

Simple, Precise Instrumentation Amplifier Features Digitally Programmable Gains from 1 to 4096

by Michael Kultgen

Introduction

The LTC[®]6915 is the simplest, most precise way to obtain digitally programmable voltage gain. Any system which needs accurate amplification of small differential voltages and rejection of large common mode signals will benefit from the LTC6915.

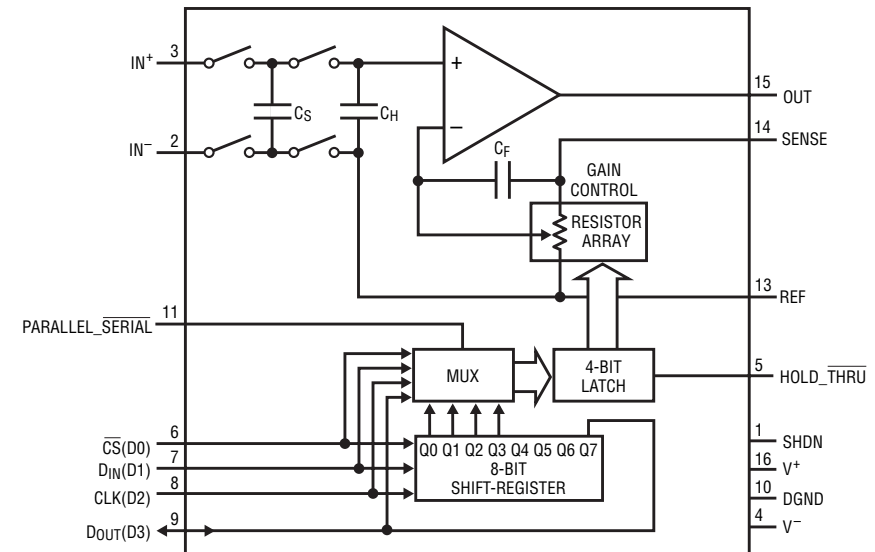
The LTC6915 is an evolution of the LTC2053, a precision rail-to-rail input and output, zero-drift instrumentation amplifier. Due to the amplifier's very low DC errors, very high levels of gain can be taken in a single stage. The LTC2053 uses external resistors to set the gain; the LTC6915 uses a serial port or a parallel port to select internal resistors, and therefore select the gain. The gain can be programmed to 0, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, or 4096. Programmable gain increases the dynamic range of any system. A fixed gain instrumentation amplifier would have about 60dB of useful range. The dynamic range of the LTC6915 is more than 120dB.

Since the high CMRR (typically 125dB) is independent of the gain setting, microvolts of differential signal can be extracted from volts of common mode noise. Furthermore, the common mode level of the differential signal can be any value within the supply rails of the LTC6915.

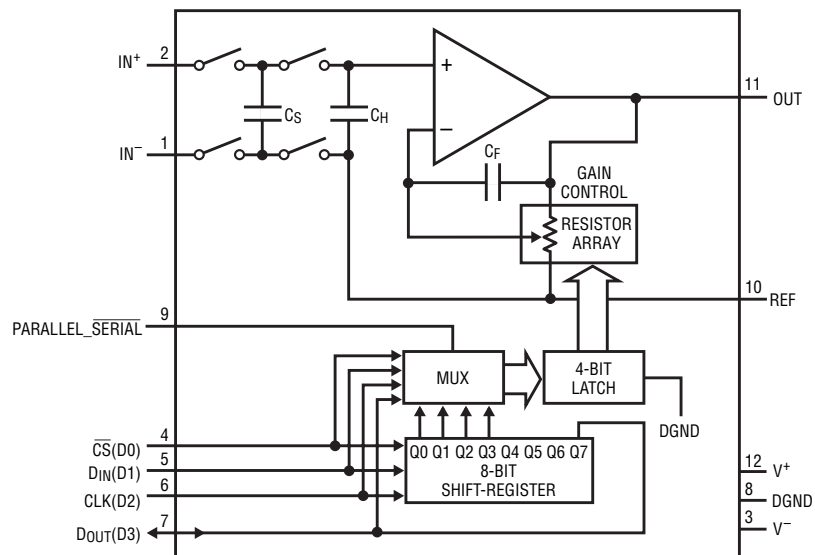
Other features of the LTC6915 include a flexible digital interface, a Kelvin connected output stage, a wide supply range, a shutdown mode, and a choice of packages.

How it Works

Figure 1 shows a block diagram of the LTC6915. A sophisticated, charge balanced sampling technique impresses the differential input voltage on to a 1000pF internal capacitor. The differential input signal is converted to a single-ended signal referenced to



a. The LTC6915 in a GN16 Package



b. The LTC6915 in a DFN12 Package

Figure 1. The LTC6915 block diagram. The small GN16 package (a) has all control features. The DFN12 package version (b) sacrifices the shutdown and data latching control features for even smaller size.

the "REF" pin of the LTC6915. This single-ended signal is then amplified by a zero-drift op amp connected as a non-inverting gain stage. With OUT connected to SENSE, the gain is set by

an integrated precision resistor ladder. For gains up to 1024V/V, the accuracy is guaranteed to be better than $\pm 0.6\%$ over temperature (Figure 2), with a typical gain drift of less than 2ppm. A

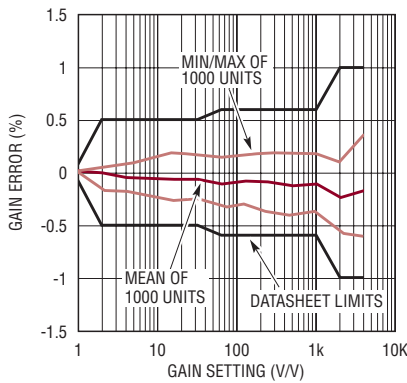


Figure 2. The gain accuracy of the LTC6915 is typically better than 0.5%.

3kHz sampling rate means that signals from DC to 1.5 kHz can be amplified by the LTC6915.

The LTC6915 has the outstanding DC precision inherent in all of Linear Technology's zero-drift amplifiers. The room temperature DC offset is less than $\pm 10\mu\text{V}$ with less than $\pm 50\text{nV}/^\circ\text{C}$ of drift. The 10nA maximum input bias current means there is no additional DC error from source impedances up

to 10k Ω . The high CMRR and PSRR make the LTC6915 immune to fluctuations in power supplies or common mode levels.

The LTC6915 has both a parallel and serial digital interface. Its unique logic design makes it possible to guarantee input high and low thresholds (V_{IH}/V_{IL}) of 2.0 and 0.8 volts for any power supply voltage from 2.7V to $\pm 5.5\text{V}$. Therefore, microprocessors or FPGAs running on a 2.5V supply can directly interface to the LTC6915 without restriction. The LTC6915 supply can be a single 2.7V up to a split $\pm 5.5\text{V}$ supply without additional level shifting of the digital inputs.

Versatile Serial Control

Connecting the PARALLEL/SERIAL pin to V^- puts the LTC6915 in serial control mode. The chip select (CS), clock (CLK), and DATA pins form a simple 3-wire serial input (Figure 3). For daisy chaining (Figure 4), there is also a data out (DOUT) pin. By

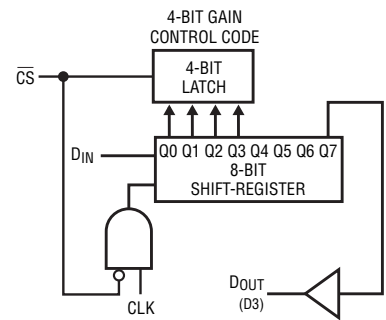
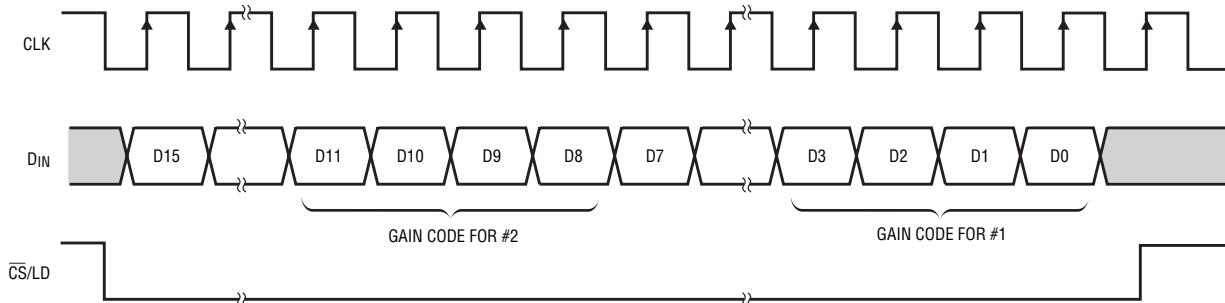
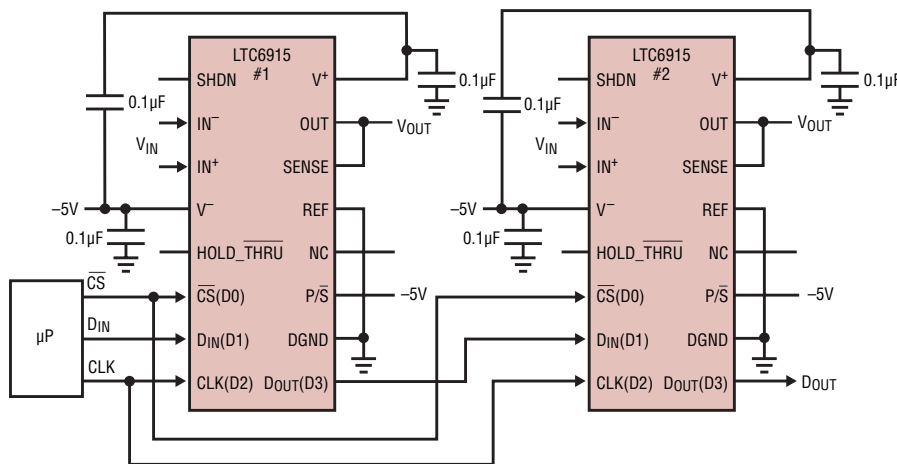


Figure 3. The LTC6915 uses a simple and standard 3-wire serial interface.

using the falling edge of the clock to output data, the LTC6915 is immune to the slow rise and fall times often encountered in optically isolated interfaces. But that does not imply that the LTC6915 is slow. When the DOUT timing is unimportant, data can be input to the LTC6915 as fast as 10MHz!

The internal shift register is eight bits wide; the four LSBs set the gain, and the four MSBs are ignored. This simplifies some software designs be-



GAIN CODE	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101-1111
GAIN	0	1	2	4	8	16	32	64	128	256	512	1024	2048	4096

Figure 4. Two LTC6915s can be connected in a daisy chain. The binary codes for each gain setting are also shown.

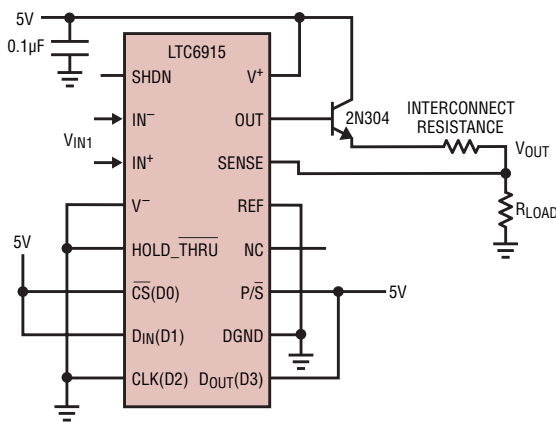


Figure 5. Kelvin sensing at the output maintains precision with increased load drive.

cause the LTC6915 appears to be a “byte wide” device, though it is still an option to load four bits at a time.

Simple Parallel Control

The gain can also be set by simple pin strapping, or through the use of a few spare I/O signals. Just connect the PARALLEL/SERIAL pin to V⁺ and put the LTC6915 in parallel control mode. Four inputs (D3...D0) directly set the gain of the amplifier as also shown in Figure 4. There is even the ability to “latch” the parallel control bits into the LTC6915 using the HOLD/THRU pin (GN16 package). When this pin goes high, whatever signals are present on D3...D0 are latched into the LTC6915. Any changes in D3 to D0 are ignored until HOLD/THRU is brought low again.

A Flexible Output

The SENSE pin allows clever improvements in the load driving or multiplexing ability of the LTC6915. In Figure 5 a discrete NPN transistor is added to increase the load driving ability. The SENSE pin is Kelvin connected to the load. Gain errors from the V_{BE} of the NPN and the IR drop in the interconnect are eliminated. A precise voltage is delivered to the load. Pin-strapping is used to fix the gain of the amplifier to Code 1011, for a gain of 1024, using the parallel interface option.

In Figure 6 two LTC6915s are connected as a multiplexer. One device is programmed for a gain of 0 (three-stated output) while the other device is programmed for a gain ≥1. Using

the serial interface, the gain change of one amplifier, and disabling of the other occurs simultaneously when the CS makes a low to high transition. As a precaution for output shorting,

200Ω resistors are in series with each output in case both amplifiers are ever on simultaneously. The SENSE pin eliminates any error due to the IR drop in the 200Ω resistor during normal operation.

In Figure 7 a software programmable current sink is created using the SENSE pin, an external MOSFET, and the internal gain network. This design can sink a wide range of currents, 0µA to 40.96mA, due to the precision of the internal zero-drift amplifier and the wide range of gain settings. With only 10µV maximum offset voltage error, the circuit operates with an input reference voltage of only 250µV to 500µV. The reference voltage is set by a small regulated current—fixed by the 400mV reference voltage of an

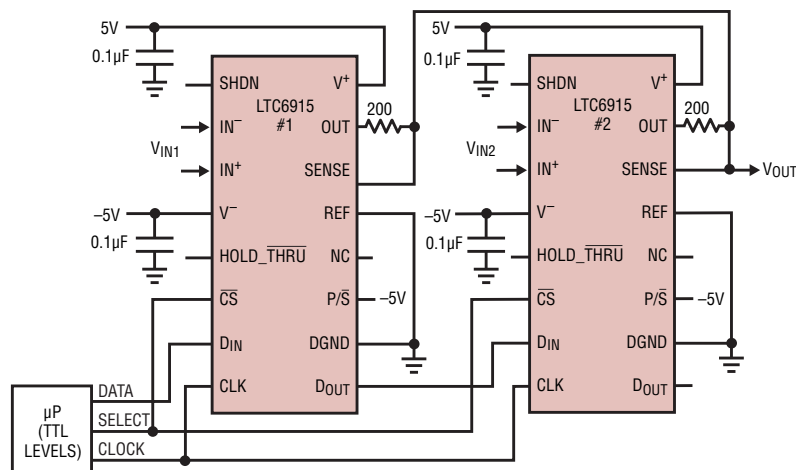


Figure 6. A robust variable gain multiplexer using the high impedance 0 gain setting allows very wide dynamic range in multichannel systems.

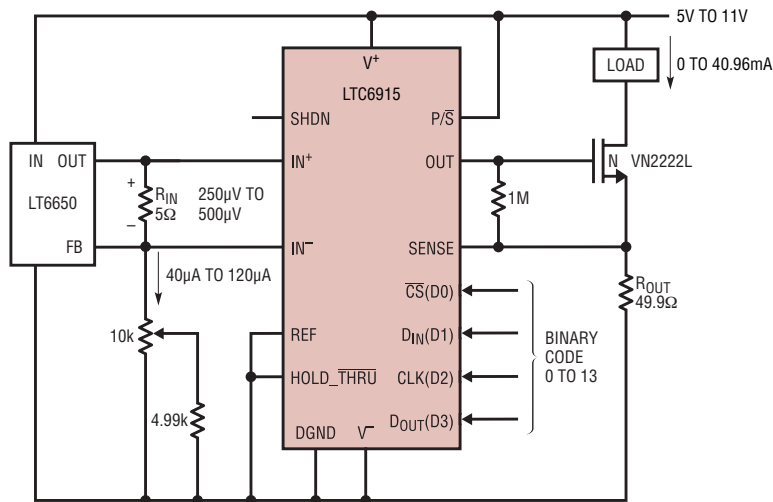


Figure 7. A wide range programmable precision current source takes advantage of the precision of the zero-drift amplifier topology.

LT6650—flowing through a 5Ω input resistor. This small voltage is amplified by the programmed gain of the LTC6915 and forces a current to flow through the 50Ω output resistor via the MOSFET. The voltage compliance of the current sink is determined by the maximum voltage output to the SENSE pin. In this example, the maximum output voltage is only 2.048V, required when the input reference is 500μV and the gain is 4096.

Each successive control code to the LTC6915 increases the output current by a factor of two. Any current level between the binary weighted intervals is achieved by adjusting the input


reference voltage. A gain of 1 provides an output current of 5μA to 10μA, and a gain of 4096 outputs 20.48mA to 40.96mA, with better than ±1% typical linearity.

Bridge Amplifier Application

The LTC6915 is ideal for current sensing, thermocouple amplifiers, strain gauges, and many other low frequency and close-to-DC applications. The internal op amp gain bandwidth product is 200kHz with a slew rate of 0.2V/μs and the response time to 0.1% accuracy to a step change in gain can vary between 4ms and 15ms. Figure 8 shows the LTC6915

amplifying a bridge sensor. When in standby the circuit draws less than 100μA. An interrupt to the processor initiates a measurement cycle, turning on the LTC6915 and acquiring a conversion result from the LTC2431 A/D converter.

Conclusion

The LTC6915 instrumentation amplifier combines outstanding precision analog performance with a flexible digital interface. The result is a software programmable gain stage which is precise and easy to use. 

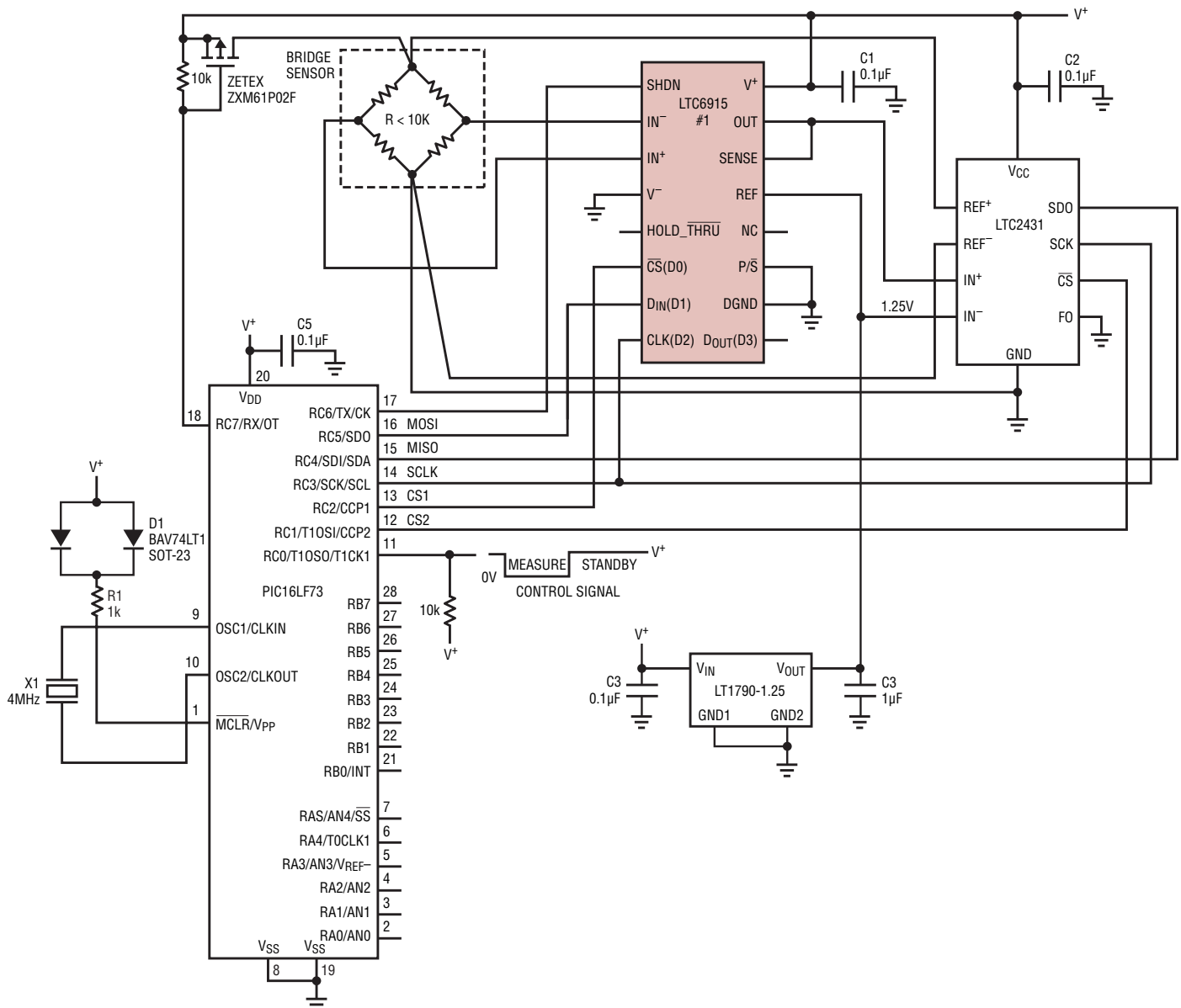


Figure 8. Using the LTC6915 as a direct bridge amplifier in a measurement system with very low standby current