

# Fully Differential Gain-Block Family Simplifies Interface Designs

by Jon Munson

## Introduction

The LTC1992 product family provides simple amplification or level translation solutions for amplifying signals that are intrinsically differential or need to be made differential.

The LTC1992 is available with uncommitted gain (base LTC1992), or in fixed gain versions with space-saving on-chip factory-trimmed resistors—namely, the LTC1992-1, LTC1992-2, LTC1992-5, and LTC1992-10, where the nominal gain is indicated by the suffix dash-number.

Figure 1 shows a typical gain-of-10 application where all gain setting components are included in the tiny MSOP-8 package. The device offers output common-mode control that operates completely independent from the input common-mode of the applied signal. The inputs and outputs can be used either differentially or as single-ended as needed.

The LTC1992 family operates with supply voltages from 2.7V single-supply to  $\pm 5V$  and typically consumes  $<1mA$ .

## Easy to Use Circuit Topology

The block diagram in Figure 2 shows the general configuration of the differential-in/differential-out CMOS amplifier core, along with an output common-mode servo. The values of the on-chip gain resistors depend on the version of the device as indicated. A convenient on-chip 200k $\Omega$  voltage-divider resistor network is

also provided to support applications where a source of mid-supply potential ( $V_{MID}$ ) is needed.

The LTC1992 is easy to use. Any signal difference at the inputs (within the input common-mode range) is amplified and presented as a voltage difference at the output pins, with a gain bandwidth product of about 4MHz. The differential gain,  $A$ , is set by resistor values:

$$A = \frac{R_F}{R_G}$$

The configurable-gain LTC1992 (no dash suffix) provides any desired differential gain by selection of external resistors, and offers flexibility for other specialized uses. Small input common-mode induced errors, primarily caused by mismatched resistor values, appear at the output as differential error. The virtue of using the LTC1992 versions with on-chip precision resistors, besides the space savings, is that a high CMRR ( $>55dB$ ) is assured without the expense of outboard precision resistor networks.

Setting the common-mode (shared offset) of the output pair is a straightforward matter of providing a  $V_{OCM}$  control voltage, and in most applications this input is simply connected to the  $V_{MID}$  pin. The output servo compares the  $V_{OCM}$  input with the  $(V_{+OUT} + V_{-OUT})/2$  signal generated by the 30k resistor pair and makes a correction voltage that is applied to both outputs

without disturbing the differential signal being produced. Driving  $V_{OCM}$  with  $V_{MID}$  automatically provides the greatest output dynamic-range. The output common-mode servo provides a bandwidth of about 50% of the main differential path, making it possible to use the  $V_{OCM}$  input for signal functions if desired.

## Easy Conversions Between Differential and Single-Ended

The LTC1992 family is especially useful for making conversions to or from differential signaling. Analog to Digital converters (ADC's) are often optimized for differential inputs with a specific common-mode input voltage. Use of an LTC1992 amplifier makes the ADC interface very simple by using the  $V_{OCM}$  control feature to establish the requisite offset. In many cases the mid-scale potential is provided by the ADC and can be tied directly to the  $V_{OCM}$  input. In addition, the source-signal input may then be differential or single ended (by grounding the unused input) or have inverted polarity. One particularly effective use of the LTC1992 is in a situation shown in Figure 3, where a ground referenced bi-polar input signal needs level translation and possibly gain for proper operation with subsequent circuitry— and no negative supply is available.

It is not necessary to connect to both outputs, so one can treat the LTC1992 as single-ended, thereby

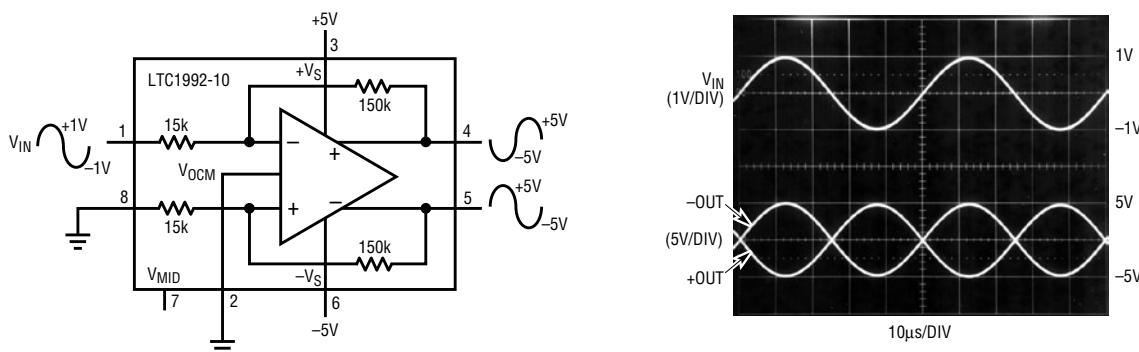
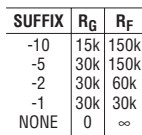


Figure 1. Single-ended to differential gain-of-10 amplifier



**Figure 2. LTC1992 functional block diagram**

permitting the  $V_{OCM}$  input to represent a third algebraic input term in addition to the basic differential input pair. Figure 4 shows the LTC1992-2 used for single-ended arithmetic processing of three discrete input signals with no external components. This capability is very useful in performing analog addition or simple translation functions. The LTC1992 family of devices is ideal for amplifying differential signal sources, such as acoustic transducers or power-line current monitors and, if required, converting the result to single ended.

## Differential Transimpedance (TIA) Preamp

A differential TIA topology has the potential of providing an S/N im-

improvement over a single-ended TIA with the same  $V/I$  by eliminating the common-mode component of the input noise. Figure 5 shows a photodiode TIA with a fully differential topology. The output common-mode is established with  $V_{OCM}$  as described previously, and the photodiode common-mode floats to the same value. This circuit maintains a 0V bias on the photodiode, regardless of the photocurrent flowing. As with a conventional TIA, the value of  $C_F$  is chosen to compensate for the photodiode and other stray capacitance. The circuit in Figure 5 has a bandwidth from DC to 20kHz, with a measured output noise spectral density less than twice the noise of the resistors alone ( $1.1\mu V/\sqrt{Hz}$  at 20kHz).

## Verify Operational Common-Mode Range

For a given input common-mode voltage ( $V_{\text{INCM}}$ ) and output common-mode voltage ( $V_{\text{OCM}}$ ), the designer needs to verify that the internal amplifier input common-mode ( $V_{\text{ICM}}$ ) is within the specified operating range of  $-V_S - 0.1\text{V}$  to  $+V_S - 1.3\text{V}$ . With a standard differential amplifier topology having gain of  $A$ , like that of the fixed gain versions of the LTC1992, the following relationship holds:

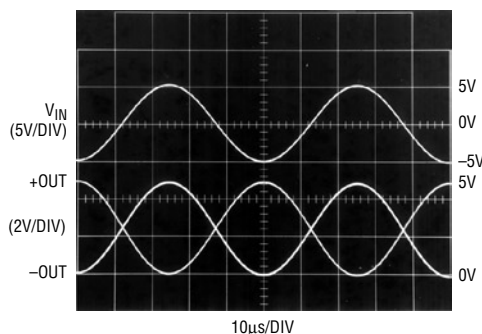
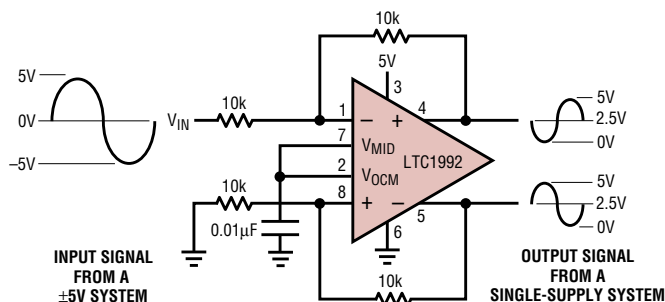
$$V_{ICM} = \frac{A}{A+1} \cdot V_{INCM} + \frac{1}{A+1} \cdot V_{OCM}$$

For example, assume an LTC1992 (no suffix) is powered from +5V, configured for a gain of 2.5,  $V_{OCM}$  is tied to  $V_{MID}$  (i.e. 2.5V), and the circuit is driven from a source with a common-mode-voltage of 0V. From the relation above,

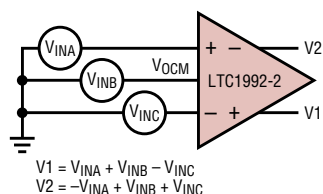
$$V_{ICM} = \frac{2.5}{3.5} \cdot 0 + \frac{1}{3.5} \cdot 2.5 = 0.71V$$

which is well within the performance range of the part. Note in this example that the differential inputs may swing 1V below ground without clipping effects or the need for a minus rail.

The fixed-gain versions have an additional input limitation due to the possibility of forward biasing the ESD input protection diodes (shown in Figure 2), which limit the maximum allowable signal swings to about 0.3V beyond the supply voltages (while the configurable-gain LTC1992 also includes the ESD diodes, conduction can only occur outside the usable  $V_{ICM}$  range). For single-ended inputs like shown in Figure 3, the applied input common-mode voltage ( $V_{INCM}$ ) is dy-



### Figure 3. Handling bipolar signals with a single supply

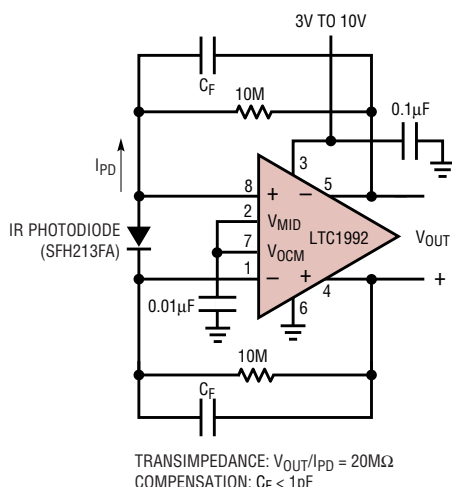


**Figure 4. Easy arithmetic processing of single-ended signals**

dynamic and has extremes that are 50% of the input swing ( $V_{INCM}$  is  $\pm 2.5V$  in the Figure 3 example). The  $V_{ICM}$  equation above is used with both the upper and lower dynamic  $V_{INCM}$  values to verify single-ended operability.

## Common-Mode Input Range Extension

The configurable-gain LTC1992 makes it possible to extend input common-mode capability to well outside the supply range by selecting gain below unity and/or introducing common-mode shunt-resistors (see  $R_S$  in Figure 6). The drawback to the shunt-resistor method is that component tolerances of  $R_G$  and  $R_S$  become magnified by approximately the gain of the circuit, leading to reduced CMRR performance for a given resistor tolerance. For

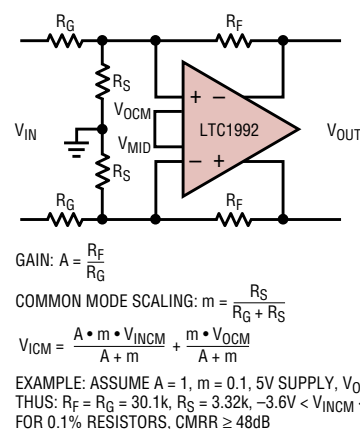


**Figure 5. Fully differential transimpedance amplifier topology**


low-gain operation, common-mode extension to beyond 35V is realizable with the use of high-accuracy resistor networks.

## Conclusion

The LTC1992 family of differential amplifiers offers easy-to-use building blocks that provide simple, minimum component-count solutions for a wide range of applications, including convenient methods of transforming signals



**Figure 6. Extending input common-mode range**

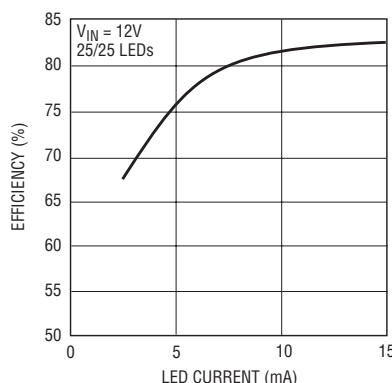
to/from differential form, providing component-free gain, or generating DC level-shifting functions. The versions that include on-chip precision resistors save space and reduce costs by eliminating expensive precision resistor networks. The configurable-gain LTC1992 saves cost by allowing single-supply applications to support input signal swings that exceed the supply-voltage window without additional design complexity. 

LT3466, continued from page 15

LT3466 enables it to drive as many as 50 white LEDs from a 12V input supply. Figure 10 shows the switching waveforms for the circuit.

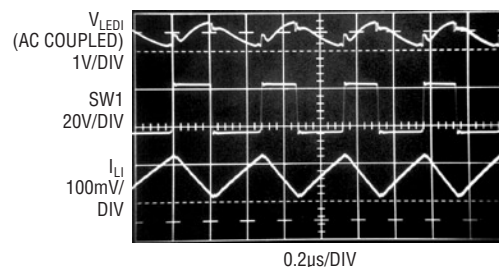
## Conclusion

The LT3466 is a dual white LED driver designed to drive up to 20 white LEDs from a single Li-Ion input. Integrated power switches, Schottky diodes, and availability in a space-saving (3mm x 3mm) DFN package make LT3466 an excellent fit for handheld applications. The wide operating voltage range and high frequency capability of the LT3466 enables it to meet the backlighting needs for automotive




**Figure 9. Efficiency for Figure 8's circuit**

instrument panels and car radio displays as well. Features like internal soft-start, open LED protection and internal loop compensation reduce the



**Figure 10. Switching waveforms for Figure 8's Circuit. Each set of 25 white LEDs driven at 15mA**

number of external components, thus reducing the overall cost and size of the white LED driver circuit. 

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