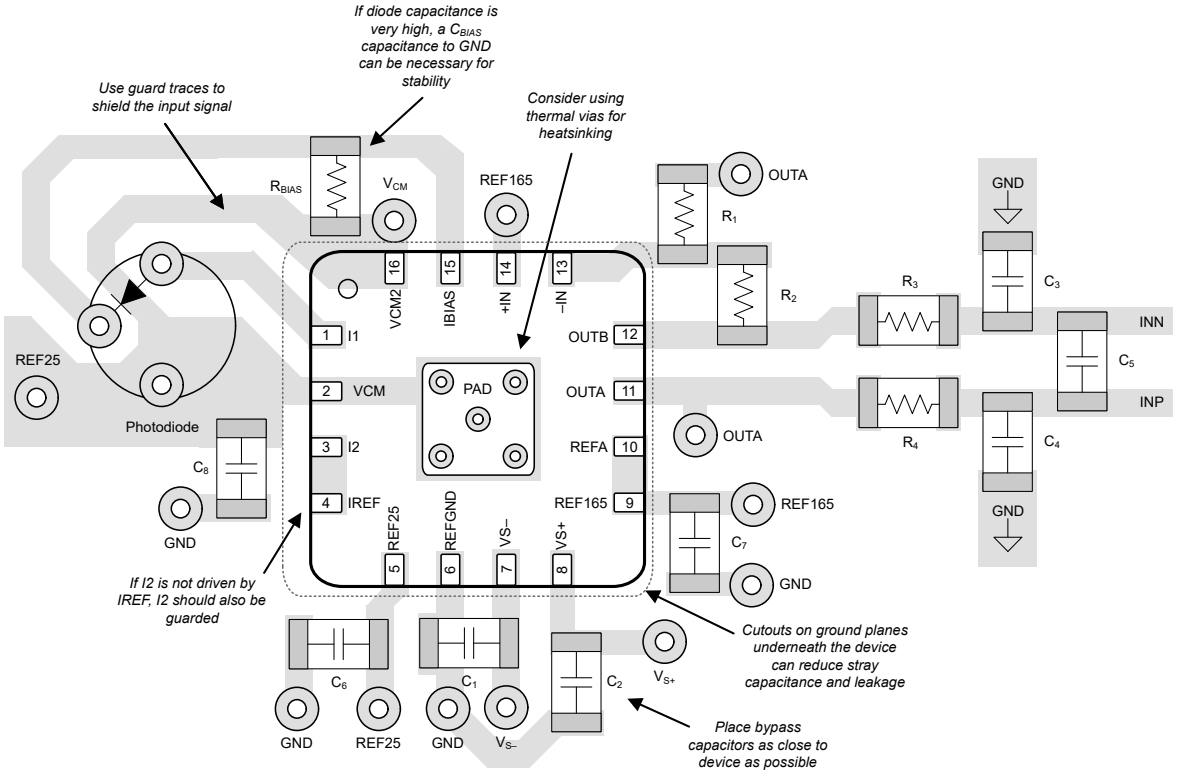


Figure 7-11. LOG200 Example Layout

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8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

8.1 Device Support

8.1.1 Third-Party Products Disclaimer

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8.2 Documentation Support

8.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, *LOG200 EVM User Guide*

8.3 Receiving Notification of Documentation Updates

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

8.4 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.

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8.5 Trademarks

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All trademarks are the property of their respective owners.

8.6 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.

8.7 Glossary

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

9 Revision History

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

Changes from Revision A (December 2024) to Revision B (August 2026)	Page
• Changed YBH (DSBGA, 16) package status from advanced information to production data (active)	1
• Added *Thermal Information for YBH* package	4
• Added package specific *scaling factor error* for YBH package	6
• Added package specific *scaling factor error across temperature* for YBH package	6
• Added package specific *offset voltage at 5V* for YBH package	6
• Added package specific *offset voltage at 10V* for YBH package	6

- Added package specific *input bias ratio at 5V* for YBH package..... 6
- Added package specific *input bias ratio at 10V* for YBH package..... 6
- Added package specific *open-loop voltage gain* for YBH package.....6

Changes from Revision * (August 2023) to Revision A (December 2024) **Page**

- Changed RGT (VQFN, 16) package status from advanced information to production data (active).....1

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.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LOG200RGTR	Active	Production	VQFN (RGT) | 16	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LOG200
LOG200RGTR.B	Active	Production	VQFN (RGT) | 16	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LOG200
LOG200RGTT	Last Time Buy	Production	VQFN (RGT) | 16	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LOG200
LOG200RGTT.B	Last Time Buy	Production	VQFN (RGT) | 16	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LOG200
LOG200YBHR	Active	Production	DSBGA (YBH) | 16	3000 | LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 125	LOG200

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

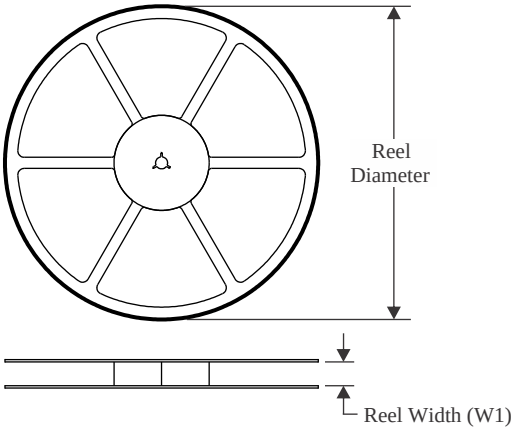
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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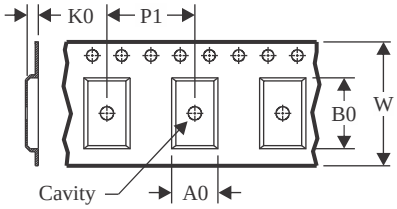
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

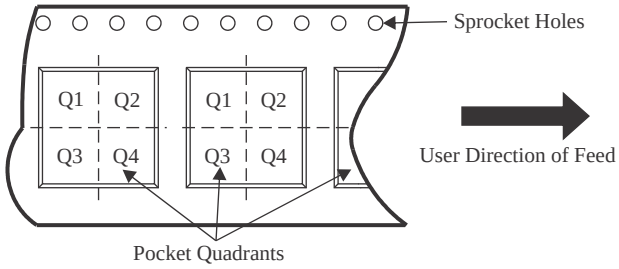


TAPE DIMENSIONS



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

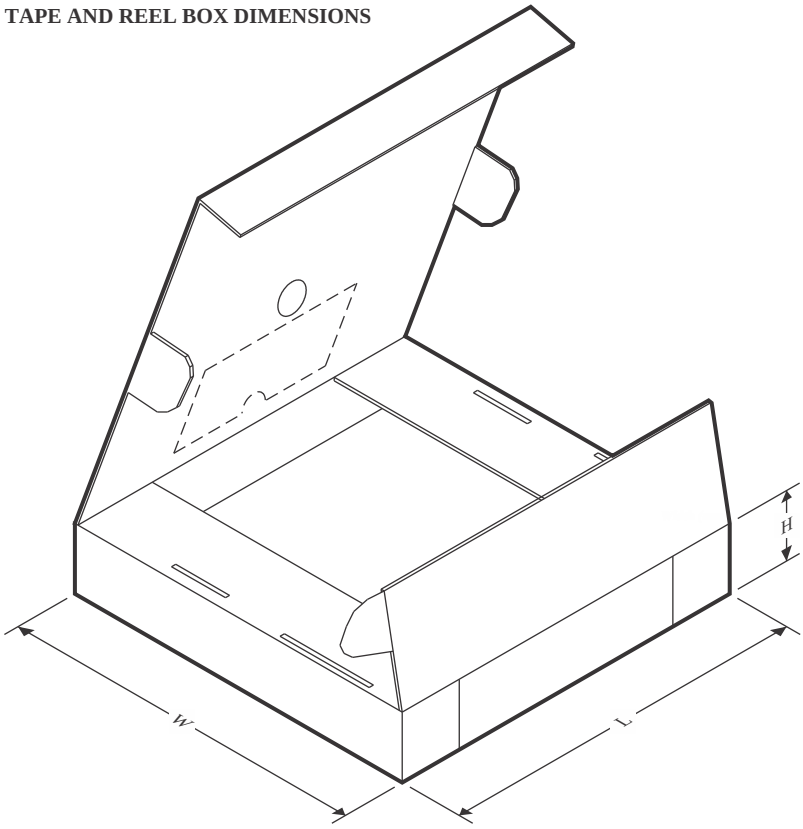
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LOG200RGTR	VQFN	RGT	16	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
LOG200RGTT	VQFN	RGT	16	250	180.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
LOG200YBHR	DSBGA	YBH	16	3000	180.0	8.4	1.78	1.78	0.69	4.0	8.0	Q1

TAPE AND REEL BOX DIMENSIONS

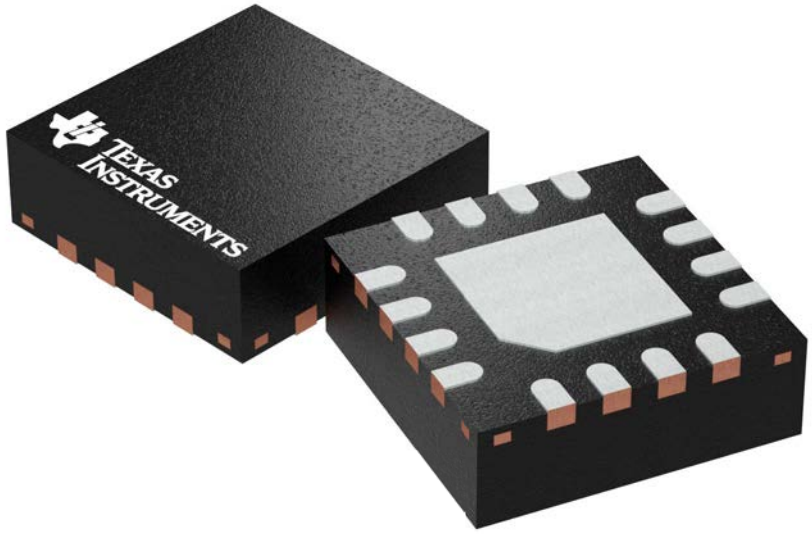


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LOG200RGTR	VQFN	RGT	16	3000	360.0	360.0	36.0
LOG200RGTT	VQFN	RGT	16	250	210.0	185.0	35.0
LOG200YBHR	DSBGA	YBH	16	3000	182.0	182.0	20.0

RGT 16 VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



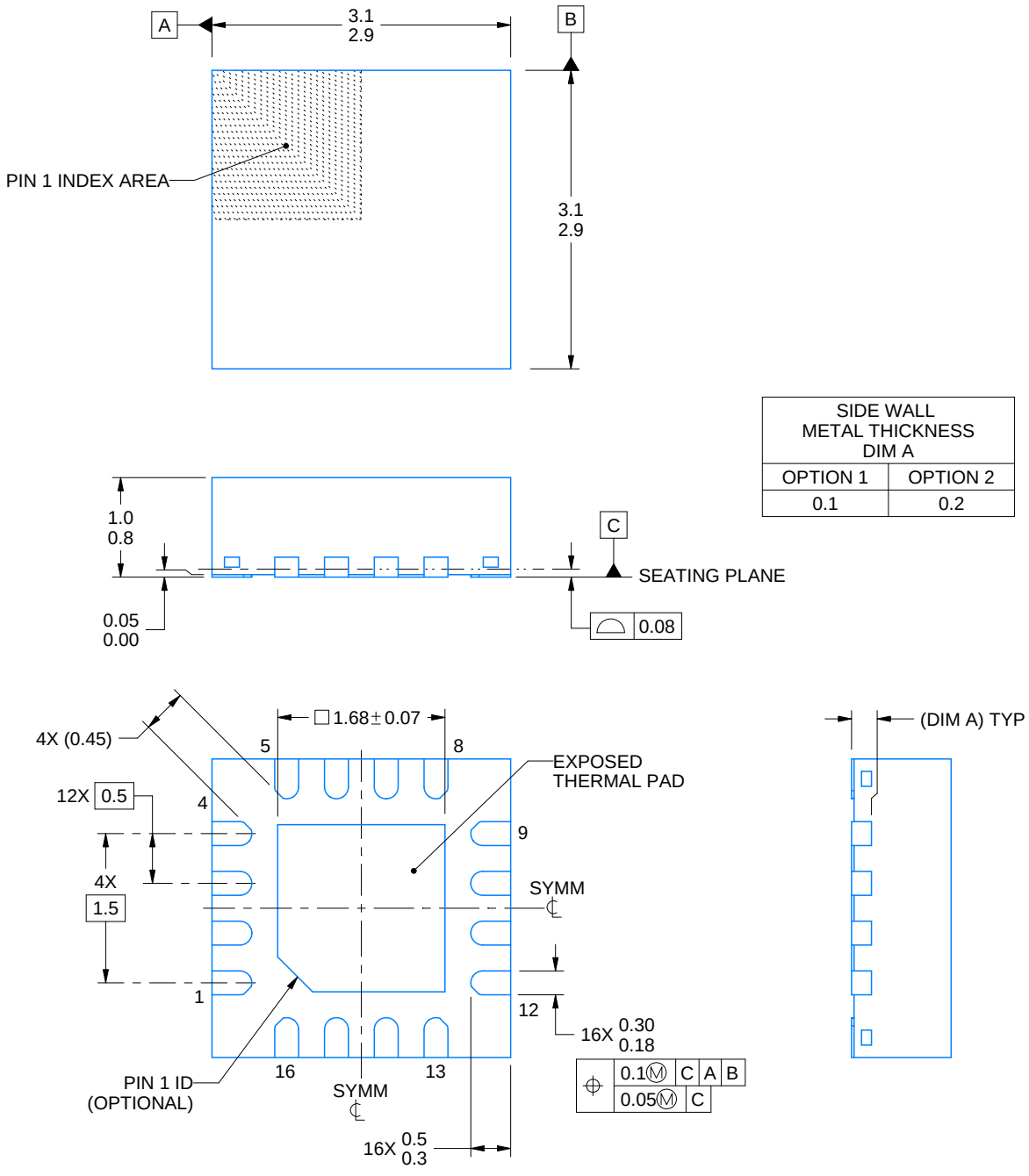
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

PACKAGE OUTLINE

RGT0016C

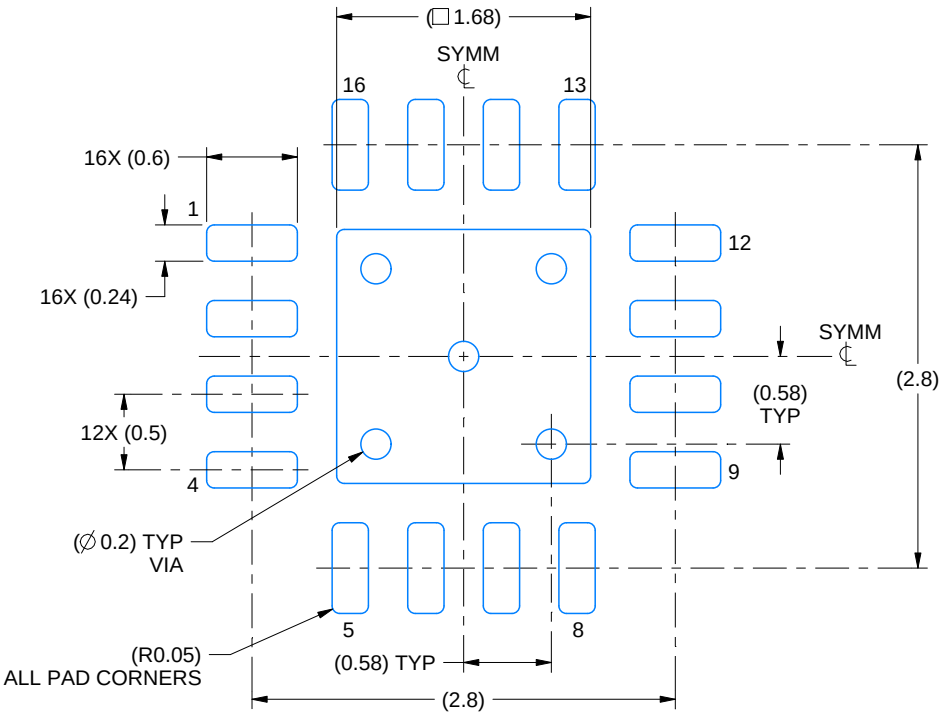
VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

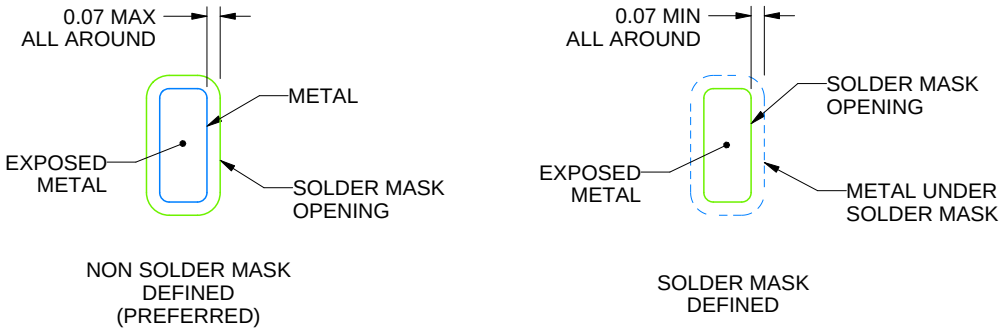


NOTES:

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

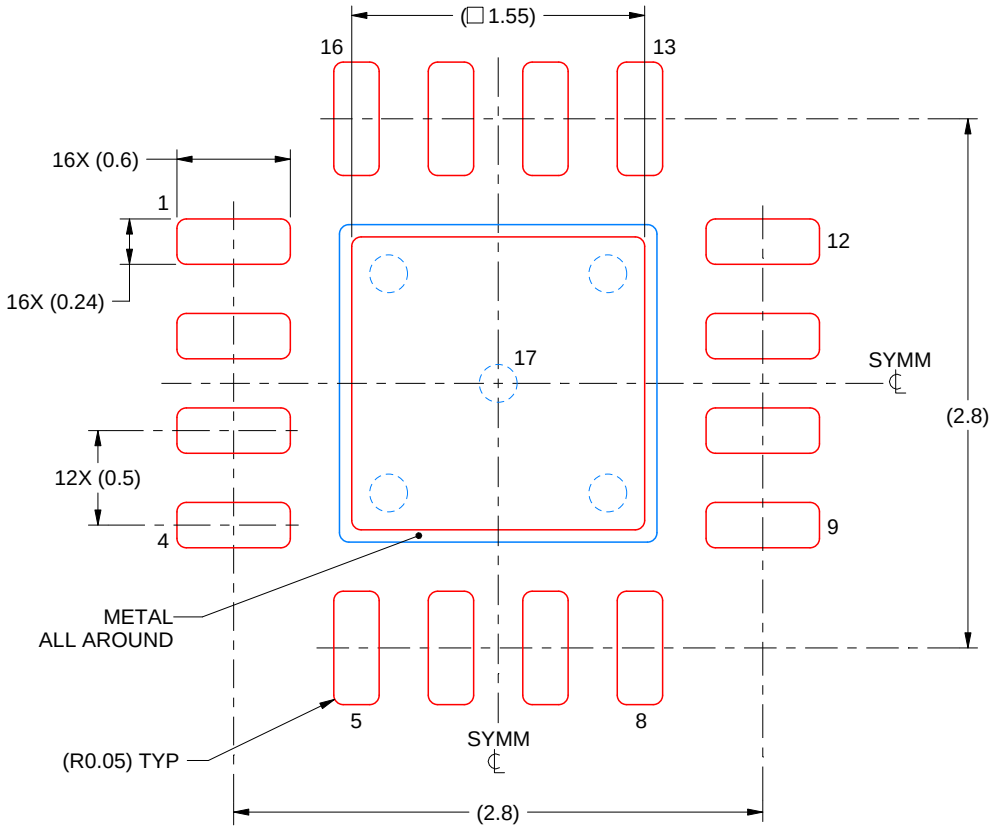


SOLDER MASK DETAILS

4222419/E 07/2025

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.



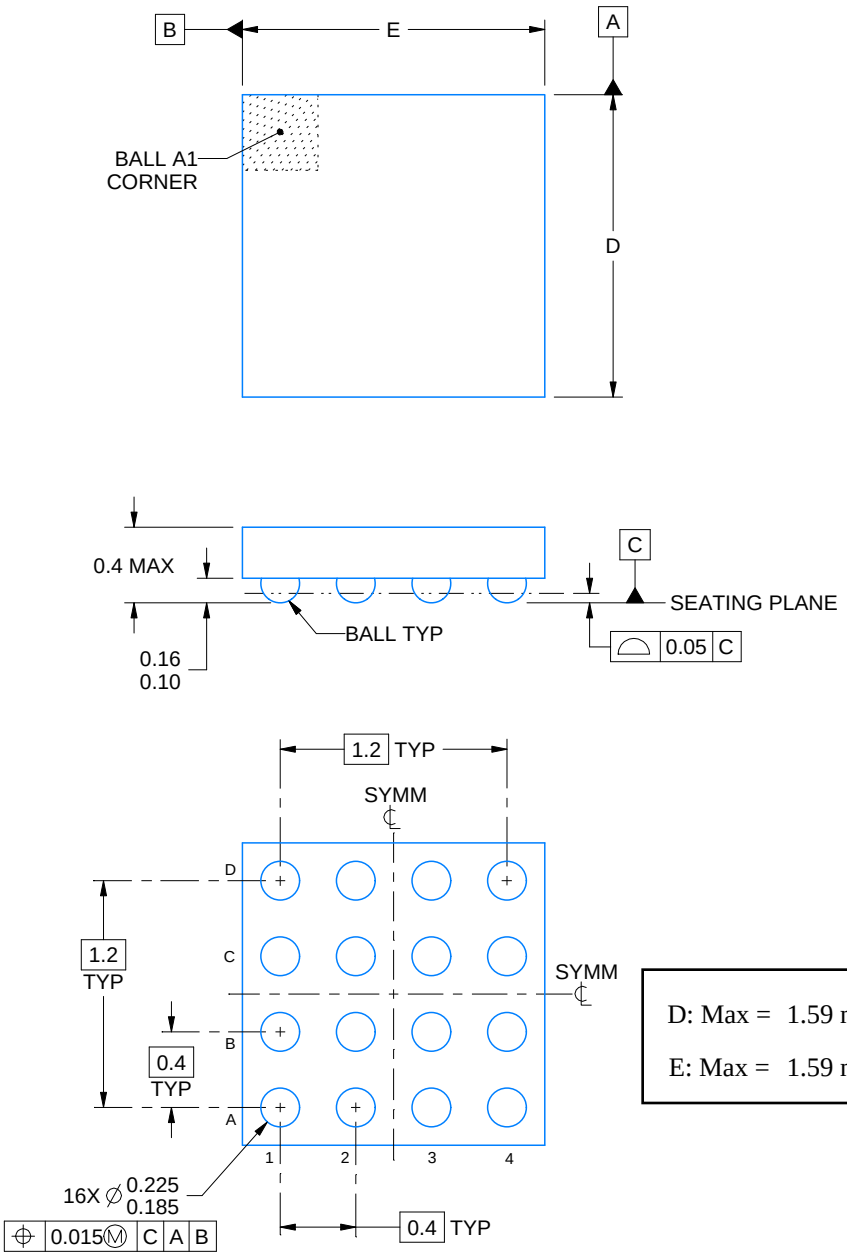
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 17:
85% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:25X

4222419/E 07/2025

NOTES: (continued)

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



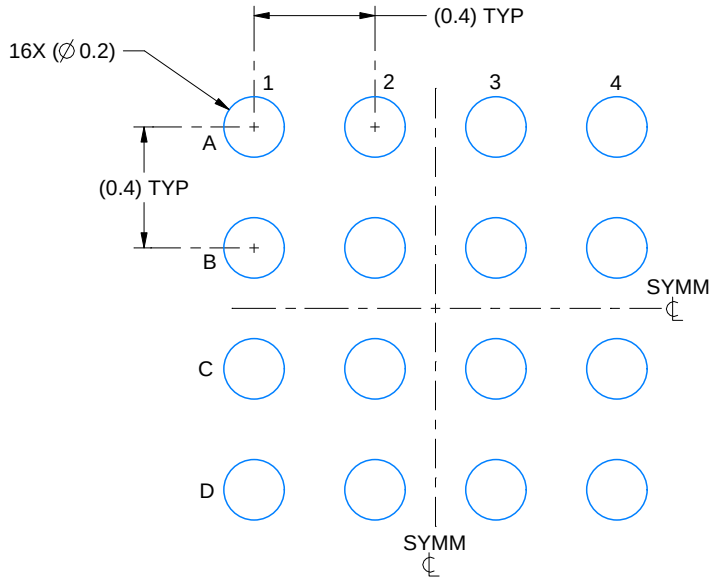
D: Max = 1.59 mm, Min = 1.53 mm

E: Max = 1.59 mm, Min = 1.53 mm

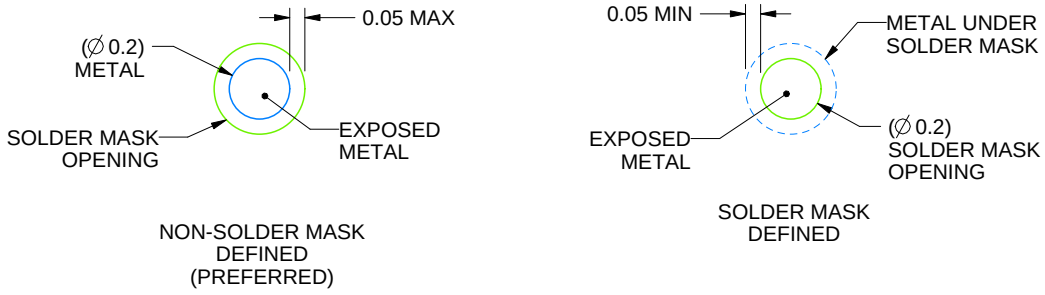
4225022/A 06/2019

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 40X

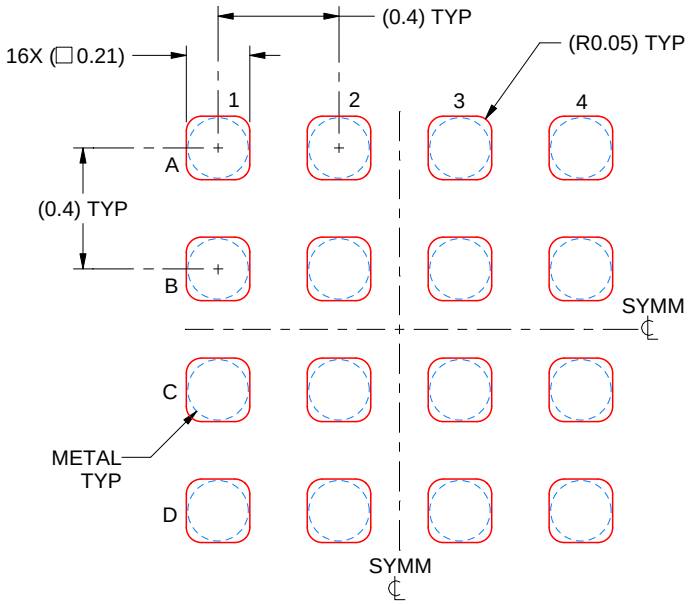


SOLDER MASK DETAILS
NOT TO SCALE

4225022/A 06/2019

NOTES: (continued)

3. Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints.
See Texas Instruments Literature No. SNVA009 (www.ti.com/lit/snva009).



SOLDER PASTE EXAMPLE
BASED ON 0.075 mm THICK STENCIL
SCALE: 40X

4225022/A 06/2019

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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