

Monolithic Operational Amplifier Works from $\pm 4.75\text{V}$ to $\pm 70\text{V}$ and Features Rail-to-Rail Output Swing and Low Input Bias Current

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Monolithic operational amplifiers have been around since the 1960s, but this ubiquitous device still sees steady improvements in performance. The LTC6090 precision monolithic operational amplifier takes a big step forward by extending the supply voltage to $\pm 70\text{V}$ without compromising the features that are expected in a precision op amp. The LTC6090 is available in a small 8-lead SO package and a 16-lead TSSOP package. Both packages feature exposed pads to reduce thermal resistance, eliminating the need for a heat sink. An easy interface to low voltage control lines and built-in thermal safety features simplify the task of high voltage analog design.

HIGH VOLTAGE AND HIGH PERFORMANCE

Operational amplifiers are expected to have low input bias current, low offset, and low noise. The LTC6090 is no exception. Designed with a MOS input stage the input bias current is typically 3pA at 25°C and less than 100pA at 85°C . This makes it well suited for high impedance applications such as a photodiode amplifier

shown in Figure 1. The low input offset voltage is less than 1.6mV , and the noise is $11\text{nV}/\sqrt{\text{Hz}}$ at 10kHz . The input common mode range is to 3V of either rail or a range of 134V across a 140V supply.

On the output side, precision op amps are expected to maintain precision when driving loads. Again, the LTC6090 does not disappoint. The unity gain stable output drive capability includes a 10MHz GBW product,

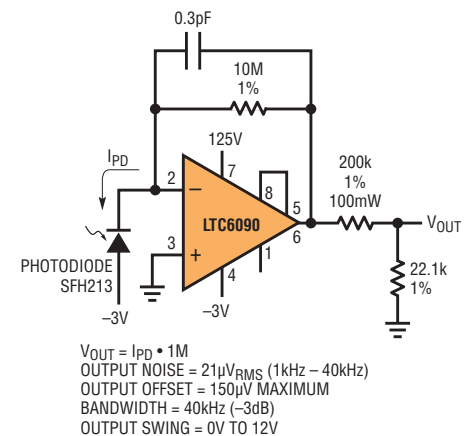


Figure 1. Extended dynamic range 1M transimpedance photodiode amplifier

fast slew rate and rail-to-rail output stage rated for $\pm 10\text{mA}$ that can drive up to 200pF . An example shown in Figure 2 is a $140\text{V}_{\text{P-P}}$ 10kHz sine wave. Figure 3 shows the output swing is well maintained as load current is increased. And the fidelity of the output voltage at $100\text{V}_{\text{P-P}}$ extends out to 8kHz as shown in Figure 4.

Figure 2. LTC6090 output voltage $140\text{V}_{\text{P-P}}$ 10kHz sine wave

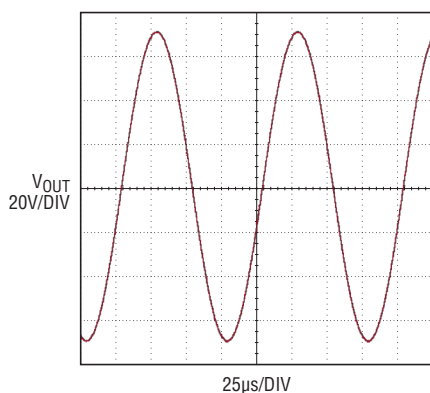


Figure 3. LTC6090 output voltage swing vs load current

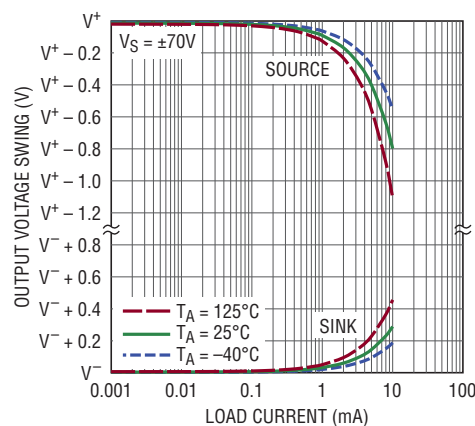
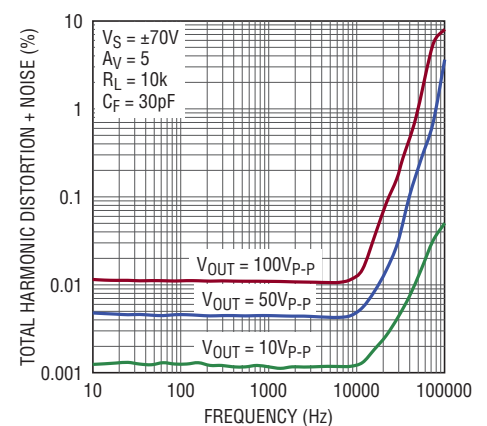


Figure 4. LTC6090 total harmonic distortion plus noise vs. frequency



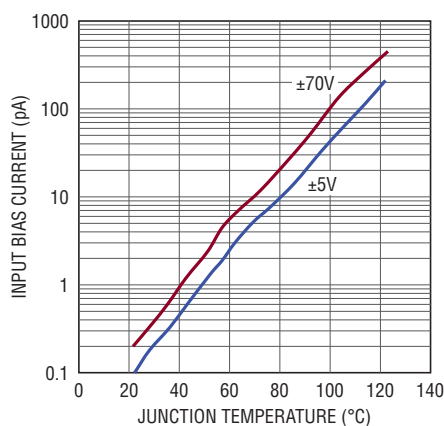
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HIGH IMPEDANCE APPLICATIONS REQUIRE LOW LEAKAGE CIRCUITS

The low input bias current of the LTC6090 make it an excellent choice for high impedance applications that require high voltage. As shown in Figure 5, input bias current is logarithmically dependent on temperature, doubling for every 10°C increase. In addition, input protection devices sit in an isolated pocket where leakage increases as the voltage on the input pin increases with respect to V^- . In Figure 5 the input pin is held at mid-supply.

In order to maintain low input bias current, care should be taken during PCB layout. Special low leakage board material can be considered. In critical applications, consider using guard rings. The TSSOP package with exposed pad has guard ring pins that can be used to protect the input pins from leakage currents. An example PCB layout of an inverting amplifier is shown in Figure 6.

Figure 5. LTC6090 input bias current versus junction temperature

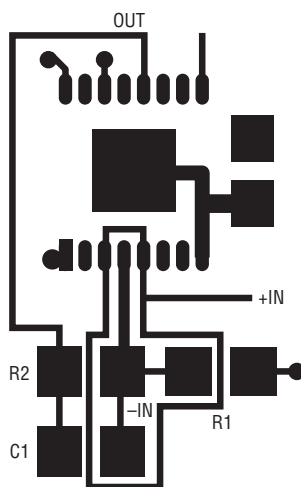


Note that the solder mask should be pulled back over the guard ring to expose the PCB metal. It is important that the PCB be clean and moisture free. Consider cleaning it with a solvent and rinsing any residue with tap water, then baking the board to remove any moisture. We have also found that thoroughly washing the board using soap and tap water (without solvent) yields good results.

INTERFACING LOW VOLTAGE CONTROL LINES TO A HIGH VOLTAGE OP AMP

The low voltage control lines on the LTC6090 can be interfaced as low as the negative supply rail, or as high as 5V below the positive supply rail. The COM pin acts as a common to interface to the low voltage control lines, and can be connected to the low voltage system ground or left to float. The output disable, OD, and overtemperature, TFLAG, pins are now referred to the low voltage

Figure 6. PCB guard ring example layout

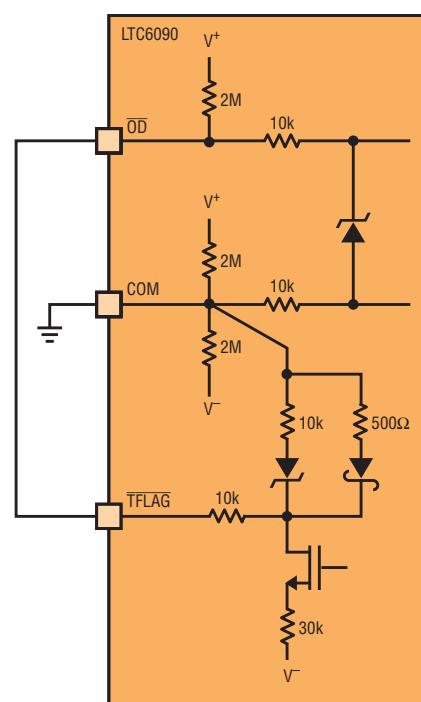


system ground. COM, OD and TFLAG pins are protected with diodes and resistors as shown in Figure 7. If left floating the COM pin will be pulled above mid-supply by the OD pin internal pull-up resistor to 21V when the supplies are $\pm 70V$.

THERMAL PROTECTION: USE \overline{OD} AND \overline{TFLAG}

At 140V total supply voltage and 2.7mA typical quiescent current, the LTC6090 consumes 378mW of power. Add a load and the power can exceed a watt, making good thermal design a priority. Both packages, the SO and TSSOP, feature an exposed pad on the bottom of the

Figure 7. The low voltage interface configured to automatically disable the output stage when the junction temperature of the die reaches 145°C



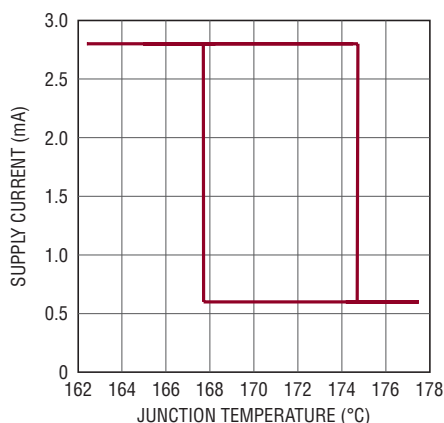
package, which is internally connected to the negative supply rail, V^- , and must be connected to the negative power plane. Connect as much PCB metal as practical to the exposed pad—the thermal resistance of the package is proportional to the amount of metal soldered to the exposed pad. In a best case scenario the thermal resistance, θ_{JA} , of the SO package is $33^{\circ}\text{C}/\text{W}$. For 1W of power, the junction temperature of the die increases 33°C above ambient temperature.

An important feature designed to protect the LTC6090 from exceeding 150°C junction temperature shuts down the output stage when the junction temperature gets too high. This is accomplished by connecting the overtemperature pin to the output disable pin. The overtemperature pin, or $\overline{\text{TFLAG}}$ pin, is an open drain pin that pulls low when the junction temperature of the die reaches 145°C . The 5°C built-in hysteresis releases the $\overline{\text{TFLAG}}$ pin when the junction temperature reaches 140°C . The output disable pin, or OD pin, is an active low pin that turns off the output stage and lowers the quiescent current

of the device to $670\mu\text{A}$ when pulled low with respect to the COM pin. When these two pins are tied together, the LTC6090 is disabled if the junction temperature of the die reaches 145°C . Note that these pins can float and be tied together.

An additional thermal safety feature shuts off the output stage when the junction temperature of the die reaches approximately 175°C . The 7°C of hysteresis enables the output stage when it returns to approximately 168°C as shown

Figure 8. LTC6090 thermal shutdown hysteresis plot



in Figure 8. Note that Figure 8 shows the junction temperature. This feature is intended to prevent the device from thermal catastrophic failure. Operating the LTC6090 above its absolute maximum junction temperature of 150°C can reduce reliability and is discouraged.

CONCLUSION

The LTC6090 features the high performance specs of a low voltage precision amplifier, but with the ability to work with $\pm 70\text{V}$ for high voltage applications. These features include high gain, low input bias current, low offset and low noise for a precision front end. A rail-to-rail output stage can drive a 200pF load capacitor and $\pm 10\text{mA}$ of load current, making this part suitable for precision high voltage applications such as high impedance amplifiers. Easily interfaced control lines for disabling the output and a thermal shutdown function are simple to implement. Small 8-lead SO and 16-lead TSSOP packages both have exposed pads to reduce thermal resistance, eliminating the need for a heat sink. ■

(LTC3115-1 continued from page 13)

In addition, many devices must remain operating for a period of time after bus failure in order to initiate a controlled shutdown. The LTC3115-1 application shown in Figure 9 is a 24V rail restorer application that maintains a clean and well-regulated 24V output rail from a noisy input supply rail, which can fluctuate above and below the regulation target. In addition, as shown in the waveforms of Figure 10, this supply is able to maintain regulation of its 24V output through momentary interruptions in bus power.

CONCLUSION

The flexibility and high efficiency of the LTC3115-1 make it perfectly suited to meet the demanding needs of the next generation of automotive electronics and

portable devices, especially those operated from multiple power sources. Its internal power switches and programmable switching frequency minimize the power solution footprint, supporting the increasing demand for miniaturization of electronic devices in the portable and automotive arenas. Low Burst Mode operation and shutdown quiescent currents prolong battery life and facilitate use in always-active automotive applications.

The LTC3115-1 is ideal for noise-sensitive applications, given its low noise, fixed frequency PWM mode, which produces a predictable and well controlled EMI spectrum with switching edges that can be synchronized to a system clock. Internal soft-start minimizes inrush current during

start-up and an internal divider in the control path reduces the impact of input voltage variations, and makes the loop easier to compensate in applications with widely varying input voltages. A programmable input undervoltage lockout allows the input voltage at which the part is enabled to be set by the user, and provides for independent control of the hysteresis. The LTC3115-1 also features complete disconnect of the output from the input in shutdown, and is fully protected with output short-circuit protection and overtemperature shutdown. ■