

## *Power Operational Amplifiers*



### FEATURES

- Low Cost
- Wide Bandwidth - 1.1 MHz
- High Output Current - 1.5A per Amplifier
- Wide Common Mode Range Includes negative supply
- Wide Supply Voltage Range Single supply: 5V to 40V Split supplies:  $\pm 2.5V$  to  $\pm 20V$
- Low Quiescent Current
- Very Low Distortion



### APPLICATIONS

- Half and Full Bridge Motor Drivers
- Audio Power Amplifier
  - Stereo- 11.3W RMS per amplifier
  - Bridge- 22.6W RMS per two amplifiers
  - Two Bridges- 45.2W RMS per package
- 3 Phase Motor Driver
  - 3 Channels- 33.9W RMS per package
- Ideal For Single Supply Systems
  - 5V - Peripherals
  - 12V- Automotive
  - 28V- Avionic
- Packaging Options
  - 20-Pin PSOP, JEDEC MO-166-AB (PA162DK)

### DESCRIPTION

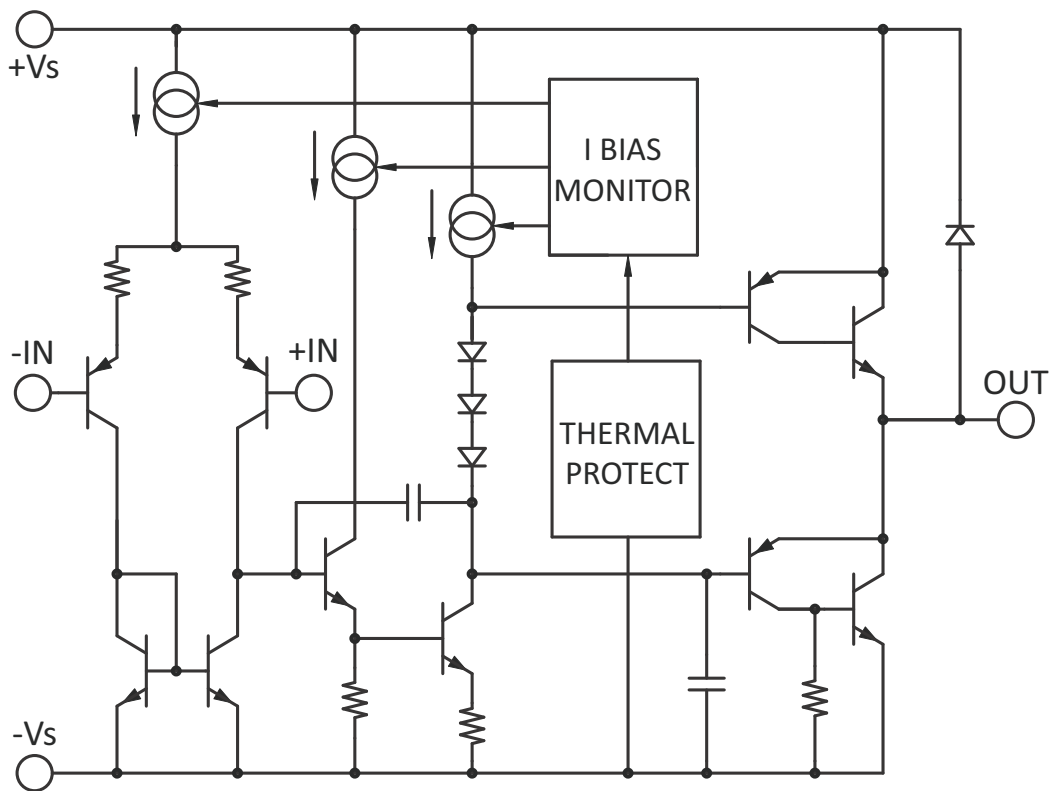
The amplifier design is a dual power op amp on a single monolithic die. The quad output PA162 combines two dual op amp die in a single PSOP package. This approach provides a cost-effective solution to applications where multiple amplifiers are required or a bridge configuration is needed. Four independent amplifiers coupled with low quiescent current and very low THD makes this an ideal low-distortion 4-channel audio amplifier for applications such as laptops and computer speakers.

The quad output PA162DK is available in a surface mount 20-pin PSOP, JEDEC MO-166-AB package. Built-in thermal shutdown allows the devices to self-protect against thermal overloads. Care must be exercised to observe the Safe Operating Area (SOA) curve and proper heatsinking will ensure maximum reliability.

The wide common mode input range includes the negative rail, facilitating single supply applications. This makes it possible to have a ground-based input driving a single supply amplifier with ground acting as the second or bottom supply of the amplifier.

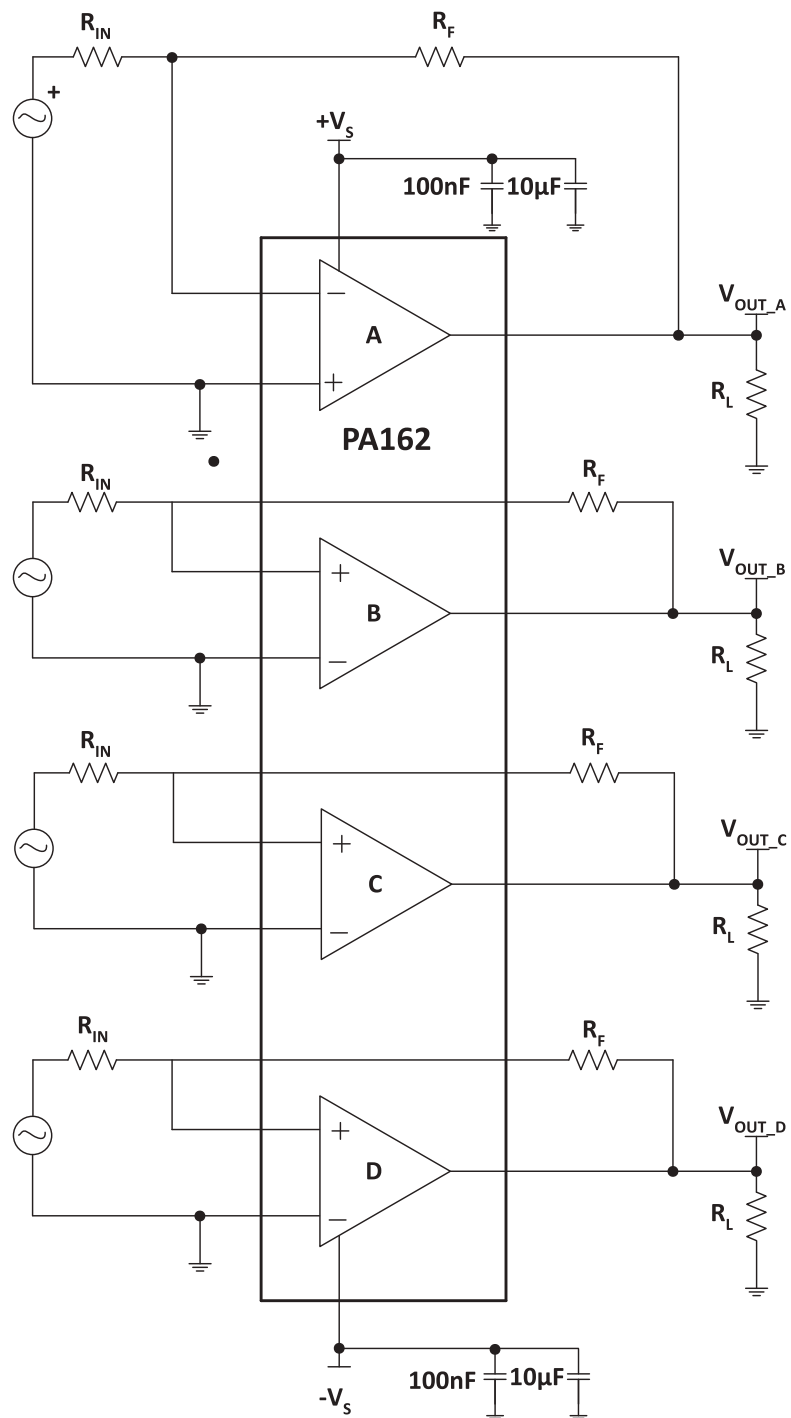
Figure 1: Equivalent Schematic

## Single Channel



## TYPICAL CONNECTION

Figure 2: Typical Connection



## PINOUT AND DESCRIPTION TABLE

Figure 3: External Connections

TOP VIEW		
1	NC	-V <sub>s</sub>
2	-IN <sub>A</sub>	OUT <sub>A</sub>
3	+IN <sub>A</sub>	+V <sub>s_A/B</sub>
4	+IN <sub>B</sub>	OUT <sub>B</sub>
5	-IN <sub>B</sub>	-V <sub>s</sub>
6	-IN <sub>C</sub>	-V <sub>s</sub>
7	+IN <sub>C</sub>	OUT <sub>C</sub>
8	+IN <sub>D</sub>	+V <sub>s_C/D</sub>
9	-IN <sub>D</sub>	OUT <sub>D</sub>
10	NC	-V <sub>s</sub>

Pin Number	Name	Description
2	-IN <sub>A</sub>	The inverting input for channel A.
3	+IN <sub>A</sub>	The non-inverting input for channel A.
4	+IN <sub>B</sub>	The non-inverting input for channel B.
5	-IN <sub>B</sub>	The inverting input for channel B.
6	-IN <sub>C</sub>	The inverting input for channel C.
7	+IN <sub>C</sub>	The non-inverting input for channel C.
8	+IN <sub>D</sub>	The non-inverting input for channel D.
9	-IN <sub>D</sub>	The inverting input for channel D.
12	OUT <sub>D</sub>	The output for channel D. Connect to load and to the feedback resistors.
13	+V <sub>s_CD</sub>	The positive supply rail for channels C and D.
14	OUT <sub>C</sub>	The output for channel C. Connect to load and to the feedback resistors.
17	OUT <sub>B</sub>	The output for channel B. Connect to load and to the feedback resistors.
18	+V <sub>s_AB</sub>	The positive supply rail for channels A and B.
19	OUT <sub>A</sub>	The output for channel A. Connect to load and to the feedback resistors.
1, 10	NC	No Connection
11, 15, 16, 20	-V <sub>s</sub>	The negative supply rail for all four channels.

## SPECIFICATIONS (PER AMPLIFIER)

All Min/Max characteristics and specifications are guaranteed over the Specified Operating Conditions. Typical performance characteristics and specifications are derived from measurements taken at typical supply voltages and  $T_C = 25^\circ\text{C}$ . Long term operation at the maximum junction temperature will result in reduced product life. Derate power dissipation to achieve high MTTF. Unless otherwise noted, the following conditions apply:  $\pm V_S = \pm 15\text{V}$ ,  $T_C = 25^\circ\text{C}$ . If  $-V_S$  is disconnected before  $+V_S$ , a diode between  $-V_S$  and ground is recommended to avoid damage.

### ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Min	Max	Units
Supply Voltage, total	$+V_S$ to $-V_S$	5	40	V
Output Current	$I_O$	SOA		
Power Dissipation, internal (1 Amplifier)	$P_D$		15	W
Power Dissipation, internal (2 Amplifiers) <sup>1</sup>	$P_D$		24	W
Power Dissipation, internal (3 Amplifiers) <sup>1</sup>	$P_D$		36	W
Power Dissipation, internal (4 Amplifiers) <sup>1</sup>	$P_D$		45	W
Input Voltage, differential	$V_{IN}(\text{Diff})$	$-V_S$	$+V_S$	V
Input Voltage, common mode	$V_{cm}$	$+V_S$	$-V_S - 0.5\text{ V}$	V
Junction Temperature, max <sup>2</sup>	$T_J$		150	$^\circ\text{C}$
Temperature, pin solder, 10s max.			220	$^\circ\text{C}$
Temperature Range, storage		-55	+150	$^\circ\text{C}$
Operating Temperature Range, case <sup>2</sup>	$T_C$	-40	+125	$^\circ\text{C}$

1. Rating applies when power dissipation is equal in each of the amplifiers. Power and thermal ratings are based on two separate dual monolithic power op-amps on one integrated copper heatslug. Amplifiers A and B are combined on one monolithic die while amplifiers C and D are on the other.
2. Long term operation at the maximum junction temperature will result in reduced product life. Derate power dissipation to achieve high MTTF.

### INPUT

Parameter	Test Conditions	Min	Typ	Max	Units
Offset Voltage, initial			1	15	mV
Offset Voltage vs. Temperature	Full temp range		20		$\mu\text{V}/^\circ\text{C}$
Bias Current, initial			100	500	nA
Common Mode Voltage Range	Full temp range	$-V_S$		$+V_S$	V
Common Mode Rejection, DC		60	90		dB
Power Supply Rejection	Full temp range	60	90		dB
Channel Separation	$I_{OUT} = 500\text{mA}$ , $f = 1\text{ kHz}$	50	68		dB
Input Noise Voltage	$R_S = 100\ \Omega$ , $f = 1\text{ to }100\text{ kHz}$		22		nV/ $\sqrt{\text{Hz}}$

**GAIN**

Parameter	Test Conditions	Min	Typ	Max	Units
Open Loop Gain	$V_O = \pm 10V$ , $R_L = 2\text{ k}\Omega$	89	100		dB
Gain Bandwidth Product	$f = 100\text{ kHz}$ , $C_L = 100\text{ pF}$ , $R_L = 2\text{ k}\Omega$		0.9	1.4	MHz
Phase Margin	Full temp range		65		°
Power Bandwidth	$V_O(\text{P-P}) = 28V$		13.6		kHz

**OUTPUT**

Parameter	Test Conditions	Min	Typ	Max	Units
Current, peak				1.5	A
Current, continuous				1	A
Slew Rate		1.0	1.4		V/ $\mu\text{s}$
Voltage Swing	Full temp range, $I_O = 100\text{ mA}$	$ V_S  - 1.1$	$ V_S  - 0.8$		V
Voltage Swing	Full temp range, $I_O = 1\text{ A}$	$ V_S  - 1.8$	$ V_S  - 1.4$		V
Harmonic Distortion	$A_V = 1$ , $R_L = 50\text{ }\Omega$ , $V_O = 0.5V_{\text{RMS}}$ , $f = 1\text{ kHz}$		0.02		%

**POWER SUPPLY**

Parameter	Test Conditions	Min	Typ	Max	Units
Voltage, $V_{SS}^1$		5	30	40	V
Current, quiescent $+V_S$ (A/B)			8	10	mA
Current, quiescent $+V_S$ (C/D)			8	10	mA
Current, quiescent, total			16	20	mA

1.  $+V_S$  and  $-V_S$  denote the positive and negative rail respectively.  $V_{SS}$  denotes total rail-to-rail supply.

**THERMAL**

Parameter	Test Conditions	Min	Typ	Max	Units
Resistance, junction to case					
DC, 1 Amplifier			7.16	7.87	°C/W
DC, 2 Amplifiers <sup>1</sup>			4.69	5.16	°C/W
DC, 3 Amplifiers <sup>1</sup>			3.08	3.39	°C/W
DC, 4 Amplifiers <sup>1</sup>			2.51	2.77	°C/W
AC, 1 Amplifier			5.37	5.90	°C/W
AC, 2 Amplifiers <sup>1</sup>			3.52	3.87	°C/W
AC, 3 Amplifiers <sup>1</sup>			2.31	2.54	°C/W
AC, 4 Amplifiers <sup>1</sup>			1.89	2.07	°C/W
Resistance, junction to air <sup>2</sup>			25		°C/W

1. Rating applies when power dissipation is equal in each of the amplifiers. Power and thermal ratings are based on two separate dual monolithic power op-amps on one integrated copper heatslug. Amplifiers A and B are combined on one monolithic die while amplifiers C and D are on the other.
2. Rating applies when the heatslug of the DK package is soldered to a minimum of 1 square inch foil area of a printed circuit board.

## TYPICAL PERFORMANCE GRAPHS

Figure 4: Quiescent Current

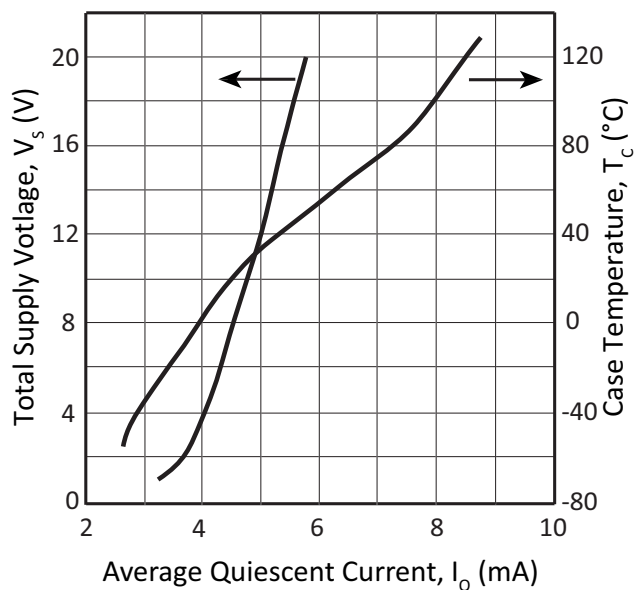


Figure 5: Bias Current

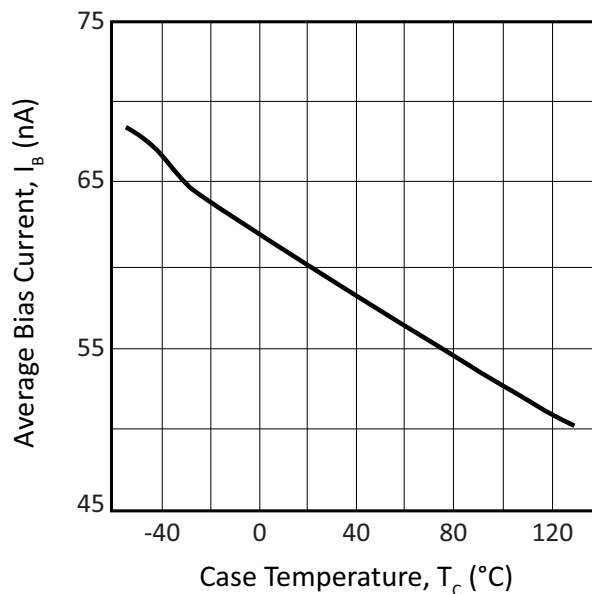
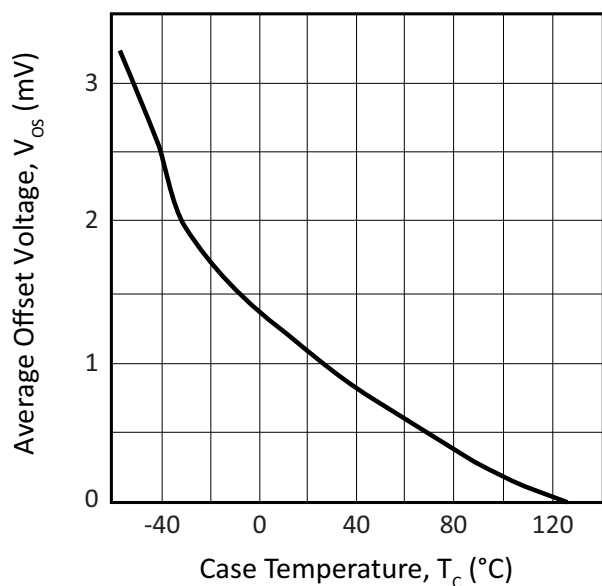
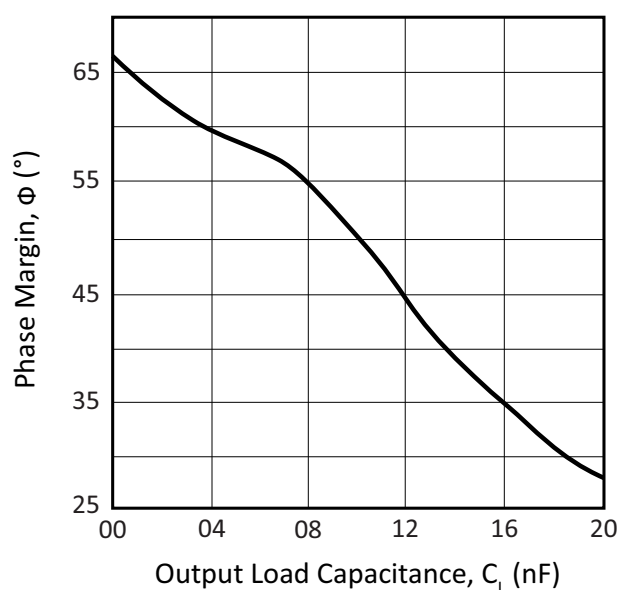
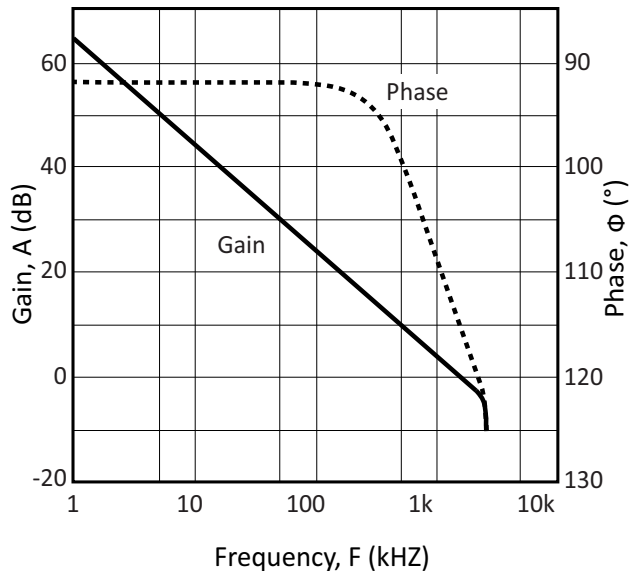
Figure 6:  $V_{OS}$ 

Figure 7: Phase Margin vs. Output Load Capacitance

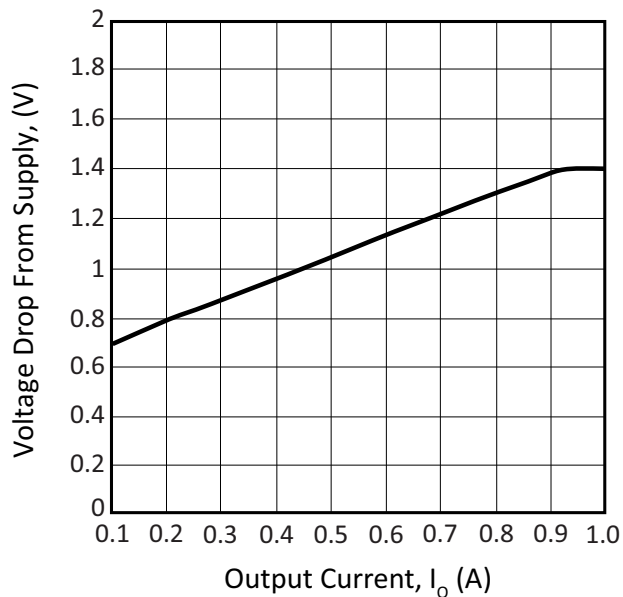




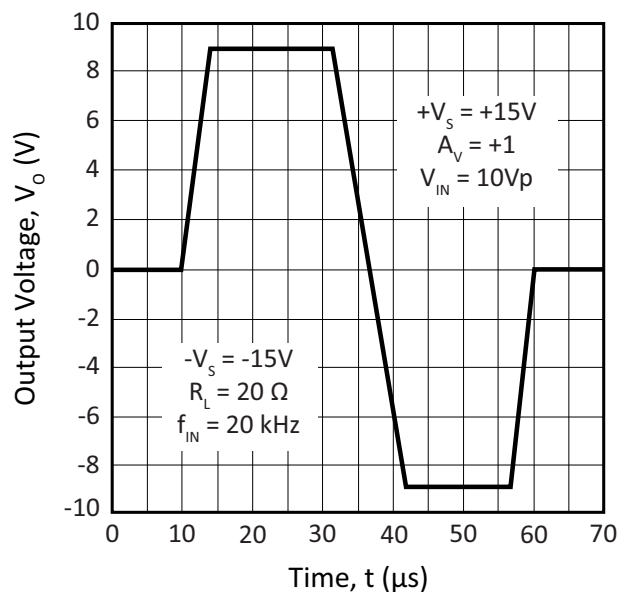
**Figure 8: Voltage Gain & Phase vs. Frequency**



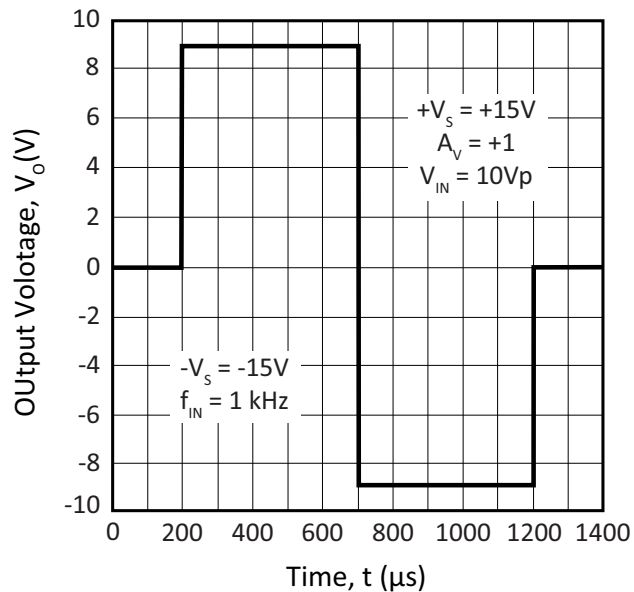
**Figure 9: Output Voltage Swing**



**Figure 10: Pulse Response**



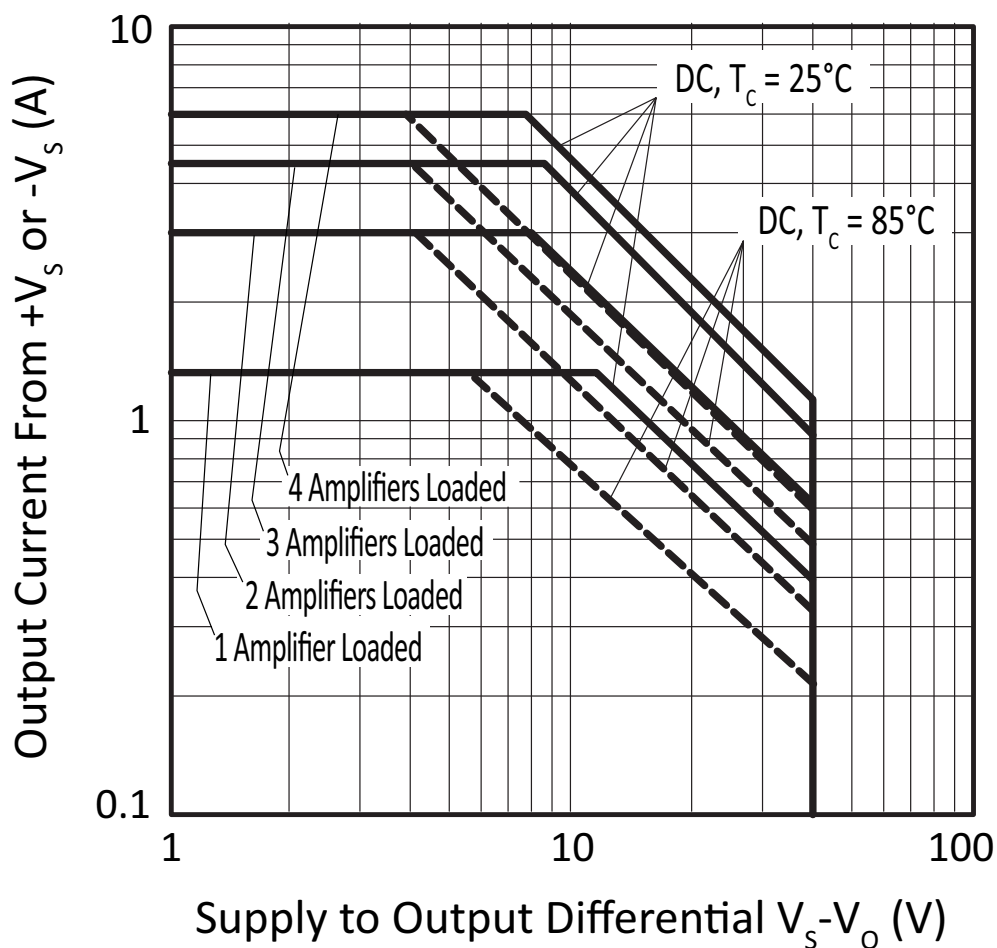
**Figure 11: Pulse Response**



## SAFE OPERATING AREA (SOA)

The SOA curves combine the effect of all limits for this power op amp. For a given application, the direction and magnitude of the output current should be calculated or measured and checked against the SOA curves. This is simple for resistive loads but more complex for reactive and EMF generating loads. The following guidelines may save extensive analytical efforts.

Figure 12: SOA



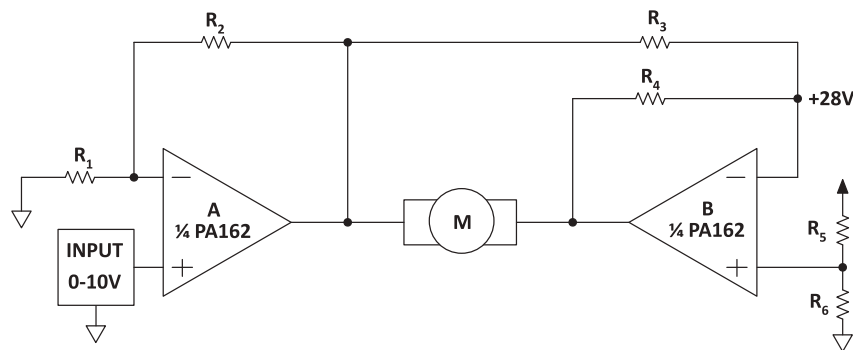
## GENERAL

Please read Application Note 1 “General Operating Considerations” which covers stability, supplies, heat sinking, mounting, current limit, SOA interpretation, and specification interpretation. Visit [www.apexanalog.com](http://www.apexanalog.com) for Apex Microtechnology’s complete Application Notes library, Technical Seminar Workbook, and Evaluation Kits.

## TYPICAL APPLICATION

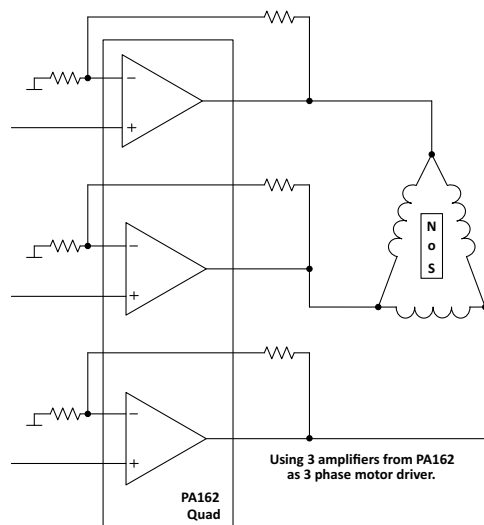
R1 and R2 set up Amplifier A as non-inverting. Amplifier B is set up as a unity gain inverter driven from the output of Amplifier A. Note that Amplifier B inverts the signals about the reference node, which is set at mid-supply by R5 and R6. When the command input is midrange, so is the output of Amplifier A. Since this is also equivalent to the reference node voltage, the output of Amplifier B is the same resulting in 0V across the motor. Inputs more positive than 5V result in motor current flow from left to right (see Figure 13). Inputs less than 5V drive the motor in the opposite direction.

**Figure 13: Bi-Directional Speed Control from a Single Supply**



The amplifiers are especially well-suited for applications such as this. The extended common mode range allows command inputs as low as 0V. The output swing lets it drive within 2V of the supply at an output of 1A. This means that a command input that ranges from 0 to 10V will drive a 24V motor from full scale CCW to full scale CW at  $\pm 1$  A. -Vs (pins 11, 15, 16 and 20) must be tied to the heatslug externally on the PCB. To ease metal routing on the PCB, run a direct trace from the -Vs pin to the center heat slug. The PA162 can be used in a three amplifier configuration for a three phase inverter or motor as shown in Figure 14.

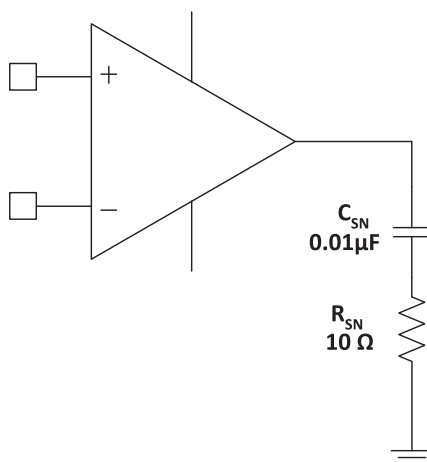
Figure 14: 3 Phase Inverter



## STABILITY CONSIDERATIONS

All monolithic power op amps use output stage topologies that present special stability problems. This is primarily due to non-complementary (both devices are NPN) output stages with a mismatch in gain and phase response for different polarities of output current. It is difficult for the op amp manufacturer to optimize compensation for all operating conditions. For applications with load current exceeding 300mA, oscillation may appear. The oscillation may occur only with the output voltage swing at the negative or positive half cycle. Under most operating and load conditions acceptable stability can be achieved by providing a series RC snubber network connected from the output to ground (see Figure 15). The recommended component values of the network are,  $R_{SN} = 10\ \Omega$  and  $C_{SN} = 0.01\ \mu\text{F}$ . Please refer to Application Note 1 for further details.

Figure 15: Stability



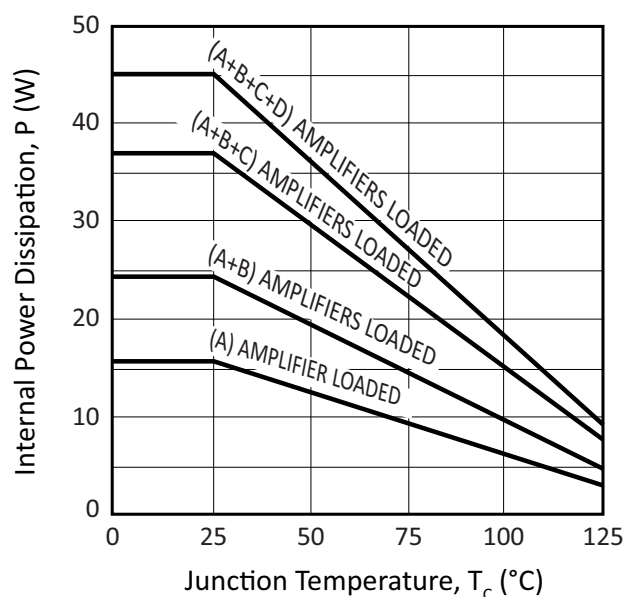
## THERMAL CONSIDERATIONS

The PA162DK has a large exposed integrated copper heatslug to which the monolithic is directly attached. The solder connection of the heatslug to a minimum of 1 square inch foil area of the printed circuit board will result in thermal performance of 25°C/W junction to air rating of the PA162DK. Solder connection to an area of 1 to 2 square inches of foil is required for minimal power applications.

Where the PA162DK is used in higher power applications, it is necessary to use surface mount techniques of heatsinking. Surface mount techniques include the use of a surface mount fan in combination with a surface mount heatsink on the backside of the FR4/ PC board with through hole thermal vias. Other highly thermal conductive substrate board materials are available for maximum heat sinking.

The Power Derating graph assumes that the power dissipation is equal in each of the amplifiers. Power and thermal ratings are based on two separate dual monolithic power op amps on one integrated copper heat slug. Amps A and B are combined on one monolithic die while amps C and D are combined on the other. This multi chip configuration provides superior thermal performance by isolating each of the dual amplifiers. When loading either of the dual amplifiers it is possible to achieve better thermal performance by loading any of the following combination of amplifiers: (A or B) + (C or D).

**Figure 16: Power Derating**



## MOUNTING PRECAUTIONS

1. Always use a heat sink. Even unloaded the PA162DK can dissipate up to 0.8 watts.
2. Avoid bending the leads. Such action can lead to internal damage.

## ELECTROSTATIC DISCHARGE

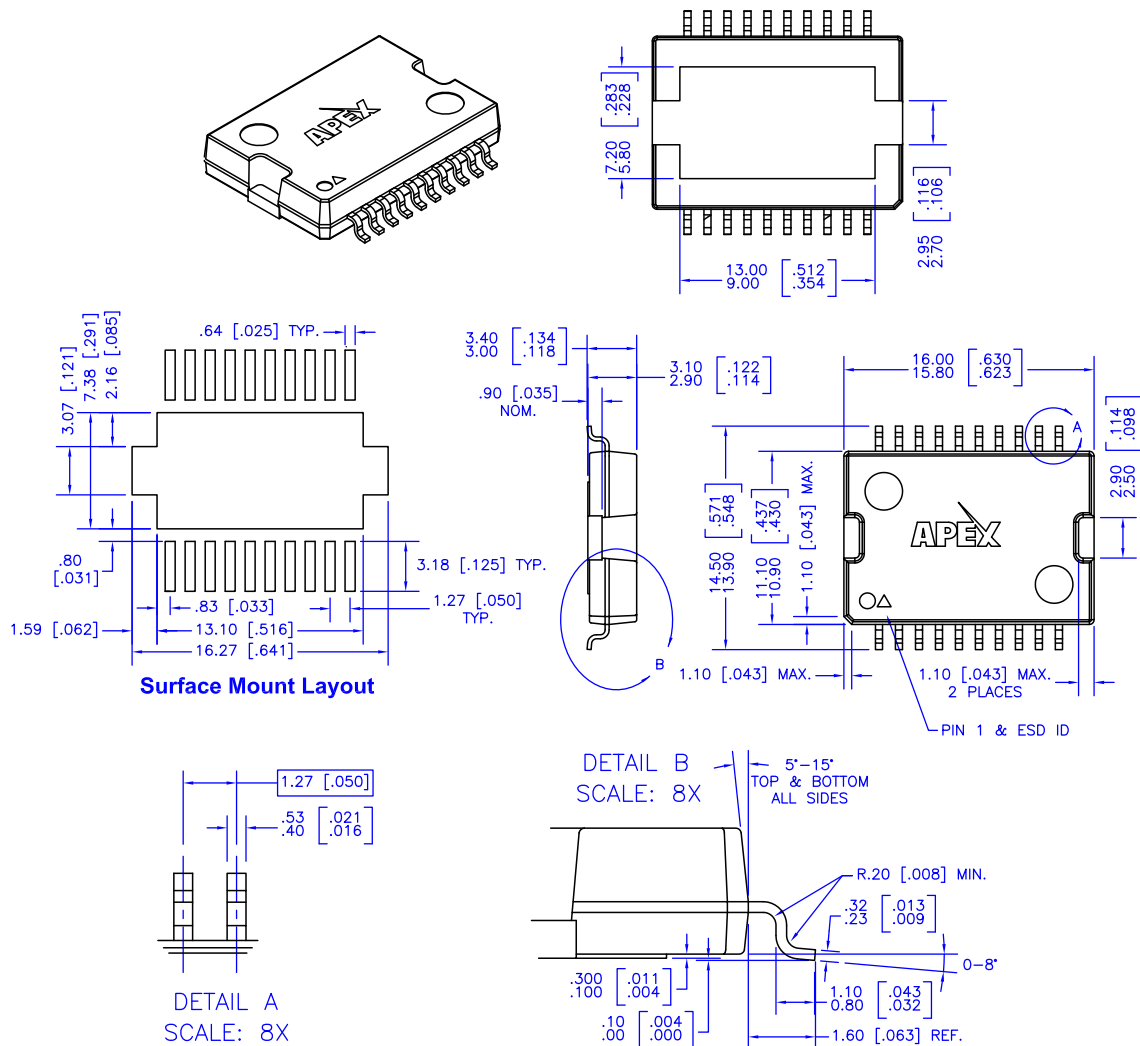
Like many high-performance amplifiers, the PA162 is very sensitive to damage due to electrostatic discharge (ESD). Failure to follow proper ESD handling procedures could have results ranging from reduced operation performance to catastrophic damage. Minimum proper handling includes the use of grounded wrist or shoe straps, grounded work surfaces. Ionizers directed at the work in progress can neutralize the charge build up in the work environment and are strongly recommended.

## PACKAGE OPTIONS

Part Number	Apex Package Style	Description	MSL <sup>1</sup>
PA162DK	DK	20-Pin PSOP	Level 3

1. The Moisture Sensitivity Level rating according to the JEDEC industry standard classification.

## PACKAGE STYLE DK



### NOTES:

1. Dimensions are millimeters & [inches].
2. Bracketed alternate units are for reference only.
3. Dimple on lid & ESD triangle denote pin 1.
4. Heat Slug: C10200 copper with Ni-Pd-Au plating
5. Lead frame: C19400 copper with SNi-Pd-Au plating.
6. Mold compound: MP-8000AN or EME6600HR epoxy
7. Package weight: .086 oz. [2.44 g]
8. Suggested surface mount layout for reference only.

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