MP165

High Voltage Power Operational Amplifier

RoHS COMPLIANT

FEATURES

- Monolithic MOS Technology for Amplifier Core
- High Voltage Operation (200V Output)
- Current Limit with Over-Current Flag
- High Output Current 4A continuous and 10A Peak
- Amplifier Disable Feature

APPLICATIONS

- High Density Voltage or Current Supplies
- Electrostatic Transducer and Deflection
- Deformable Mirror Focusing
- Piezo Electric Positioning

DESCRIPTION

The MP165 is a high voltage, MOSFET based operational amplifier with a monolithic amplifier core developed for high density power applications with high output currents or voltages. It is designed for operation up to 200V, and 4A of continuous current. Separate supplies for the amplifier core and the output stage optimize the overall power dissipation in the devices. The MP165 offers a wide-range (4000:10), temperature compensated current limit. An additional over-current flag allows for a flexible implementation of system protection, with an output disable function adding another layer of optional protection. Pins for external compensation provides the user flexibility in choosing optimum gain and bandwidth for the application. The V_{TEMP} pin helps in measuring the case temperature of the amplifier.

PINOUT DESCRIPTION TABLE

Pin Number	Name	Description
1	$-V_S$	Negative supply voltage pin
2	OUT	Output current pin
3	$+I_{LIM}$	Current limit sense pin. Connect this pin to MP165 side of current limit resistor. Refer to typical connection figure.
4	$-I_{LIM}$	Current limit sense pin. Connect this pin to load side of the current limit resistor. Refer to typical connection figure.
5	$-V_B$	Negative boost supply voltage
6	C_{C2}	Compensation pin, connect compensation capacitor from this pin to ground
7	C_{C1}	Compensation pin, connect compensation capacitor from this pin to ground
8	-IN	Inverting input pin
9	+IN	Non-inverting Input pin
10	V_{TEMP}	Temperature sensor output pin
12	PDWN	Power down pin
13	OCFLG	Over current flag. High = No current limit, Low = Current limit (must be connected to 5V source through 5K resistor)
14	TRX	Connect to ground
15	GND	Amplifier Ground Connection
11, 16, 17, 18, 19, 20, 21	NC	No connection pins. Do not connect anything to these pins.
22	$+V_B$	Positive boost supply pin
23	$+V_S$	Positive supply pin

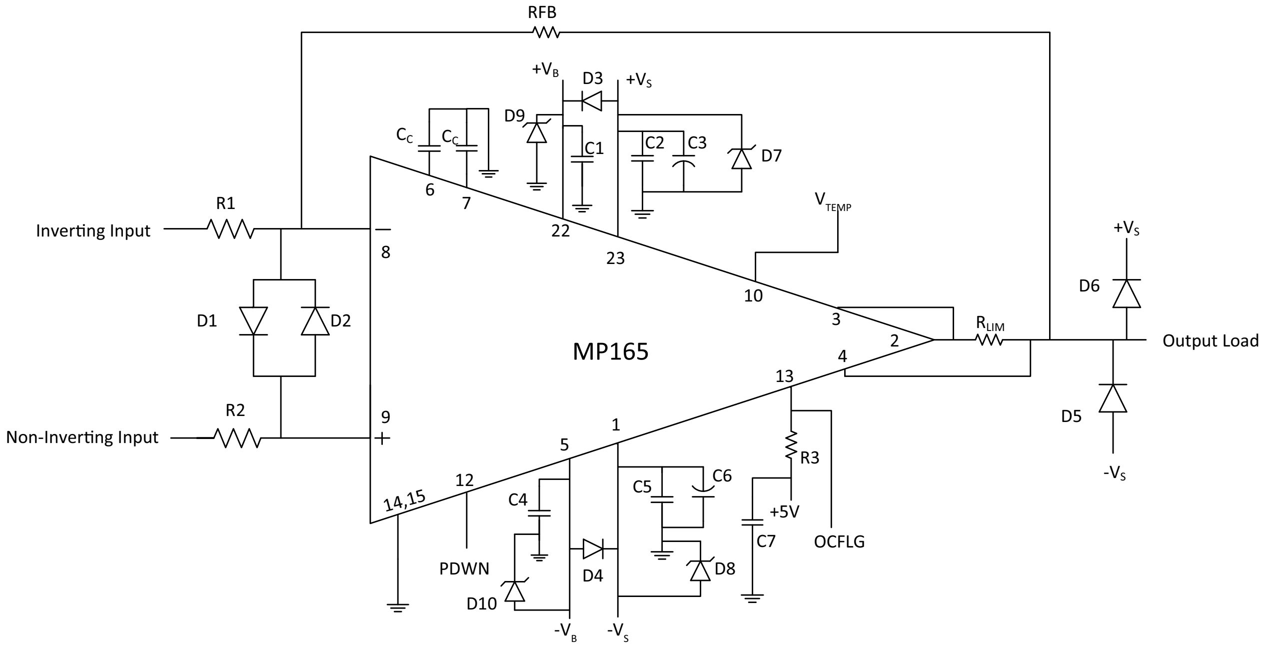


Figure 1: Typical Connection

SPECIFICATIONS

Unless otherwise noted; T_C = 25°C. The power supply voltages are set at $\pm V_S = \pm 100V$, and $\pm V_B = \pm V_S$. Load R_L = 1 kΩ.

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Min	Max	Units
Supply Voltage, total [1]	$+V_s$ to $-V_s$		205	V
Supply Voltage [2]	$+V_B$	$+V_s$	$+V_s+15$	V
Supply Voltage	$-V_B$	$-V_S-15$	$-V_s$	V
Supply Voltage [3]	$+V_B$ to $-V_B$		235	V
Output Current, peak, within SOA			10	A
Power Dissipation, internal, continuous [4]			100	W
Input Voltage, common mode		$-V_B+10$	$+V_B-10$	V
Input Voltage, differential mode			+22	V
Temperature, pin solder, 10s			225	°C
Temperature, junction			150	°C
Temperature, storage		-40	+105	°C
Operating Temperature Range, case		-40	+85	°C

1. Valid only for device temperature of 25°C or higher.
2. The supply of a boost voltage is optional and can be replaced by the general supply voltage ($+V_s$, $-V_s$). Please also note the restriction of the overall supply voltage $+V_B$ to $-V_B$.
3. If V_S is also used for V_B, then the maximum voltage can't exceed the 205V.
4. The case temperature is 25°C.

INPUT

Parameter	Test Conditions	Min	Typ	Max	Units
Offset Voltage, initial			-2	+20	mV
Offset Voltage vs. Temperature	-25°C to 85°C		6	250	µV/°C
Offset Voltage vs. Supply			0.2		µV/V
Offset Voltage vs. Time			80		µV/kh
Bias Current, initial			23	200	pA
Bias Current vs. Supply			2		pA/V
Offset Current, initial			50	200	pA
Input Impedance, DC			10^{11}		Ω
Input Capacitance			3		pF
Common Mode Voltage Range		$-V_B+15$		$+V_B-15$	V
Common Mode Rejection, DC	$V_{CM}=\pm 90V$ DC	97	115		dB
Noise	1 MHz		15		$nV/\sqrt{Hz}$

GAIN

Parameter	Test Conditions	Min	Typ	Max	Units
Open Loop @ 15 Hz	C_C = 3.3pF	90	118		dB
Gain Bandwidth Product @ 1 MHz			20		MHz
Power Bandwidth	$150V_{P-P}$		60		kHz

OUTPUT

Parameter	Test Conditions	Min	Typ	Max	Units
Voltage Swing (no boost voltage) $\|V_B\|=\|V_S\|$	I_{OUT}=1A	$+V_S$-10	$+V_S$-8		V
	I_{OUT}=-1A	$-V_S$+10	$-V_S$+6		V
Voltage Swing (with boost voltage, $\|V_B\|=\|V_S\|+10V$)	I_{OUT}=1A		$+V_S$-1.3		V
	I_{OUT}=-1A		$-V_S$+1.6		V
Voltage Swing (with boost voltage, $\|V_B\|=\|V_S\|+10V$)	I_{OUT}=4A	$+V_S$-2	$+V_S$-1.5		V
	I_{OUT}=-4A	$-V_S$+2.8	$-V_S$+2.3		V
Current, peak, within SOA	<1ms		10		A
Current, continuous. within SOA			4		A
Settling Time to 0.1%[1]	10V step, A_V=-10		3		µs
Slew Rate	A_V=-10, C_C = 0pF		31		V/µs
Slew Rate	A_V=-10, C_C = 4.3pF		25		V/µs

1. Confirmed by design, but not tested in production

CURRENT LIMIT

Parameter	Test Conditions	Min	Typ	Max	Units
Absolute Accuracy over Temperature	+25°C to 85°C		10		%
Temperature Dependency	+25°C to 85°C		0.05		%/K
Clamping Settling Time	Short to ground, settling to the ±10% of limit		3		µs
Current Limit Range	Normalized range	10		4000	mA
Current Limit Delay (OC Flag)	50mA current limit, 10V output voltage, R_L=1 kΩ, short to ground		600		µs
Current Limit Circuit Input Bias/ Leakage Current			<1		µA

POWER SUPPLY

Parameter	Test Conditions	Min	Typ	Max	Units
Supply Voltage V_S=+V_S-(-V_S)		20		205	V
Supply Voltage V_B=+V_B-(-V_B)		30		V_S+30[1]	V
Current, quiescent			6	10	mA
Power Dissipation, quiescent	200V supply		1.2	2	W

1. Please also note the conditions under Absolute Maximum Ratings.

THERMAL

Parameter	Test Conditions	Min	Typ	Max	Units
Resistance, AC, junction to case	F≥60 Hz			1	°C/W
Resistance, DC, junction to case	F<60 Hz			1.25	°C/W
Resistance, junction to air	Full temperature range		13		°C/W
Temperature Range, case	Meet full range specs	-40		+85	°C

TEMPERATURE SENSOR

Parameter	Test Conditions	Min	Typ	Max	Units
Temp Sensor Output Voltage, V_{TEMP}	T_C=25°C	1.8	2	2.2	V
Temp Sensor “Gain” [1]		14.5	14.7	14.9	mV/°C
Temperature Accuracy	T_C=-25°C to +85°C		± 2.2		°C

1. Confirmed by design, but not tested in production

SAFE OPERATING AREA (SOA)

The MOSFET output stage of the MP165 is not limited by second breakdown considerations as in bipolar output stages. Only thermal considerations and current handling capabilities limit the SOA. The output stage is protected against transient flyback by the parasitic body diodes of the output stage MOSFET structure. However, for protection against sustained high energy flyback external fast recovery diodes must be used.

Figure 2: Safe Operating Area (SOA)

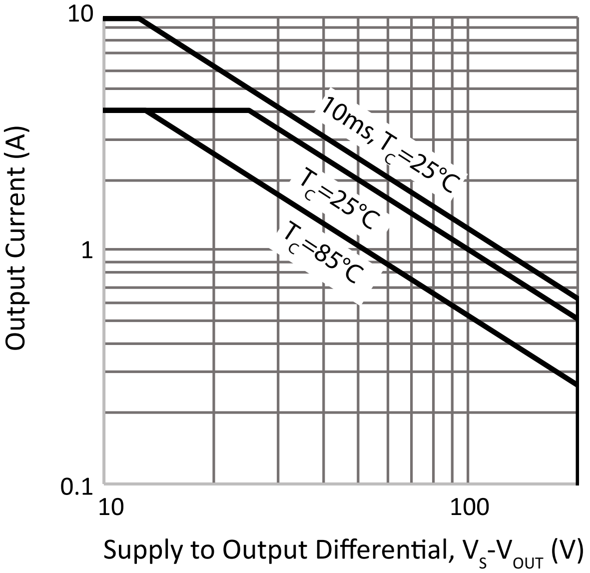


Figure 3: Power Derating

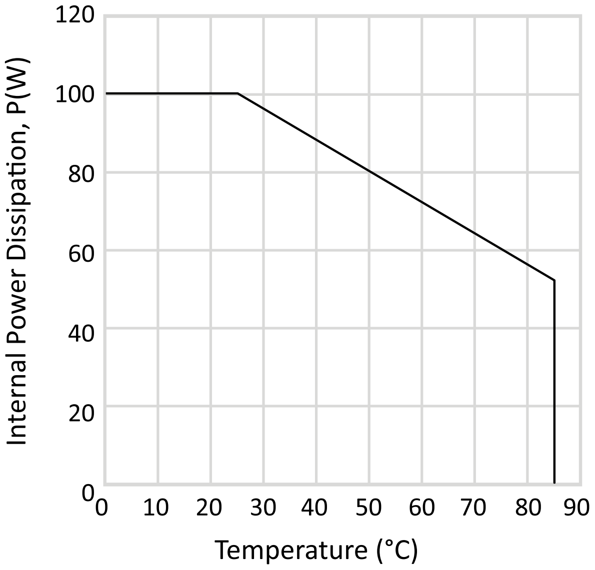


Figure 4: Power Response vs Compensation

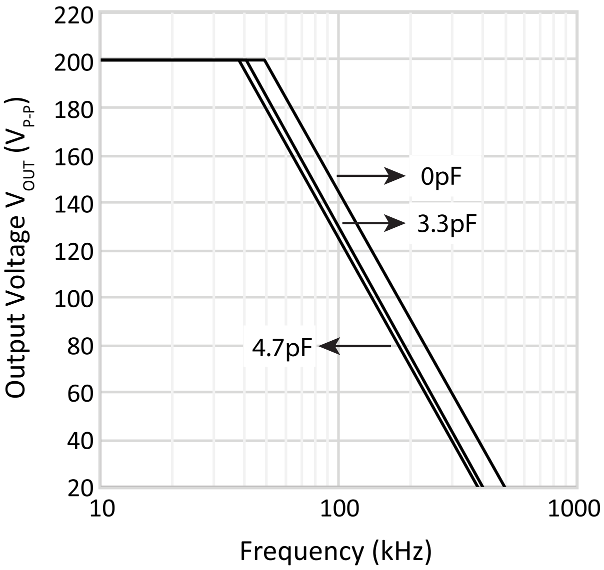


Figure 5: Slew Rate vs Compensation

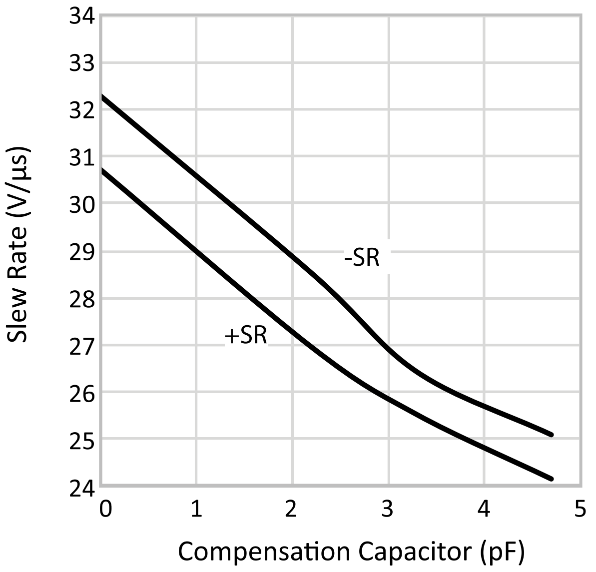


Figure 6: Input Noise

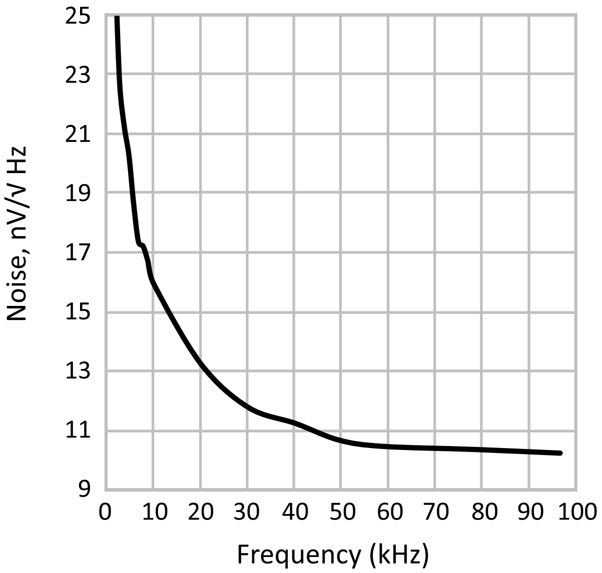


Figure 7: V_{TEMP} vs. Temperature

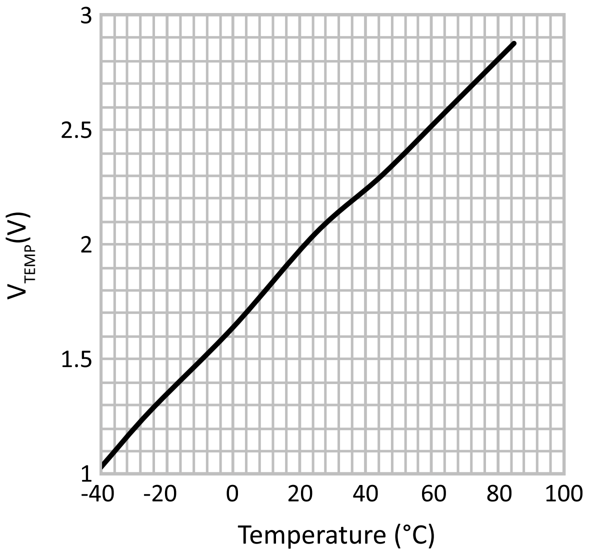


Figure 8: I_Q vs. Supply

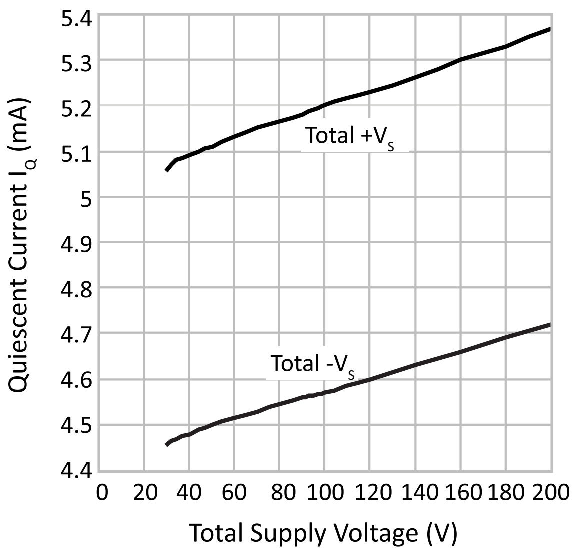


Figure 9: Output Voltage Swing (with additional boost voltage)

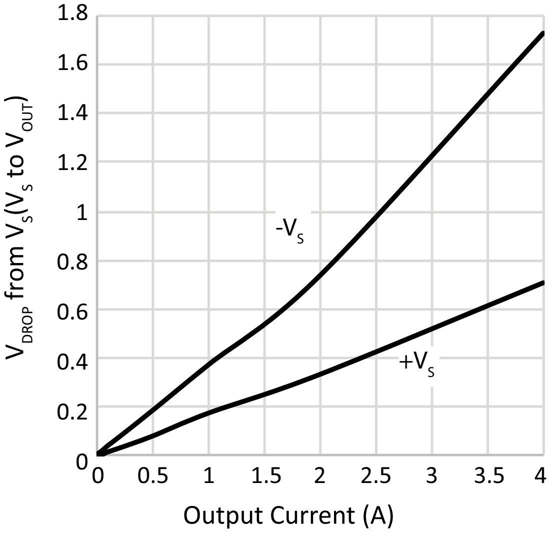


Figure 10: Output Voltage Swing (without additional boost voltage)

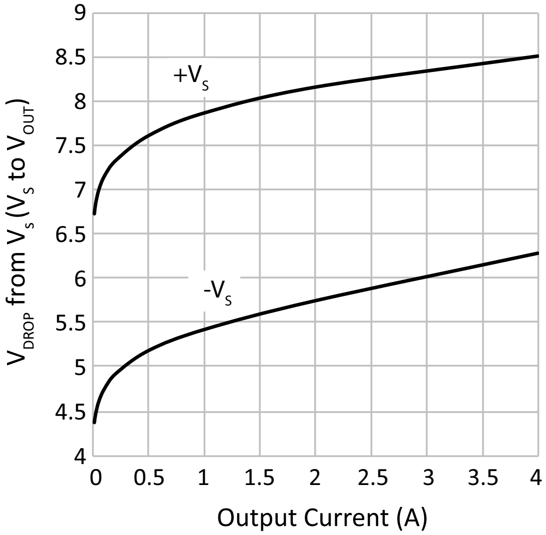


Figure 11: Open Loop Phase Response, C_C=0pF

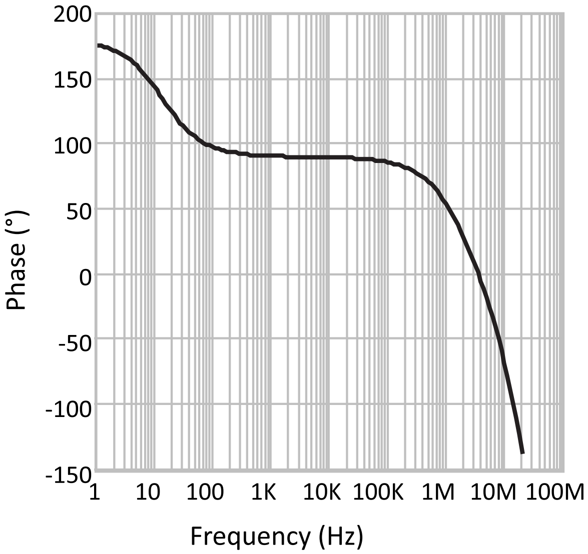


Figure 12: Open Loop Frequency Response, C_C=0pF

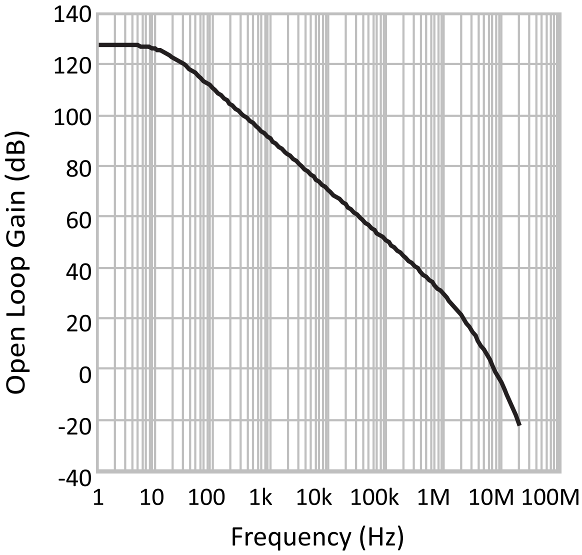


Figure 13: Small Signal Pulse

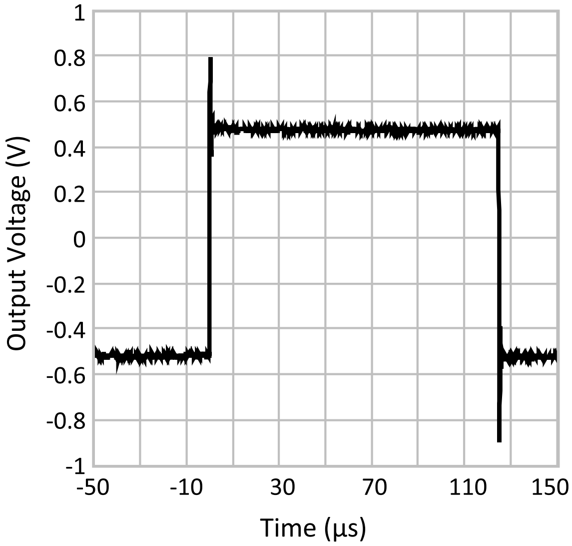


Figure 14: V_S Quiescent Current vs. Temperature

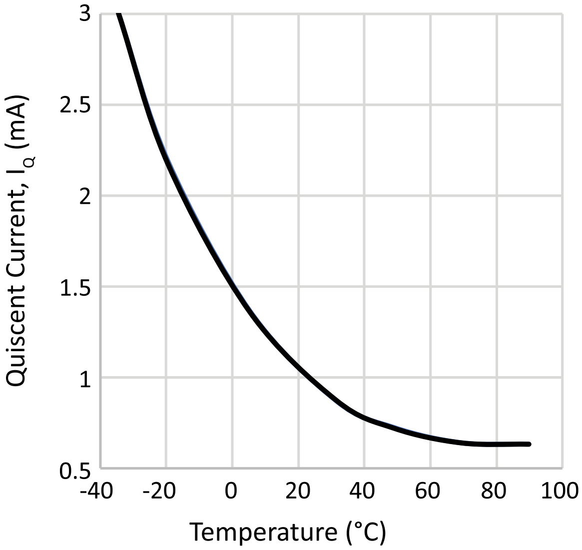
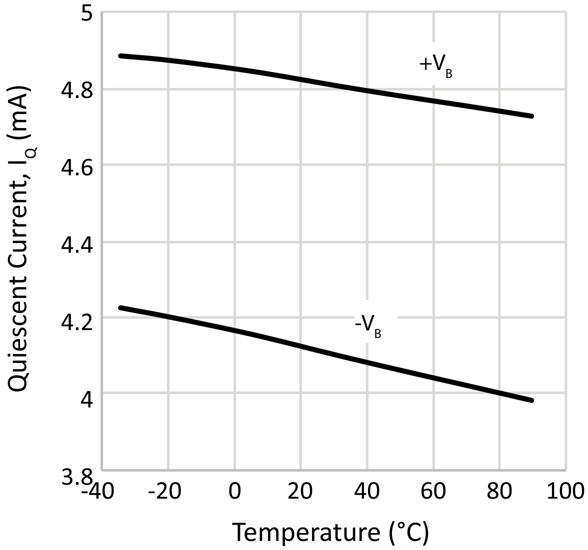


Figure 15: V_B Quiescent Current vs. Temperature



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 for Apex Microtechnology's complete Application Notes library, Technical Seminar Workbook, Apex Power Design Tool and Evaluation Kits.

POWER SUPPLY BYPASSING

Bypass capacitors to power supply terminals $+V_S$ and $-V_S$ must be connected physically close to the pins to prevent local parasitic oscillation in the output stage of the MP165. Use electrolytic capacitors at least 10µF per output amp. Bypass the electrolytic capacitors with high quality ceramic capacitors (X7R) 0.1µF or greater. Connect a 0.1µF ceramic bypass capacitor for the 5V power supply used for OCFLG pin.

CURRENT LIMIT

For proper operation, the current limit resistor (R_{LIM}) must be connected as shown in the external connection diagram. The R_{LIM} resistor sets the precision current limit for the amplifier output. The resistor should be connected inside the feedback loop. The current limit level can be determined by the following equation:

$$R_{LIM} = \frac{0.465\,V}{I_{LIM}}$$

POWER SUPPLY SEQUENCING

If separate boost supplies are not used, then connect $+V_B$ to $+V_S$ and $-V_B$ to $-V_S$.
If separate boost supplies are used, then use the following sequence:

Turn ON Sequence: +5V, $\pm V_S$, $\pm V_B$, (+5V is the voltage source for over current flag)
Turn OFF Sequence: $\pm V_B$, $\pm V_S$, +5V

To make sure $\pm V_B$ are not less than 1 diode drop below $\pm V_S$, Apex requires (small signal) diodes to be connected between $+V_S$ (anode) and $+V_B$ (cathode) and between $-V_S$ (cathode) and $-V_B$ (anode). See the “Typical Connections” diagram.

POWER SUPPLY PROTECTION

Unidirectional transient voltage suppressors are recommended as protection on the supply pins. TVS diodes clamp transients to voltages within the power supply rating and clamp power supply reversals to ground. Whether the TVS are used or not, the system power supply should be evaluated for transient performance including power-on overshoot and power-off polarity reversal as well as line regulation. Conditions which can cause open circuits or polarity reversals on either power supply rail should be avoided or protected against. Reversals or opens on the negative supply rail is known to induce input stage failure. Unidirectional TVS diodes prevent this, and it is desirable that they be both electrically and physically as close to the amplifier as possible.

INPUT PROTECTION

Although the MP165 can withstand differential input voltages up to ±20V, additional external protection is recommended. In most applications, 1N4148 or 1N914 signal diodes are sufficient (D1 and D2 in figure 1). These diodes help in clamping the input differential voltage to ±0.7V. This is enough overdrive to produce maximum power bandwidth. Note that this protection does not automatically protect the amplifier from excessive common mode input voltages.

TEMPERATURE SENSING

The case temperature of the MP165 can be monitored using the V_{TEMP} pin. The V_{TEMP} pin provides an output voltage that corresponds to the change in case temperature. The scale factor of the temperature sensor is 14.7mV/°C. At an ambient temperature of 25°C, the typical output voltage of the pin is 2V. The temperature error of the sensor is +2.2°C.

This temperature may be used to monitor system level failures that can result in unsafe temperature on the device like heatsink fan failure or obstruction to airflow on heatsink. The temperature will not respond quickly to overstress condition of the MP165 that results in a rapid rise in junction temperature. The safe operating area (SOA) and power derating criteria of the MP165 must be observed for all operating conditions to avoid damages to the MP165.

INTEGRATED OVER CURRENT FLAG

The MP165 contains an over-current flag pin. Connect a 5 kΩ resistor between this pin and a 5V source referenced to ground, as shown in the typical connection drawing Connect a 0.1µF ceramic bypass capacitor for the 5V power supply. The over current flag pin can be then used as a 0-5V logic. When the amplifier goes into current limit mode, the pin will sink 1mA current and 5V will be dropped across the resistor. In this configuration, 5V at the pin will indicate no current limit, while 0V at the pin indicates that the amplifier is set in current limit.

INTEGRATED SHUT DOWN FEATURE

The MP165 includes a shut-down circuit that allows turning off the output stage of the amplifier, preventing any input signal from passing through the amplifier. The amplifier will work in normal operating mode when the shut down pin is grounded or left floating. The output is disabled when the shut down pin is brought high, 5V.

BOOST OPERATION

With the boost feature the small signal stages of the amplifier are operated at higher supply voltages than the amplifier's high current output stage. $+V_B$ and $-V_B$ are connected to the small signal stages and $+V_S$ and $-V_S$ are connected to the high current output stage. An additional 5V on the $+V_B$ and $-V_B$ pins is sufficient to allow the small signal stages to drive the output stage into the triode region and improve the output voltage swing for extra efficient operation when required. When the boost feature is not needed, $+V_S$ and $-V_S$ are connected to the $+V_B$ and $-V_B$ pins respectively. The $+V_B$ and $-V_B$ pins must not be operated at supply voltages less than $+V_S$ and $-V_S$ respectively.

OUTPUT PROTECTION

Two external diodes as shown in Figure 1, are required to protect these amplifiers from fly back (kick-back) pulses exceeding the supply voltages of the amplifier when driving inductive loads. For component selection, these external diodes must be very quick, such as ultra-fast recovery diodes with no more than 200 nanoseconds of reverse recovery time. The diode will turn on to divert the fly back energy into the supply rails thus protecting the output transistors from destruction due to reverse bias.

A note of caution about the supply. The energy of the fly back pulse must be absorbed by the power supply. As a result, a transient will be superimposed on the supply voltage, the magnitude of the transient being a function of its transient impedance and current sinking capability. If the supply voltage plus transient exceeds the maximum supply rating or if the AC impedance of the supply is unknown, it is best to clamp the output and the supply with a Zener diode to absorb the transient.

NEED TECHNICAL HELP? CONTACT APEX SUPPORT!

For all Apex Microtechnology product questions and inquiries, call toll free 800-546-2739 in North America. For inquiries via email, please contact apex.support@apexanalog.com. International customers can also request support by contacting their local Apex Microtechnology Sales Representative. To find the one nearest to you, go to www.apexanalog.com

IMPORTANT NOTICE

Apex Microtechnology, Inc. has made every effort to insure the accuracy of the content contained in this document. However, the information is subject to change without notice and is provided "AS IS" without warranty of any kind (expressed or implied). Apex Microtechnology reserves the right to make changes without further notice to any specifications or products mentioned herein to improve reliability. This document is the property of Apex Microtechnology and by furnishing this information, Apex Microtechnology grants no license, expressed or implied under any patents, mask work rights, copyrights, trademarks, trade secrets or other intellectual property rights. Apex Microtechnology owns the copyrights associated with the information contained herein and gives consent for copies to be made of the information only for use within your organization with respect to Apex Microtechnology integrated circuits or other products of Apex Microtechnology. This consent does not extend to other copying such as copying for general distribution, advertising or promotional purposes, or for creating any work for resale.
APEX MICROTECHNOLOGY PRODUCTS ARE NOT DESIGNED, AUTHORIZED OR WARRANTED TO BE SUITABLE FOR USE IN PRODUCTS USED FOR LIFE SUPPORT, AUTOMOTIVE SAFETY, SECURITY DEVICES, OR OTHER CRITICAL APPLICATIONS. PRODUCTS IN SUCH APPLICATIONS ARE UNDERSTOOD TO BE FULLY AT THE CUSTOMER OR THE CUSTOMER'S RISK.
Apex Microtechnology, Apex and Apex Precision Power are trademarks of Apex Microtechnology, Inc. All other corporate names noted herein may be trademarks of their respective holders.