OPA355-Q1 200-MHz CMOS Operational Amplifier With Shutdown

1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results
  - Device Temperature Grade 1: –40°C to +125°C Ambient Operating Temperature
  - Device HBM ESD Classification Level 2
  - Device CDM ESD Classification Level C4B
- Unity-Gain Bandwidth: 450 MHz
- Wide Bandwidth: 200 MHz GBW
- High Slew Rate: 360 V/μs
- Low Noise: 5.8 nV/$\sqrt{Hz}$
- Excellent Video Performance:
  - Differential Gain: 0.02%
  - Differential Phase: 0.05° (0.1 dB)
  - Gain Flatness: 75 MHz
- Input Range Includes Ground
- Rail-to-Rail Output (Within 100 mV)
- Low Input Bias Current: 3 pA
- Low Shutdown Current: 3.4 μA
- Enable and Disable Time: 100 ns and 30 ns
- Thermal Shutdown
- Single-Supply Operating Range: 2.5 V to 5.5 V
- *Micro*SIZE Packages

2 Applications

- Automotive
- Active Filters
- High-Speed Integrators
- Analog-to-Digital Converter (ADC) Input Buffers
- Digital-to-Analog Converter (DAC) Output Amplifiers

3 Description

The OPA355-Q1 device is a high-speed, voltage-feedback CMOS operational amplifier designed for applications requiring wide bandwidth. The OPA355-Q1 device is unity-gain stable and can drive large output currents. In addition, the OPA355-Q1 device has a digital shutdown (enable) function. This feature provides power saving during idle periods and places the output in a high-impedance state to support output multiplexing. The differential gain is 0.02% and the differential phase is 0.05°. The quiescent current is 8.3 mA per channel.

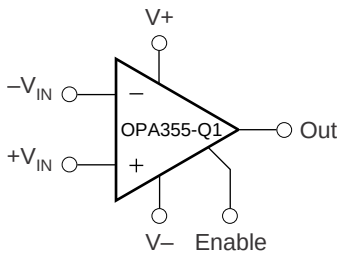
The OPA355-Q1 device is optimized for operation on single supply or dual supplies as low as 2.5 V (±1.25 V) and up to 5.5 V (±2.75 V). The common-mode input range for the OPA355-Q1 device extends 100 mV below ground and up to 1.5 V from V+. The output swing is within 100 mV of the rails, supporting wide dynamic range.

The OPA355-Q1 device is available in a single SOT-23-6 package and is specified over the extended –40°C to +125°C temperature range.

Device Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
OPA355-Q1	SOT-23 (6)	2.90 mm × 1.60 mm

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



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4 Revision History

Changes from Revision B (June 2014) to Revision C **Page**

- Deleted "C55" marking on pinout drawing in *Pin Configuration and Functions* section ... 3
- Added Pin Functions table to *Pin Configuration and Functions* section ... 3
- Deleted storage temperature range from *ESD Ratings* table and moved to *Absolute Maximum Ratings* table ... 4
- Changed title of *Handling Ratings* table to *ESD Ratings* table ... 4
- Added *Recommended Operating Conditions* table ... 4
- Added *Functional Block Diagram* ... 12
- Deleted "Independent enable pins are available for each channel, which provide maximum design flexibility" from *Enable Function* section ... 12
- Deleted *Input and ESD Protection* subsection in *Feature Description* section ... 13
- Added *Device Functional Modes* section ... 13
- Added *Typical Applications* section to *Application and Implementation* section ... 14
- Added *Design Requirements* subsection to *Typical Applications* section ... 14
- Added *Detailed Design Procedure* subsection to *Typical Application* section ... 14
- Added application curves to the *Typical Application* section ... 16
- Added *High-Impedance Sensor Interface*, *Driving ADCs*, and *Active Filter* subsections to *Typical Application* section ... 16
- Added *Power Supply Recommendations* section ... 19
- Added layout example image to *Layout* section ... 19

Changes from Revision A (December 2013) to Revision B **Page**

- Changed device status from *Product Preview* to *Production Data* ... 1

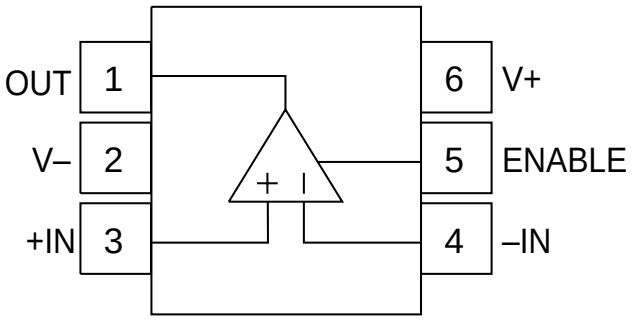
5 Device Comparison Table

5.1 Device Comparison Table

OPA355-Q1 RELATED PRODUCTS	FEATURES
OPA356	200-MHz, Rail-to-Rail Output, CMOS, No Shutdown
OPAx350	38-MHz, Rail-to-Rail Input and Output, CMOS
OPAx631	75-MHz, Rail-to-Rail Output
OPAx634	150-MHz, Rail-to-Rail Output
THS412x	Differential Input and Output, 3.3-V Supply

6 Pin Configuration and Functions

DBV Package
6-Pin SOT-23
Top View



Pin 1 of the SOT-23-6 is determined by orienting the package marking as indicated in the diagram.

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
ENABLE	5	—	Amplifier power down. Low = disabled, high = normal operation (pin must be driven) .
IN+	3	I	Noninverting input pin
IN–	4	I	Inverting input pin
OUT	1	O	Output pin
V+	6	—	Positive power supply
V–	2	—	Negative power supply

7 Specifications

7.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply voltage	V+ to V–		7.5	V
Signal input terminals	Voltage	(V–) – 0.5	(V+) + 0.5	V
	Current		10	mA
Output short circuit(2)		Continuous		
Operating temperature		–55	150	°C
Junction temperature			160	°C
Lead temperature (soldering, 10 seconds)			300	°C
Storage temperature range, T_{stg}		–65	150	°C

(1) Stresses above *Absolute Maximum Ratings* may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) Short-circuit to ground, one amplifier per package.

7.2 ESD Ratings

			MIN	MAX	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human body model (HBM), per AEC Q100-002(1)			2000	V
	Charged device model (CDM), per AEC Q100-011	Corner pins (1, 3, 4, and 6)		750	
		Other pins		500	

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

7.3 Recommended Operating Conditions

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

	MIN	NOM	MAX	UNIT
V_S Total supply voltage	2.7		5.5	V
T_A Ambient temperature	–40	25	125	°C

7.4 Thermal Information

THERMAL METRIC(1)		OPA355-Q1 DBV (SOT-23) 6 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	187.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	126.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	32.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	24.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	32.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

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

7.5 Electrical Characteristics

V_S = 2.7 V to 5.5 V (single-supply). At T_A = 25°C, R_F = 604 Ω, R_L = 150 Ω, and connected to V_S / 2, (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V_{OS}	Input offset voltage	V_S = 5 V	T_A = 25°C		±2	±9	mV
			T_A = –40°C to +125°C			±15	
DV_{OS}/dT	Input offset voltage vs temperature	T_A = 25°C					µV/°C
		T_A = –40°C to +125°C			±7		
PSRR	Input offset voltage vs power supply	V_S = 2.7 to 5.5 V, V_{CM} = V_S / 2 – 0.15 V	T_A = 25°C		±80	±350	µV/V
			T_A = –40°C to +125°C				
INPUT BIAS CURRENT							
I_B	Input bias current	T_A = 25°C			3	±50	pA
		T_A = –40°C to +125°C				±50	
I_{OS}	Input offset current	T_A = 25°C			±1		pA
		T_A = –40°C to +125°C					
NOISE							
e_n	Input noise voltage density	f = 1 MHz	T_A = 25°C		5.8		$nV/\sqrt{Hz}$
			T_A = –40°C to +125°C				
i_n	Current noise density	f = 1 MHz	T_A = 25°C		50		$fA/\sqrt{Hz}$
			T_A = –40°C to +125°C				
INPUT VOLTAGE RANGE							
V_{CM}	Common-mode voltage range	T_A = 25°C		(V–) – 0.1		(V+) – 1.5	V
		T_A = –40°C to +125°C					
CMRR	Common-mode rejection ratio	V_S = 5.5 V, –0.1 V < V_{CM} < 4 V	T_A = 25°C	66	80		dB
			T_A = –40°C to +125°C	66			
INPUT IMPEDANCE							
	Differential	T_A = 25°C			10^{13} || 1.5		Ω || pF
		T_A = –40°C to +125°C					
	Common-mode	T_A = 25°C			10^{13} || 1.5		Ω || pF
		T_A = –40°C to +125°C					
OPEN-LOOP GAIN							
	Open-loop gain	V_S = 5 V, 0.3 V < V_O < 4.7 V	T_A = 25°C	84	92		dB
			T_A = –40°C to +125°C	80			
FREQUENCY RESPONSE							
f_{-3dB}	Small-signal bandwidth	G = 1, V_O = 100 mVp-p, R_F = 0 Ω, T_A = 25°C			450		MHz
		G = 2, V_O = 100 mVp-p, R_L = 50 Ω, T_A = 25°C			100		MHz
		G = 2, V_O = 100 mVp-p, R_L = 150 Ω, T_A = 25°C			170		MHz
		G = 2, V_O = 100 mVp-p, R_L = 1 kΩ, T_A = 25°C			200		MHz
GBW	Gain-bandwidth product	G = 10, R_L = 1 kΩ, T_A = 25°C			200		MHz
$f_{0.1\ dB}$	Bandwidth for 0.1-db gain flatness	G = 2, V_O = 100 mVp-p, R_F = 560 Ω, T_A = 25°C			75		MHz
SR	Slew rate	V_S = 5 V, G = 2, 4-V output step, T_A = 25°C			300 / –360		V/µs
	Rise and fall time	G = 2, V_O = 200 mVp-p, 10% to 90%, T_A = 25°C			2.4		ns
		G = 2, V_O = 2 Vp-p, 10% to 90%, T_A = 25°C			8		ns
	Settling time	V_S = 5 V, G = 2, 2-V output step, 0.1%, T_A = 25°C			30		ns
		V_S = 5 V, G = 2, 2-V output step, 0.01%, T_A = 25°C			120		ns
	Overload recovery time	V_I × G = V_S, T_A = 25°C			8		ns

Electrical Characteristics (continued)

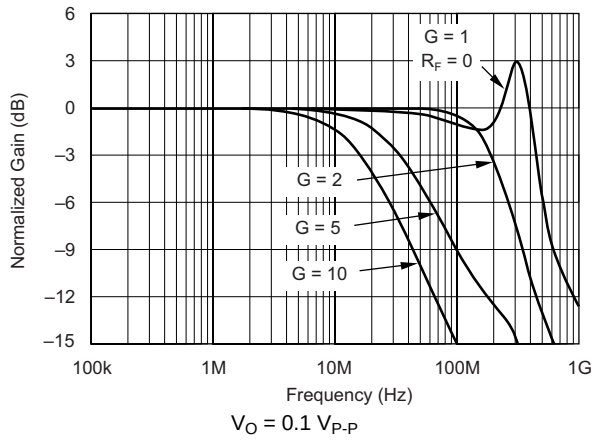
V_S = 2.7 V to 5.5 V (single-supply). At T_A = 25°C, R_F = 604 Ω, R_L = 150 Ω, and connected to V_S / 2, (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
	Harmonic distortion	G = 2, f = 1 MHz, V_O = 2 Vp-p, R_L = 200 Ω T_A = 25°C (second harmonic)			–81		dBc
		G = 2, f = 1 MHz, V_O = 2 Vp-p, R_L = 200 Ω T_A = 25°C (third harmonic)			–93		dBc
	Differential gain error	NTSC, R_L = 150 Ω, T_A = 25°C			0.02%		
	Differential phase error	NTSC, R_L = 150 Ω, T_A = 25°C			0.05		°
OUTPUT							
	Voltage output swing from rail	V_S = 5 V, R_L = 150 Ω, A_{OL} > 84 dB			0.2	0.3	V
		V_S = 5 V, R_L = 1 kΩ			0.1		V
I_O	Output current (continuous) (1)				±60		mA
	Output current (peak) (1)	V_S = 5 V, T_A = 25°C			±100		mA
		V_S = 3 V, T_A = 25°C			±80		
	Closed-loop output impedance	f < 100 kHz			0.02		Ω
POWER SUPPLY							
V_S	Specified voltage range	T_A = 25°C		2.7		5.5	V
	Operating voltage range	T_A = 25°C			2.5 to 5.5		V
I_Q	Quiescent current (per amplifier)	V_S = 5 V, enabled; I_O = 0	T_A = 25°C		8.3	11	mA
			T_A = –40°C to +125°C			14	
SHUTDOWN							
	Logic-LOW threshold (2) (disabled)	T_A = 25°C				0.8	V
	Logic-HIGH threshold (2) (enabled)	T_A = 25°C		2			V
	Enable time	T_A = 25°C			100		ns
	Disable time	T_A = 25°C			30		ns
	Shutdown current (per amplifier)	V_S = 5 V, disabled, T_A = 25°C			3.4		µA
THERMAL SHUTDOWN							
	Junction temperature	Shutdown, T_A = 25°C			160		°C
		Reset from shutdown, T_A = 25°C			140		°C
	Specified range	T_A = 25°C		–40		125	°C
	Operating range	T_A = 25°C		–55		150	°C
	Storage range	T_A = 25°C		–65		150	°C

(1) See the *Output Voltage Swing vs Output Current* (Figure 21 and Figure 23) in the *Typical Characteristics* section.
(2) Logic LOW and HIGH levels are CMOS logic compatible. They are referenced to V–.

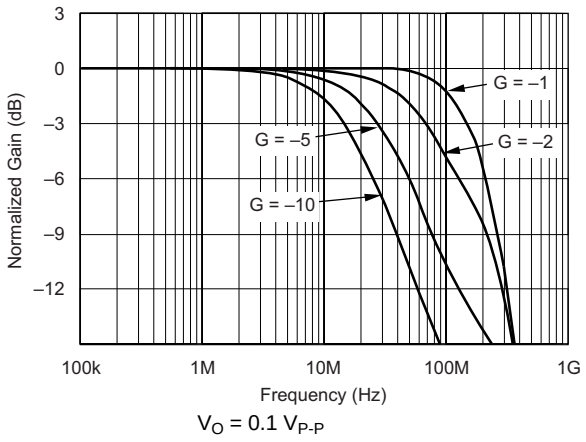
7.6 Typical Characteristics

T_A = 25°C, V_S = 5 V, G = 2, R_F = 604 Ω, and R_L = 150 Ω connected to V_S / 2, (unless otherwise noted)



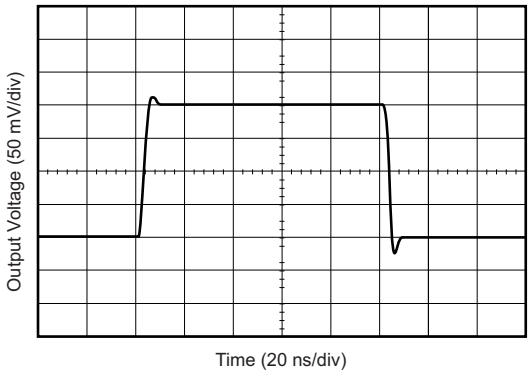
V_O = 0.1 V_{P-P}

Figure 1. Noninverting Small-Signal Frequency Response



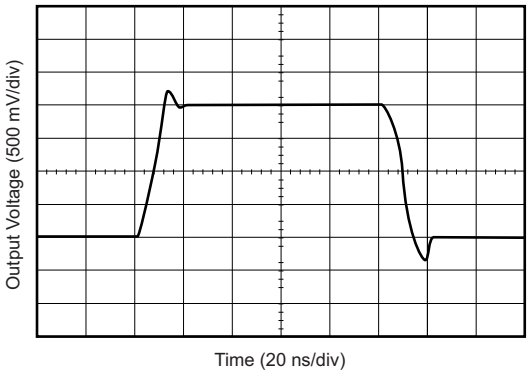
V_O = 0.1 V_{P-P}

Figure 2. Inverting Small-Signal Frequency Response



G = 2

Figure 3. Noninverting Small-Signal Step Response



G = 2

Figure 4. Noninverting Large-Signal Step Response

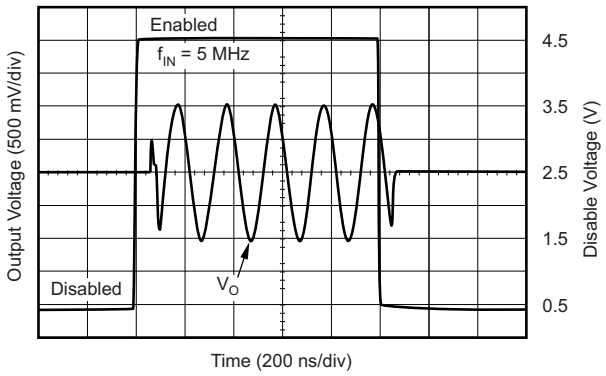
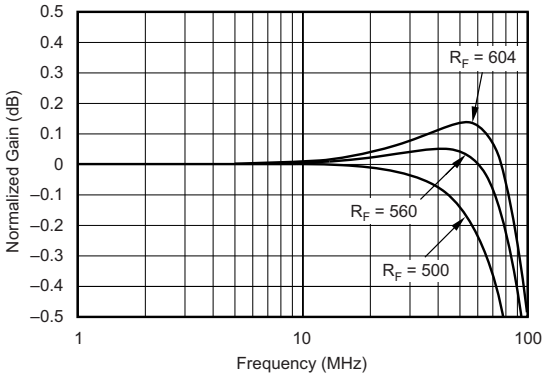


Figure 5. Large-Signal Disable and Enable Response

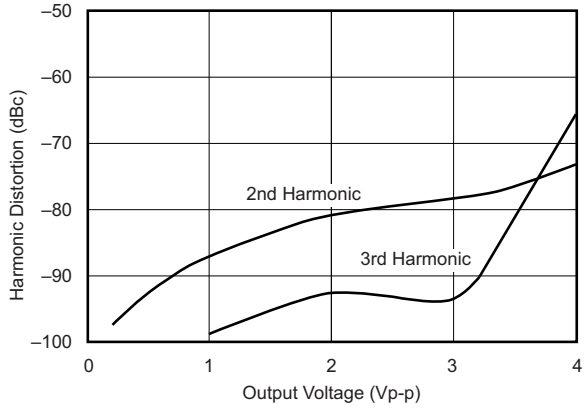


C_L = 0 pF V_O = 0.1 V_{P-P}

Figure 6. 0.1-dB Gain Flatness for Various R_F Values?

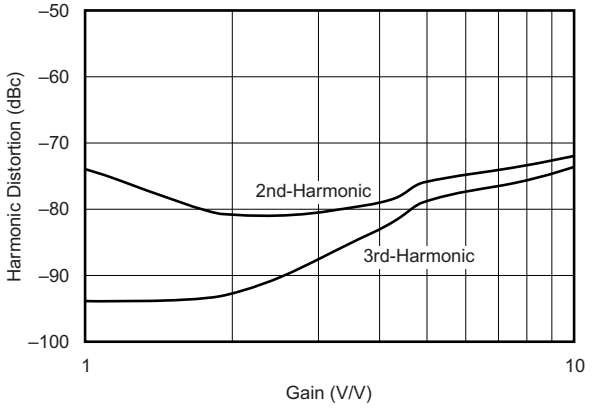
Typical Characteristics (continued)

T_A = 25°C, V_S = 5 V, G = 2, R_F = 604 Ω, and R_L = 150 Ω connected to V_S / 2, (unless otherwise noted)



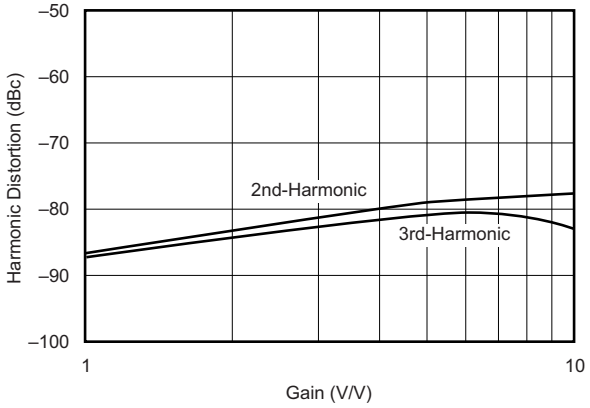
R_L = 200 f = 1 MHz

Figure 7. Harmonic Distortion vs Output Voltage



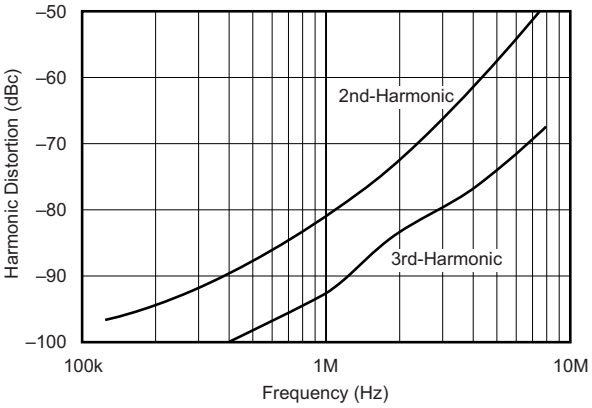
R_L = 200 V_O = 2 V_{P-P} f = 1 MHz

Figure 8. Harmonic Distortion vs Noninverting Gain



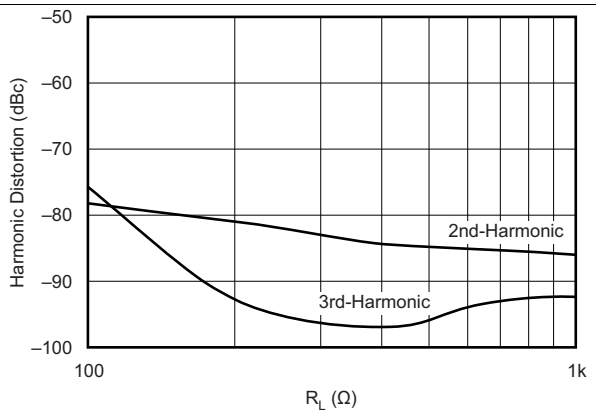
R_L = 200 V_O = 2 V_{P-P} f = 1 MHz

Figure 9. Harmonic Distortion vs Inverting Gain



R_L = 200 V_O = 2 V_{P-P}

Figure 10. Harmonic Distortion vs Frequency



f = 1 MHz V_O = 2 V_{P-P}

Figure 11. Harmonic Distortion vs Load Resistance

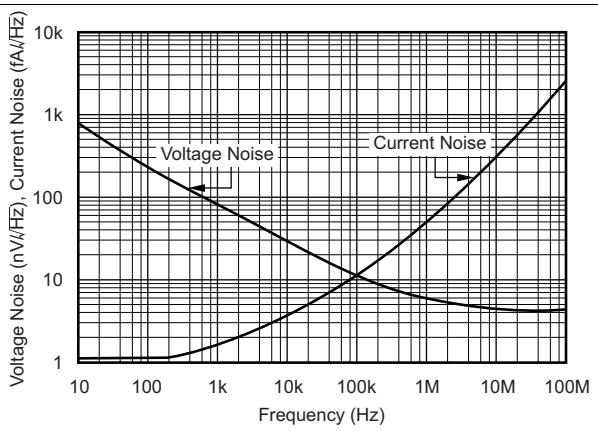
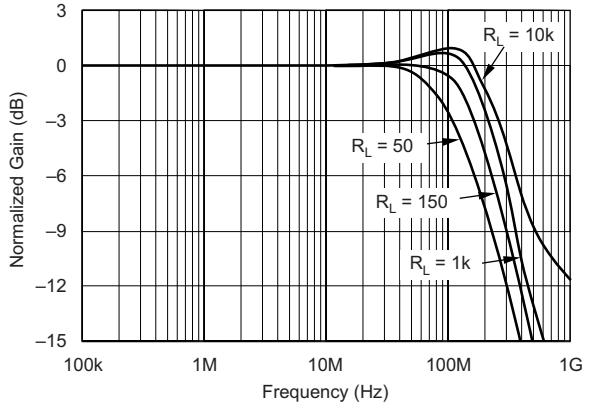


Figure 12. Input Voltage and Current Noise Spectral Density vs Frequency

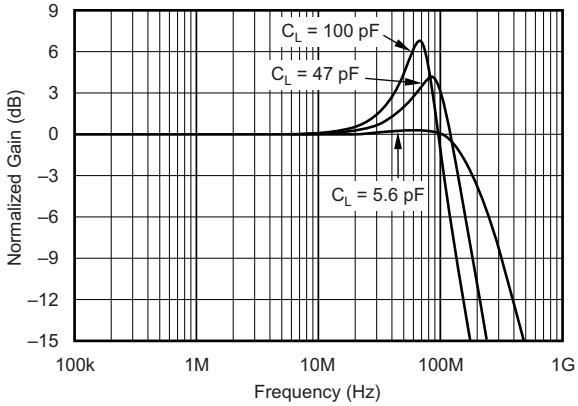
Typical Characteristics (continued)

T_A = 25°C, V_S = 5 V, G = 2, R_F = 604 Ω, and R_L = 150 Ω connected to V_S / 2, (unless otherwise noted)



C_L = 0 pF V_O = 0.1 V_{P-P}

Figure 13. Frequency Response for Various R_L Values



R_S = 0 V_O = 0.1 V_{P-P}

Figure 14. Frequency Response for Various C_L Values?

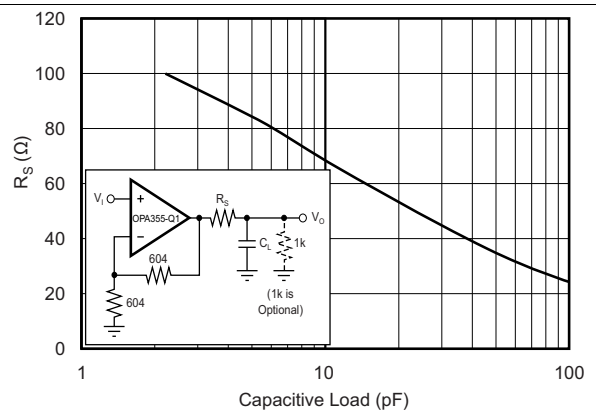


Figure 15. Recommended R_S Values vs Capacitive Load

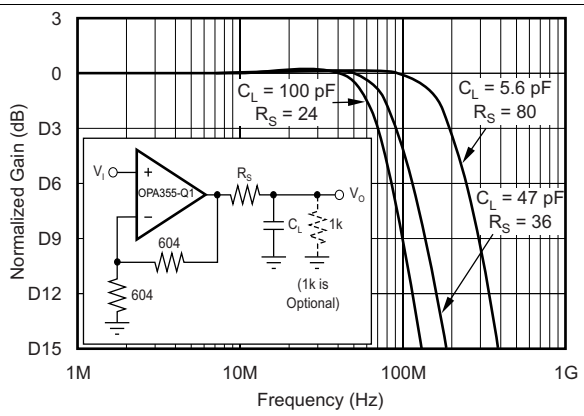


Figure 16. Frequency Response vs Capacitive Load

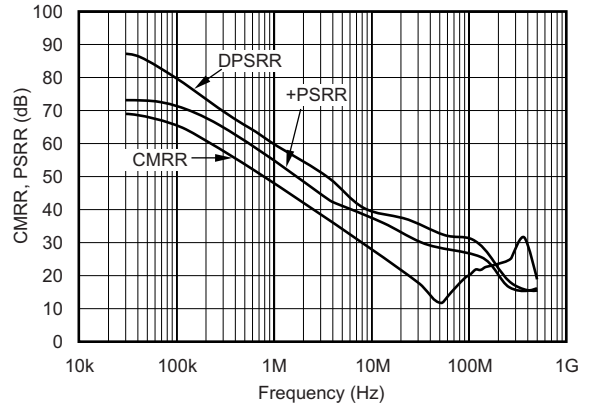


Figure 17. Common-Mode Rejection Ratio and Power-Supply Rejection Ratio vs Frequency

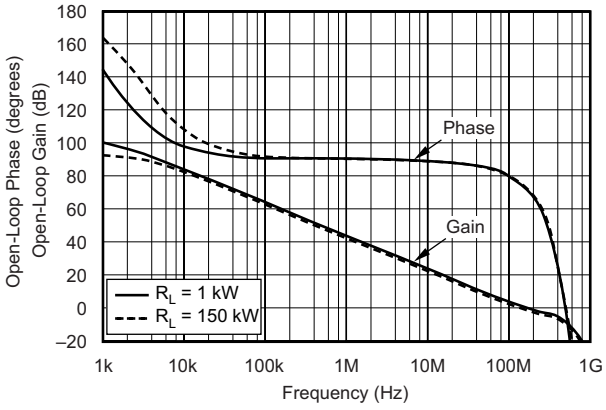


Figure 18. Open-Loop Gain and Phase

Typical Characteristics (continued)

T_A = 25°C, V_S = 5 V, G = 2, R_F = 604 Ω, and R_L = 150 Ω connected to V_S / 2, (unless otherwise noted)

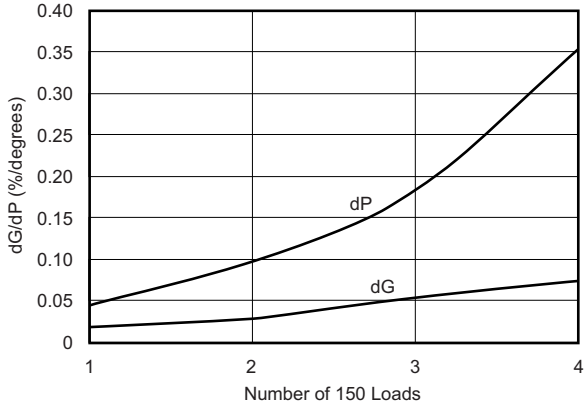


Figure 19. Composite Video Differential Gain and Phase

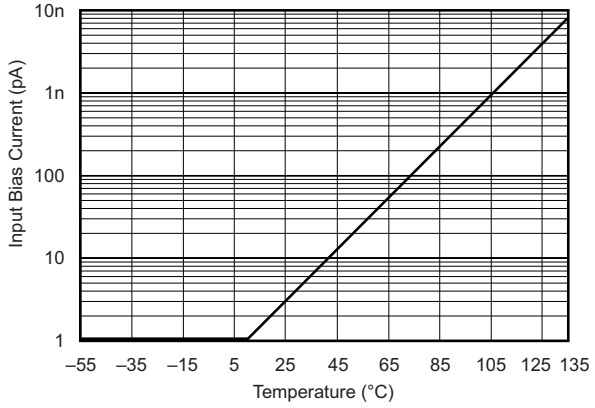
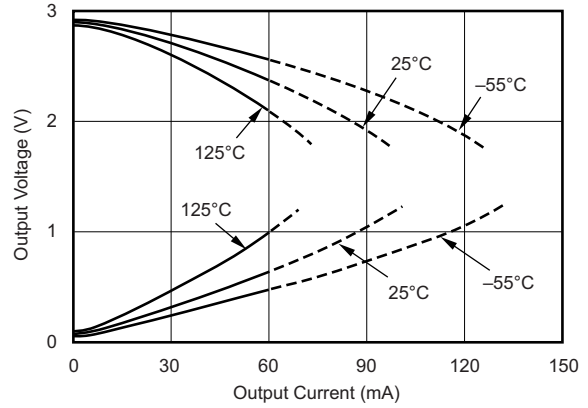


Figure 20. Input Bias Current vs Temperature



Continuous currents above 60 mA are not recommended

V_S = 3 V

Figure 21. Output Voltage Swing vs Output Current

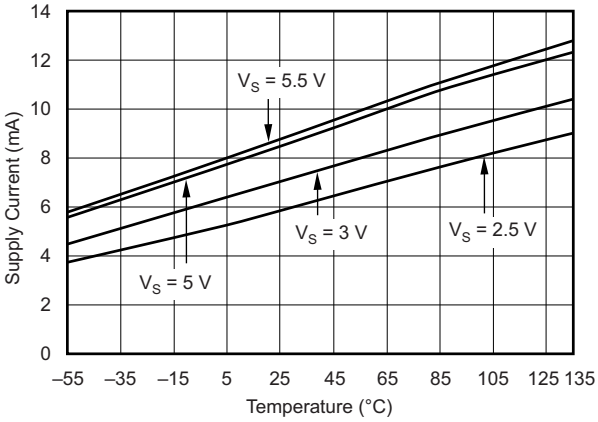
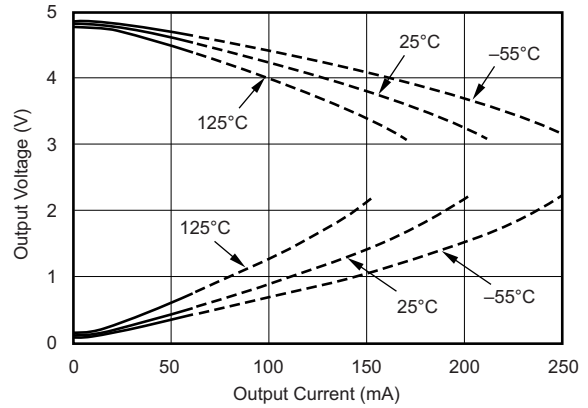


Figure 22. Supply Current vs Temperature



Continuous currents above 60 mA are not recommended

V_S = 5 V

Figure 23. Output Voltage Swing vs Output Current

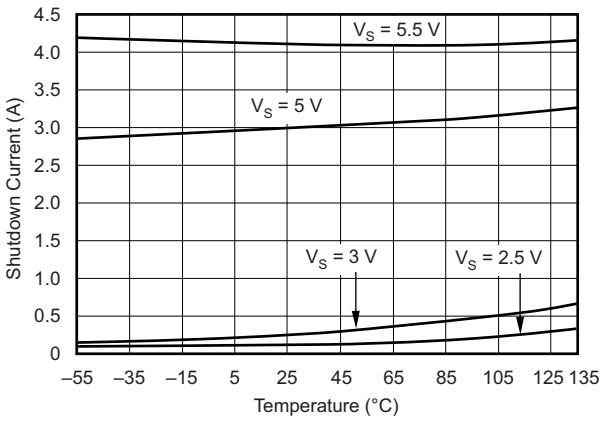


Figure 24. Shutdown Current vs Temperature

Typical Characteristics (continued)

T_A = 25°C, V_S = 5 V, G = 2, R_F = 604 Ω, and R_L = 150 Ω connected to V_S / 2, (unless otherwise noted)

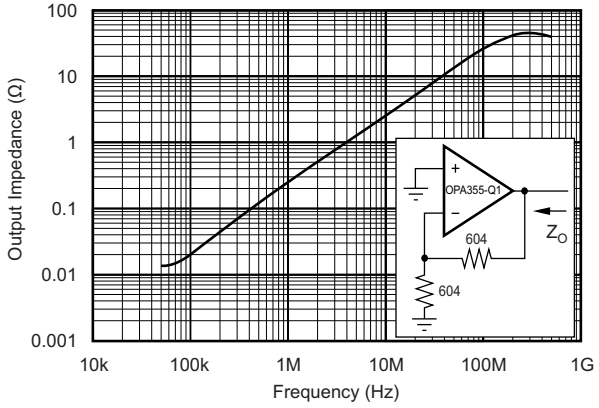
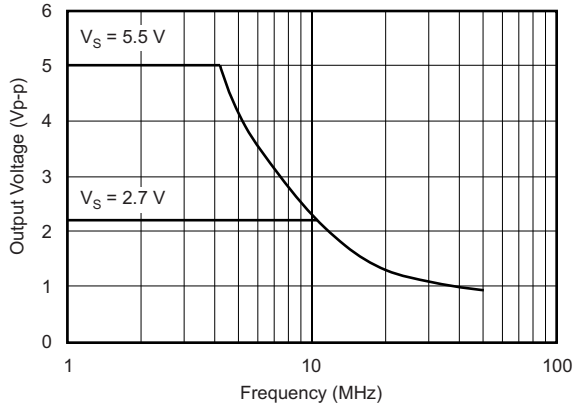
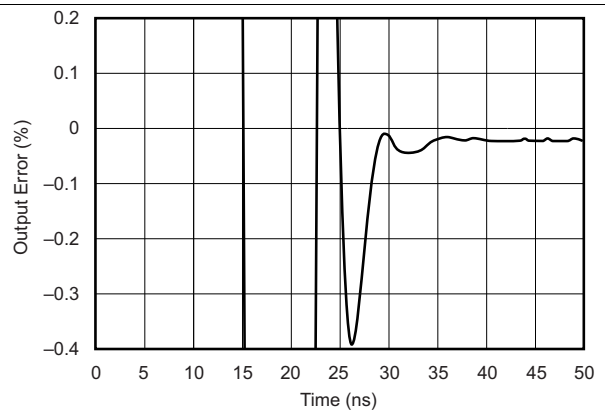


Figure 25. Closed-Loop Output Impedance vs Frequency



Maximum output voltage without slew-rate induced distortion

Figure 26. Maximum Output Voltage vs Frequency



V_O = 2 V_{P-P}

Figure 27. Output Settling Time to 0.1%

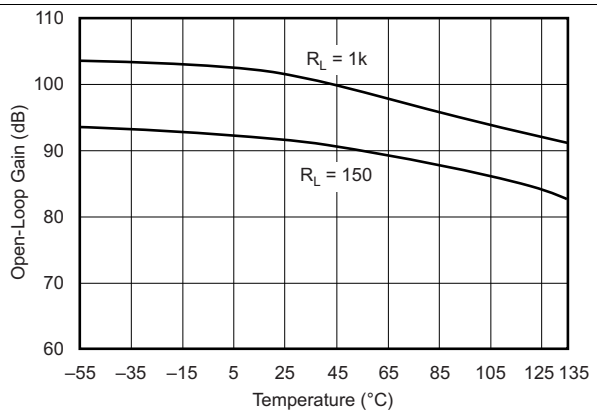


Figure 28. Open-Loop Gain vs Temperature

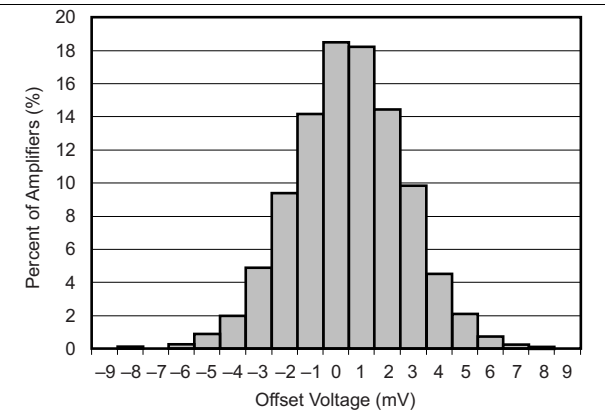


Figure 29. Offset Voltage Production Distribution

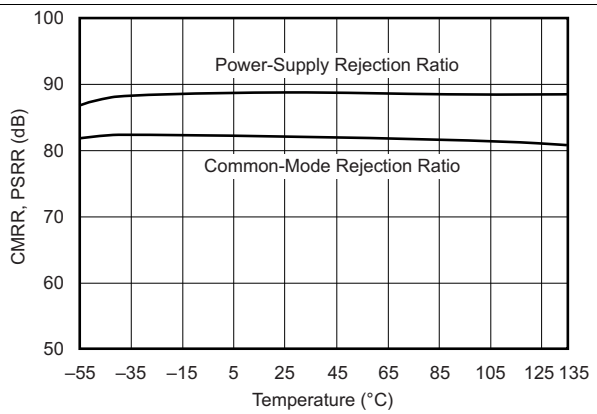


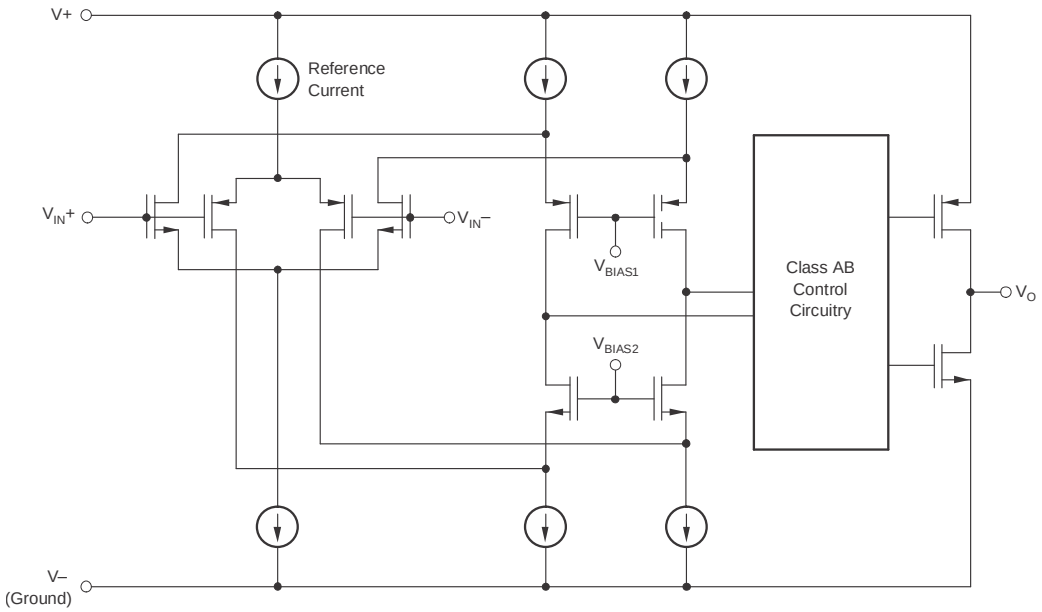
Figure 30. Common-Mode Rejection Ratio and Power-Supply Rejection Ratio vs Temperature

8 Detailed Description

8.1 Overview

The OPA355-Q1 operational amplifier is a high-speed, 300-V/μs, amplifier, making the device a great option for transimpedance applications. The device is unity-gain stable and can operate on a single-supply voltage (2.7 V to 5.5 V), or a split-supply voltage (±1.35 V to ±2.75 V), making the device highly versatile and simple to use. The OPA355-Q1 amplifier is specified from 2.7 V to 5.5 V and over the automotive temperature range of –40°C to +125°C.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Operating Voltage

The OPA355-Q1 device is specified over a power-supply range of 2.7 V to 5.5 V (±1.35 to ±2.75 V). However, the supply voltage ranges from 2.5 to 5.5 V (±1.25 to ±2.75 V). Supply voltages higher than 7.5 V (absolute maximum) can permanently damage the amplifier.

Parameters that vary significantly over supply voltage or temperature are shown in the Typical Characteristics section of this data sheet.

8.3.2 Enable Function

The OPA355-Q1 device is enabled by applying a TTL high-voltage level to the enable pin. Conversely, a TTL low -voltage level disables the amplifier, which reduces the supply current from 8.3 mA to 3.4 μA per amplifier. This pin voltage is referenced to a single-supply ground. When using a split-supply, such as ±2.5 V, the enable and disable voltage levels are referenced to V–. For portable battery-operated applications, this feature is used to greatly reduce the average current and as a result, extend battery life.

The enable input is modeled as a CMOS input gate with a 100-kΩ pullup resistor to V+. The enable pin assumes a logic high and the amplifier turns on if the enable pin is left open.

The enable time is 100 ns and the disable time is 30 ns, which allows the OPA355-Q1 device to operate as a *gated* amplifier, or to have the output multiplexed onto a common output bus. When disabled, the output assumes a high-impedance state.

Feature Description (continued)

8.3.3 Output Drive

The output stage supplies a high short-circuit current (typically over 200 mA). Therefore, an on-chip thermal shutdown circuit is provided to protect the OPA355-Q1 device from dangerously-high junction temperatures. At 160°C, the protection circuit shuts down the amplifier. Normal operation resumes when the junction temperature cools to below 140°C.

NOTE

Running a continuous DC current in excess of ±60 mA is not recommended. See the *Output Voltage Swing vs Output Current* graphs (Figure 21 and Figure 22) in the Typical Characteristics section.

8.4 Device Functional Modes

The OPA355-Q1 device is powered on when the supply is connected. The device can operate as a single supply operational amplifier or dual supply amplifier depending on the application. The device can also be used with asymmetrical supplies as long as the differential voltage (V– to V+) is at least 1.8 V and no greater than 5.5 V (example: V– set to –3.5 V and V+ set to 1.5 V).

9 Application and Implementation

9.1 Application Information

The OPA355-Q1 device is a CMOS, high-speed, voltage-feedback, operational amplifier (op-amp) designed for general-purpose applications.

The amplifier features a 200-MHz gain bandwidth and 300-V/μs slew rate, but the device is unity-gain stable and operates as a 1-V/V voltage follower.

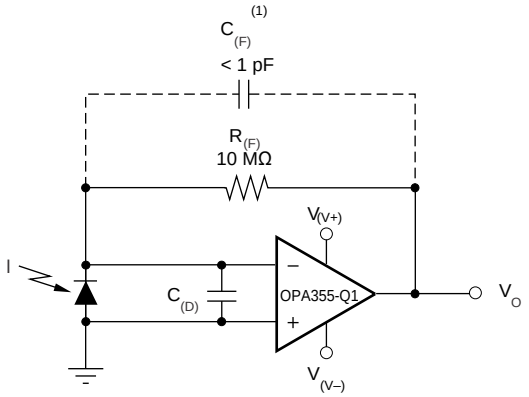
The input common-mode voltage range of the device includes ground, which allows the OPA355-Q1 to be used in virtually any single-supply application up to a supply voltage of 5.5 V.

9.2 Typical Applications

9.2.1 Transimpedance Amplifier

Wide gain bandwidth, low input bias current, low input voltage, and current noise make the OPA355-Q1 device a preferred wideband photodiode transimpedance amplifier. Low-voltage noise is important because photodiode capacitance causes the effective noise gain of the circuit to increase at high frequency.

The key elements to a transimpedance design, as shown in Figure 31, are the expected diode capacitance ($C_{(D)}$), which must include the parasitic input common-mode and differential-mode input capacitance (4 pF + 5 pF), the desired transimpedance gain ($R_{(FB)}$), and the gain-bandwidth (GBW) for the OPA355-Q1 device (20 MHz). With these three variables set, the feedback capacitor value ($C_{(FB)}$) is set to control the frequency response. $C_{(FB)}$ includes the stray capacitance of $R_{(FB)}$, which is 0.2 pF for a typical surface-mount resistor.



(1) $C_{(FB)}$ is optional to prevent gain peaking. $C_{(FB)}$ includes the stray capacitance of $R_{(FB)}$.

Figure 31. Dual-Supply Transimpedance Amplifier

9.2.1.1 Design Requirements

PARAMETER	VALUE
Supply voltage $V_{(V+)}$	2.5 V
Supply voltage $V_{(V–)}$	–2.5 V

9.2.1.2 Detailed Design Procedure

To achieve a maximally-flat, second-order Butterworth frequency response, the feedback pole must be set to:

$$\frac{1}{2 \times \pi \times R_{(FB)} \times C_{(FB)}} = \sqrt{\frac{GBW}{4 \times \pi \times R_{(FB)} \times C_{(D)}}} \quad (1)$$

Use Equation 2 to calculate the bandwidth.

$$f_{(-3\ dB)} = \sqrt{\frac{GBW}{2 \times \pi \times R_{(FB)} \times C_{(D)}}} \quad (2)$$

For other transimpedance bandwidths, consider the high-speed CMOS OPA380 (90-MHz GBW), OPA354 (100-MHz GBW), OPA300 (180-MHz GBW), OPA355 (200-MHz GBW), or OPA656 and OPA657 (400-MHz GBW).

For single-supply applications, the +INx input can be biased with a positive DC voltage to allow the output to reach true zero when the photodiode is not exposed to any light, and respond without the added delay that results from coming out of the negative rail; this configuration is shown in Figure 32. This bias voltage appears across the photodiode, providing a reverse bias for faster operation.

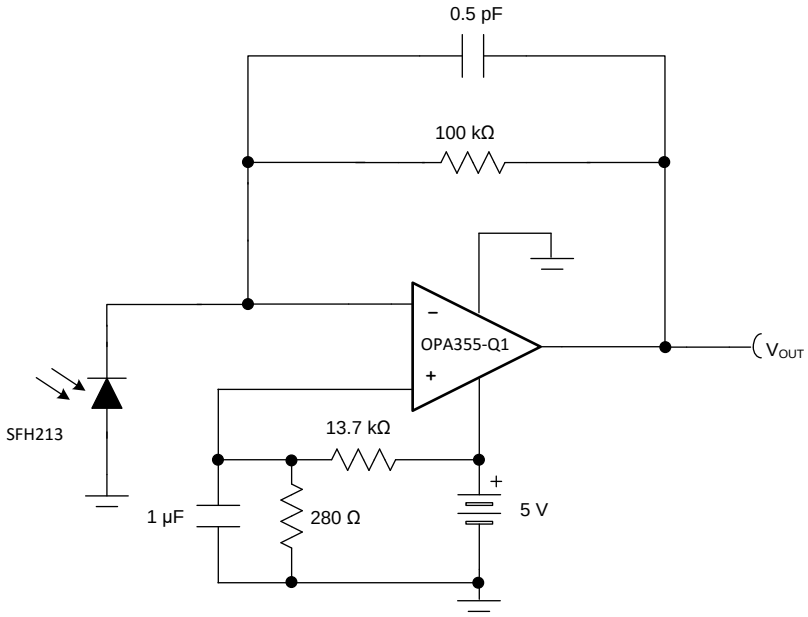


Figure 32. Single-Supply Transimpedance Amplifier

For additional information, see the *Compensate Transimpedance Amplifiers Intuitively* application bulletin.

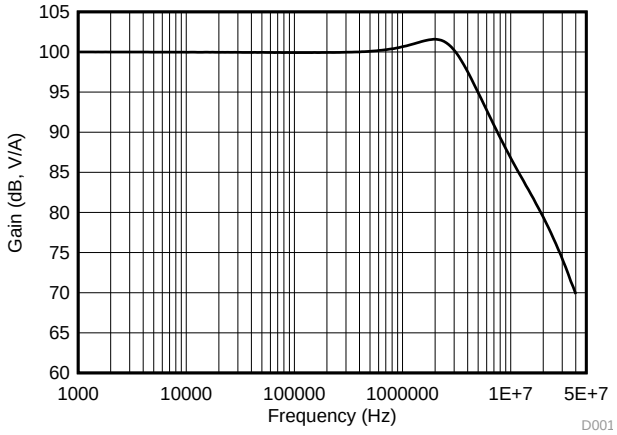
9.2.1.2.1 Optimizing The Transimpedance Circuit

To achieve the best performance, select components according to the following guidelines:

1. For lowest noise, select $R_{(FB)}$ to create the total required gain. Using a lower value for $R_{(FB)}$ and adding gain after the transimpedance amplifier generally produces poorer noise performance. The noise produced by $R_{(FB)}$ increases with the square-root of $R_{(FB)}$, whereas the signal increases linearly. Therefore, signal-to-noise ratio improves when all the required gain is placed in the transimpedance stage.
2. Minimize photodiode capacitance and stray capacitance at the summing junction (inverting input). This capacitance causes the voltage noise of the op amp to amplify (increasing amplification at high frequency). Using a low-noise voltage source to reverse-bias a photodiode can significantly reduce the capacitance. Smaller photodiodes have lower capacitance. Use optics to concentrate light on a small photodiode.
3. Noise increases with increased bandwidth. Limit the circuit bandwidth to only that required. Use a capacitor across the $R_{(FB)}$ to limit bandwidth, even if not required for stability.
4. Circuit board leakage can degrade the performance of an otherwise well-designed amplifier. Clean the circuit board carefully. A circuit board guard trace that encircles the summing junction and is driven at the same voltage can help control leakage.

For additional information, see the *Noise Analysis of FET Transimpedance Amplifiers* and *Noise Analysis for High-Speed Op Amps* application bulletins).

9.2.1.3 Application Curve



–3 dB bandwidth is 4.56 MHz

Figure 33. AC Transfer Function

9.2.2 High-Impedance Sensor Interface

Many sensors have high source impedances that may range up to 10 MΩ, or even higher. The output signal of sensors often must be amplified or otherwise conditioned by means of an amplifier. The input bias current of this amplifier can load the sensor output and cause a voltage drop across the source resistance, as shown in Figure 34, where ($V_{(+INx)} = V_S – I_{(BIAS)} \times R_{(S)}$). The last term, $I_{(BIAS)} \times R_{(S)}$, shows the voltage drop across $R_{(S)}$. To prevent errors introduced to the system as a result of this voltage, an op amp with very low input bias current must be used with high impedance sensors. This low current keeps the error contribution by $I_{(BIAS)} \times R_{(S)}$ less than the input voltage noise of the amplifier, so that it does not become the dominant noise factor. The OPA355-Q1 op amp features very low input bias current (typically 200 fA), and is therefore a preferred choice for such applications.

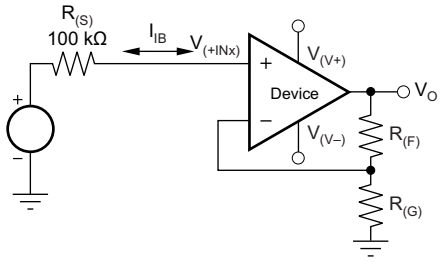
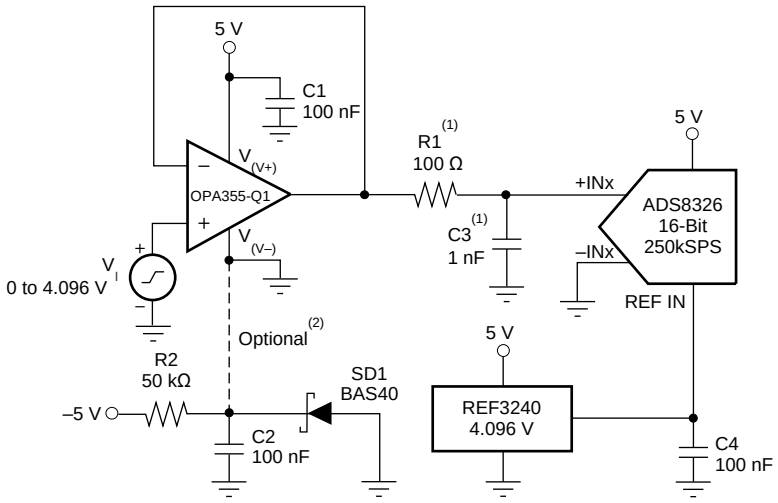


Figure 34. Noise as a Result of $I_{(BIAS)}$

9.2.3 Driving ADCs

The OPA355-Q1 op amps are designed for driving sampling analog-to-digital converters (ADCs) with sampling speeds up to 1 MSPS. The zero-crossover distortion input stage topology allows the OPA355-Q1 device to drive ADCs without degradation of differential linearity and THD.

The OPA355-Q1 device can be used to buffer the ADC switched input capacitance and resulting charge injection while providing signal gain. Figure 35 shows the OPA355-Q1 device configured to drive the ADS8326.



(1) Suggested value; may require adjustment based on specific application.

(2) Single-supply applications lose a small number of ADC codes near ground as a result of op amp output swing limitation. If a negative power supply is available, this simple circuit creates a –0.3-V supply to allow output swing to true ground potential.

Figure 35. Driving the ADS8326

9.2.4 Active Filter

The OPA355-Q1 device is designed for active filter applications that require a wide bandwidth, fast slew rate, low-noise, single-supply operational amplifier. Figure 36 shows a 500 kHz, second-order, low-pass filter using the multiple-feedback (MFB) topology. The components are selected to provide a maximally-flat Butterworth response. Beyond the cutoff frequency, roll-off is –40 dB/dec. The Butterworth response is preferred for applications requiring predictable gain characteristics, such as the anti-aliasing filter used in front of an ADC.

One point to observe when considering the MFB filter is that the output is inverted, relative to the input. If this inversion is not required, or not desired, a noninverting output can be achieved through one of the following options:

1. Adding an inverting amplifier
2. Adding an additional second-order MFB stage
3. Using a noninverting filter topology, such as the Sallen-Key (see Figure 37).

MFB and Sallen-Key, low-pass and high-pass filter synthesis is quickly accomplished using TI's FilterPro™ program. This software is available as a free download at www.ti.com.

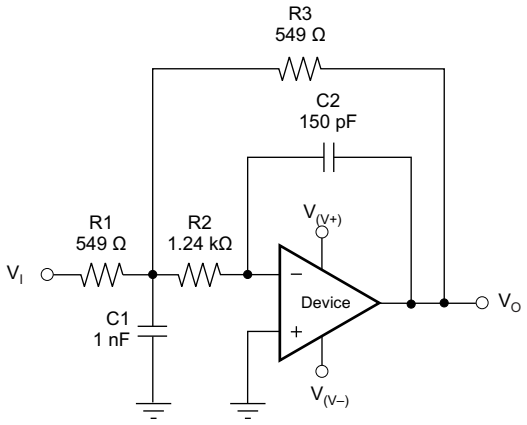


Figure 36. Second-Order Butterworth 500-kHz Low-Pass Filter

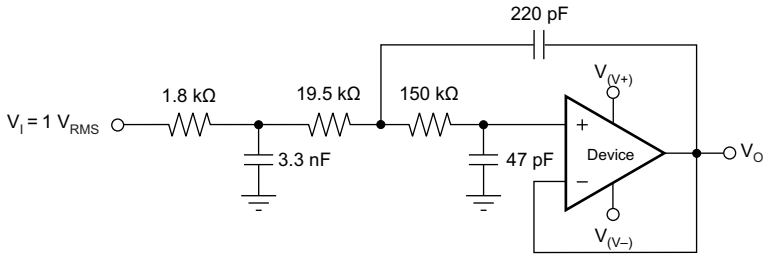


Figure 37. OPA355-Q1 Configured as a Three-Pole, 20-kHz, Sallen-Key Filter

10 Power Supply Recommendations

The OPA355-Q1 device is specified for operation from 2.7 to 5.5 V (±1.35 to ±2.75 V); many specifications apply from –40°C to +125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are shown in the *Typical Characteristics* section.

Place 0.1-μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see the *Layout Guidelines* section.

Power dissipation depends on power-supply voltage, signal and load conditions. With DC signals, power dissipation is equal to the product of output current times the voltage across the conducting output transistor, VS – VO. Minimize power dissipation by using the lowest possible power-supply voltage required to ensure the required output voltage swing.

For resistive loads, the maximum power dissipation occurs at a DC output voltage of one-half the power-supply voltage. Dissipation with AC signals is lower. Application bulletin AB-039, *Power Amplifier Stress and Power Handling Limitations* explains how to calculate or measure power dissipation with unusual signals and loads, and is available on www.ti.com.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heat sink. For reliable operation, limit junction temperature to 150°C maximum. To estimate the margin of safety in a complete design, increase the ambient temperature to trigger the thermal protection at 160°C. The thermal protection must trigger more than 35°C above the maximum expected ambient condition of the application.

11 Layout

11.1 Layout Guidelines

Good high-frequency printed-circuit board (PCB) layout techniques must be used for the OPA355-Q1. Generous use of ground planes, short direct-signal traces, and a preferred bypass capacitor located at the V+ pin ensures clean and stable operation. Large areas of copper help dissipate heat generated within the amplifier in normal operation.

Sockets are not recommended for use with any high-speed amplifier.

A 10-nF ceramic bypass capacitor is the minimum recommended value; adding a 1-μF or larger tantalum capacitor in parallel is beneficial when driving a low-resistance load. Providing adequate bypass capacitance is essential to achieving very low harmonic and intermodulation distortion.

11.2 Layout Example

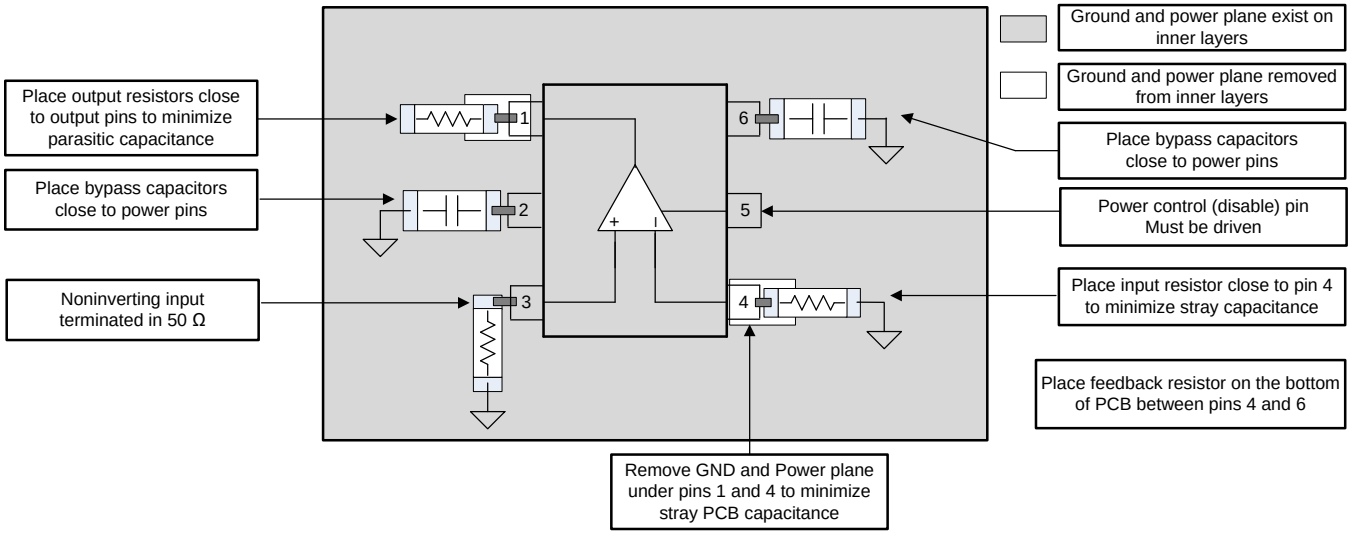


Figure 38. Layout Example

12 Device and Documentation Support

12.1 Trademarks

FilterPro is a trademark of Texas Instruments Incorporated.
All other trademarks are the property of their respective owners.

12.2 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.3 Glossary

SLYZ022 — *TI Glossary*.

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

13 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/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
OPA355QDBVRQ1	ACTIVE	SOT-23	DBV	6	3000	Green (RoHS & no Sb/Br)	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	SLN	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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

OTHER QUALIFIED VERSIONS OF OPA355-Q1 :

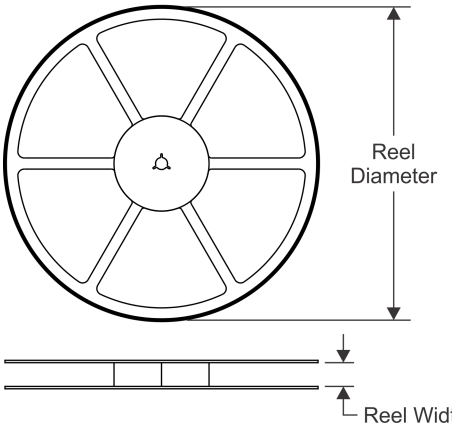
- Catalog: OPA355

NOTE: Qualified Version Definitions:

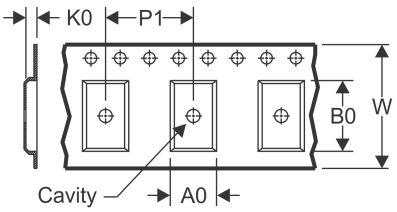
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

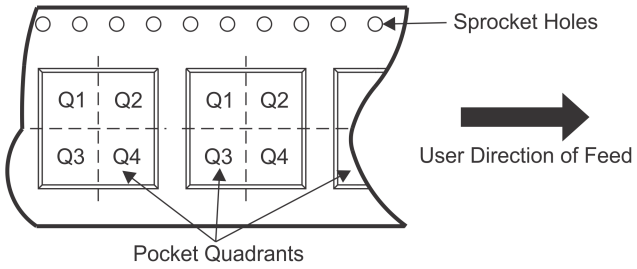


TAPE DIMENSIONS



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

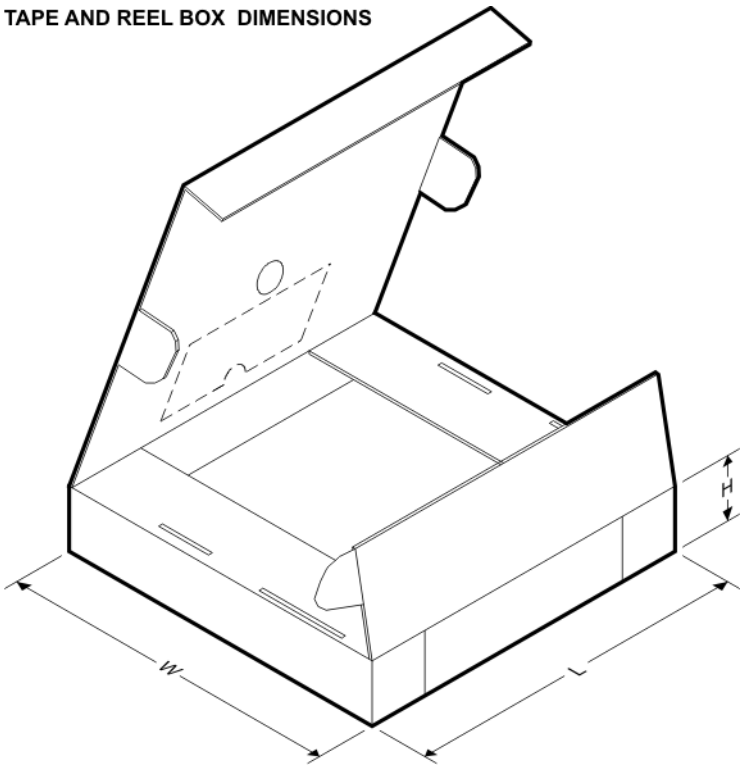
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
OPA355QDBVRQ1	SOT-23	DBV	6	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

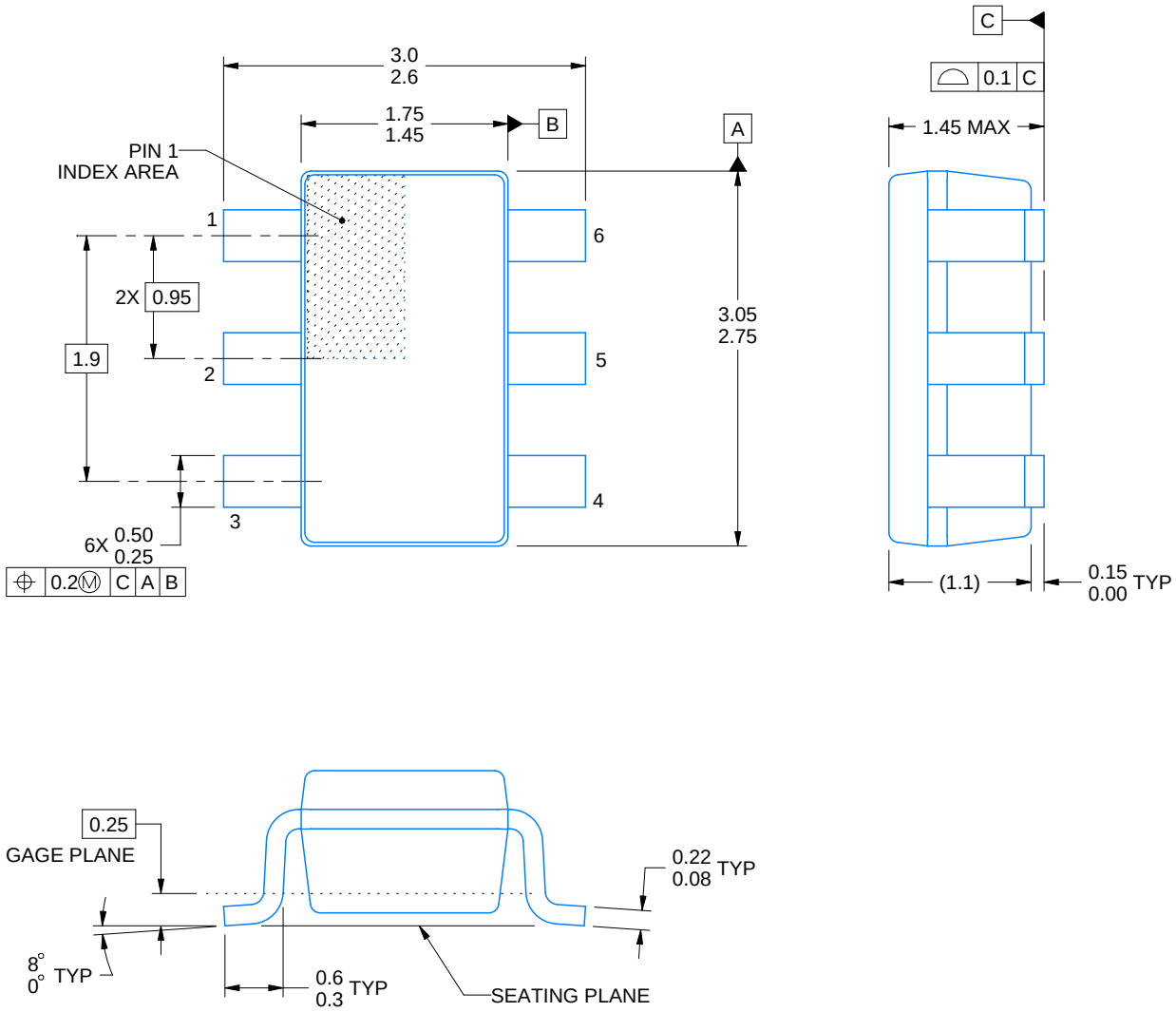
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA355QDBVRQ1	SOT-23	DBV	6	3000	445.0	220.0	345.0

PACKAGE OUTLINE

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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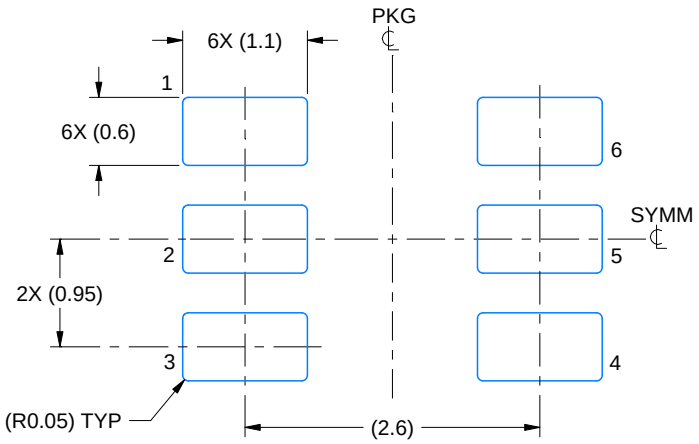
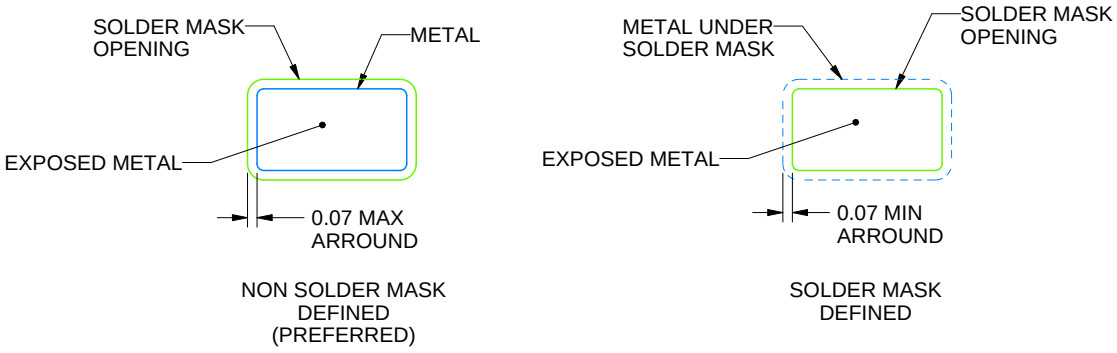
NOTES:

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. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Refernce JEDEC MO-178.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

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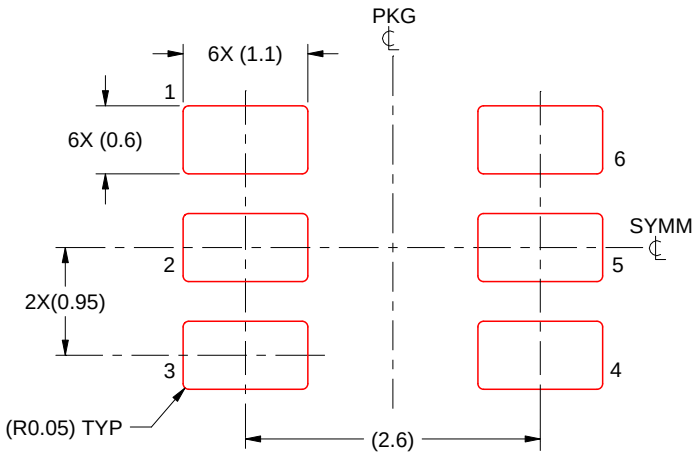
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214840/B 03/2018

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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