

## **Solve Data Acquisition Compatibility Problems by Combining Features and Performance**

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Modern data acquisition and signal generation systems are both sophisticated and refined. Decades of IC and application development and generations of designs have optimized performance and features, while broadening both. New designs must differentiate from the prior with well-chosen combinations of performance, size, supply range, stability, and more. Simultaneously, high performance integrated circuits such as DACs, ADCs and voltage references have been pushed to the limit for performance. Concerning the voltage reference, often design choices must be made between precision and features. When highest performance is required, flexibility and compatibility can be lacking.

Historically, the highest precision and most stable systems have been designed using deep buried Zener references, as shown in Figure 1. The combination of low drift, high stability and low noise enables systems with both high dynamic range and good stability. However, Zeners are generally not suitable for most new systems. They require significant supply voltage to operate, and many designs are optimized only for particular systems, such as those with greater than 10V supplies, large available board area, and well-understood load impedance. These assumptions are rarely applicable in many new designs. Furthermore, there has been little new development using Zener architectures, so more commonly used reference voltages less than 5V, such as 4.096V, 2.5V and 1.25V, are rare.

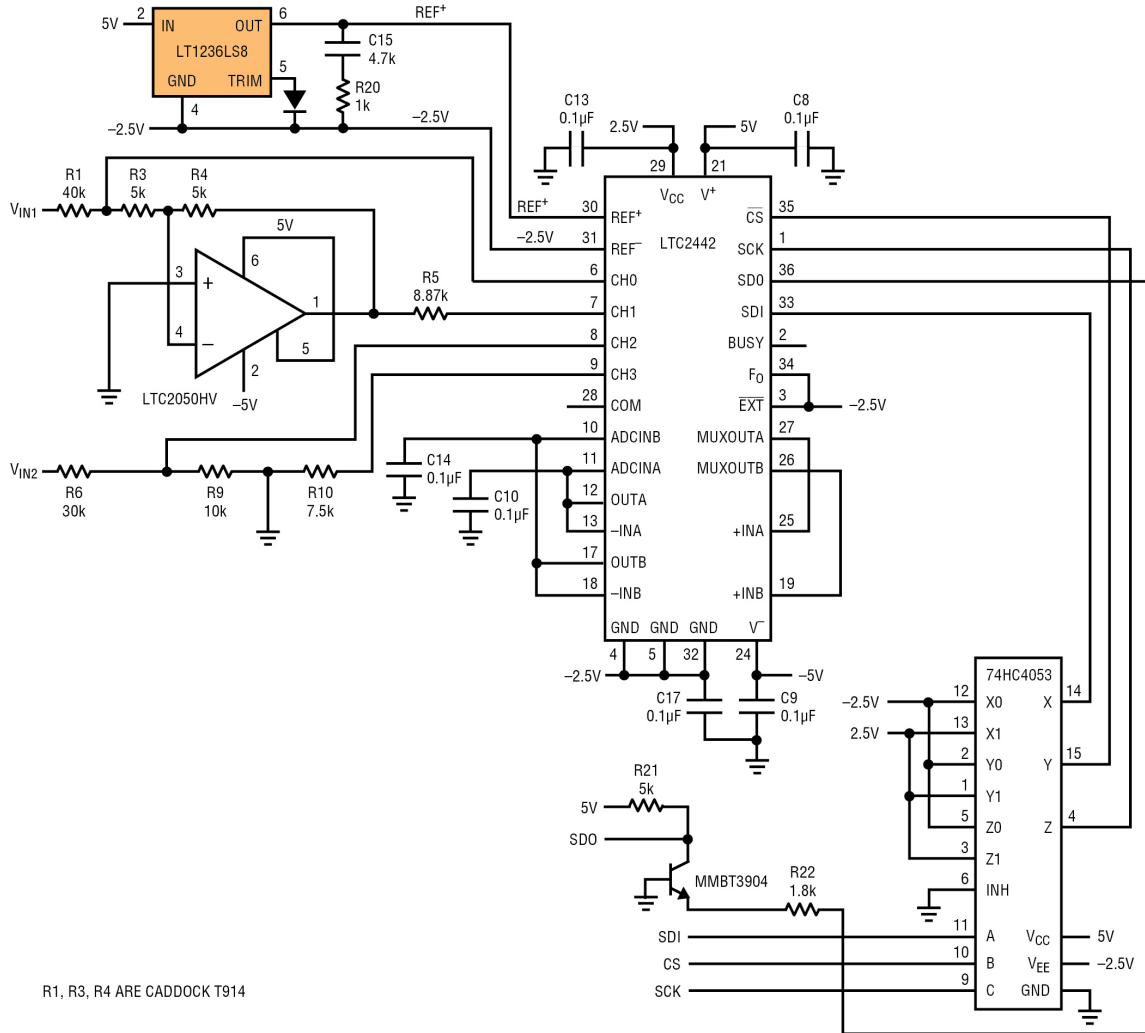


Figure 1 High dynamic range system with the LT1236

In contrast, bandgap voltage references have long been the best choice for a combination of features and performance. The bandgap architecture, while sacrificing some stability as compared to the Zener architecture, has made it possible to design references with many useful features, including low dropout, wide temperature range, low power, small size, wide operating range and wide load current capability. These features have given rise to a host of high-performance LDO regulators as well as precision voltage references. The relatively low bandgap voltage of approximately 1.2V facilitates the design of products with many output voltages, including 1.25V, 2.048V, 2.5V, 3V, 3.3V, 4.096V, 5V and 10V. It also makes it possible to operate from a supply of only a few millivolts above the output voltage, as in Figure 2.

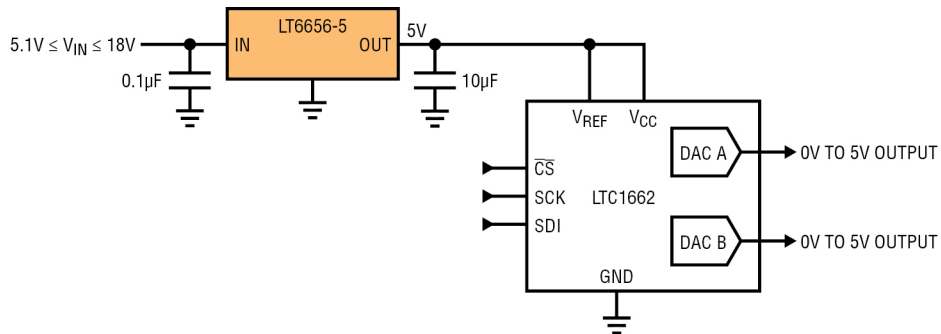


Figure 2 Low power, low dropout voltage reference circuit

For voltage references, the largest error is usually the temperature coefficient (TC). For many precision systems, a voltage reference with 20ppm/°C temperature coefficient is appropriate. However, over an industrial temperature range (-40°C to 85°C), this temperature coefficient would give a maximum error of 2500ppm, or 0.25%. By comparison, the error due to the initial accuracy (0.1%), thermal hysteresis (usually around 100ppm), and long-term drift (50ppm/√(kHr)) is small. While sufficient for many industrial and medical systems, precision applications such as test and measurement, as well as wide temperature range automotive applications, demand better stability.

Over time, bandgap performance has improved, and in some cases exceeded buried Zener stability and noise. New architectures, processes and manufacturing techniques have pushed the limits of precision and stability. Where previous “precision” bandgap references might have boasted 20-50ppm/°C temperature coefficient, newer products provide temperature stability of less than 5ppm/°C. Simultaneously, the range of features has been preserved or improved.

Such is the case for the LT6657, a high precision bandgap voltage reference. The LT6657 provides a new alternative, giving highest precision while retaining significant flexibility for a wide array of system requirements and limitations.

With a temperature coefficient of 1.5ppm/°C, the LT6657 is the lowest temperature coefficient bandgap voltage reference. High-order temperature compensation keeps the output voltage error low and predictable over temperature (Figure 3), while state of the art manufacturing ensures consistent performance from part to part and lot to lot. To ensure that every device meets this high level of performance, the LT6657’s temperature coefficient is guaranteed by 100% five-temperature testing. From -40°C to 125°C, the LT6657 guarantees less than 250 parts per million of error due to temperature drift.

It should be noted that a box is included in Figure 3 to indicate 1ppm/°C of error. A typical LT6657 unit fits well within this box, allowing for reasonable yield to the 1.5ppm/°C limit in automated production testing.

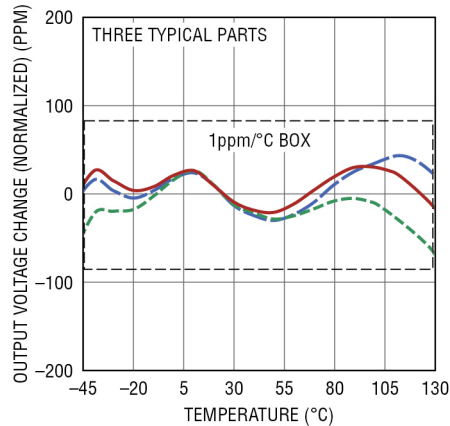


Figure 3 LT6657 temperature drift

Adding to the overall stability are low thermal hysteresis and excellent long-term drift stability. These measures predict how well the system will stay within specification over time and temperature cycles. For systems that are located remotely or difficult to calibrate, lower thermal hysteresis and long-term drift translates to fewer calibration events, saving time and expense. While typical values in the electrical table provide helpful guidance, it is never clear if these represent a mean, a deviation, or a single unit. Linear Technology provides substantial data to give meaningful guidance when designing with voltage references. Long term drift and hysteresis distribution data is available in the LT6657 data sheet showing that both are low and consistent.

Another aspect of voltage reference performance is noise. Many systems are not sensitive to long-term drifts such as temperature or aging, but require very low noise to enable high resolution measurements. With the LT6657, noise performance is comparable to some of the best low-noise buried Zener references. At only 0.5ppm, the noise is appropriate for many high dynamic range systems. The LT6657 produces only 1.25 $\mu$ V peak-to-peak noise in 0.1Hz to 10Hz for a 2.5V reference voltage. Wideband noise is also low, at 0.8ppm (2 $\mu$ V) RMS to 1 kHz. The low noise of the device makes it a good candidate for high dynamic range and very low noise systems. To illustrate the importance of this low noise, a 20-bit converter with 5V full-scale input has an LSB of only 4.8 $\mu$ V (~1ppm).

In addition to the low temperature drift, high stability and low noise, the LT6657 adds further features. The LT6657 requires only 50mV of headroom for operation. It is possible to power a 2.5V reference from less than 2.6V with no DC load, or less than 3V with a heavy DC load current. The supply range extends to 40V with less than 1ppm/V of line regulation error and excellent ripple rejection, allowing the flexibility to power the reference from almost any available power supply which is a big differentiator over a Zener reference.

As with most of Linear Technology's recent voltage reference products, the LT6657 exhibits low output impedance over frequency. This reduces the effect of

changing load over frequency and helps prevent signals present at the load from backfeeding the reference and causing interference, errors or noise. This feature is critical for reference settling when driving a high performance analog to digital converter (ADC), or surviving operational tests such as bulk current injection in automotive systems. In addition, the LT6657 is designed to drive large output capacitance. Given that many high-performance ADCs draw large charge-injection currents from the voltage reference during sampling, the combination of fast settling and the ability to remain stable by design into a large charge-reservoir capacitor gives this voltage reference an edge in squeezing the best performance from a high dynamic range converter.

The LT6657 also has ample drive capability, and can source and sink up to 10mA of load current, with less than 1ppm per milliamp of load regulation error. This load-driving capability enables the LT6657 to bias a variety of sensors, drive difficult ADC reference inputs, drive multiple ADCs and DACs, or power a small subsystem with reference-grade precision. This little-utilized feature can help a system designer make the most of board area and power dissipation by merging the power and reference functions in some small data acquisition systems. It is ideal when the ADC or DAC uses the same voltage for both power and reference voltages; the small MSOP package of the LT6657 adds to the space-savings. Furthermore, the LT6657 includes current and thermal protection to avoid damage from excessive load during fault conditions.

Finally, the LT6657 can operate as a shunt reference. One benefit of shunt-mode operation is the ability to create a negative voltage reference. Shunt mode operation also allows the LT6657 to work from a very high supply voltage or to operate from the lowest possible dropout voltage. Figure 4 shows a positive shunt configuration for the LT6657.

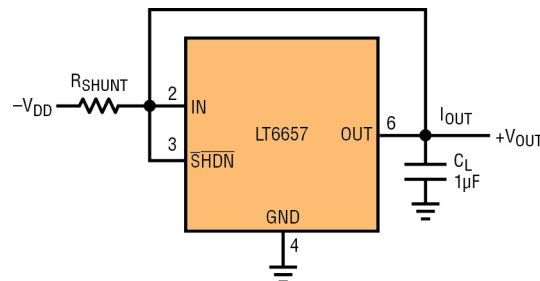


Figure 4 Using the LT6657 in a shunt mode configuration

Figure 5 shows the LT6657 in a low noise precision 20-bit ADC application. In this case, the low noise, low temperature drift and high stability of the LT6657 allows use of a high precision ADC such as the LTC2378-20 with improved performance, but without the added board space and supply headroom of older buried Zener solutions.

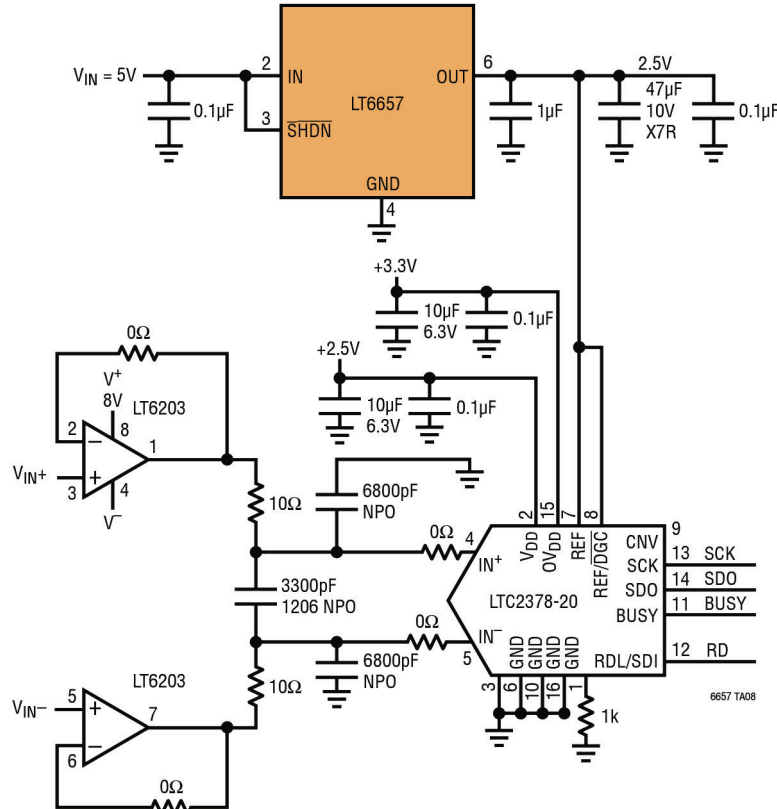


Figure 5 Low noise precision 20-bit analog-to-digital converter application

In conclusion, the LT6657 offers high precision, low noise and high stability, combined with the flexibility provided by its many features. The device's features enable design of a system that is power and area efficient, compatible with a wide range of supply voltages and environmental conditions, and capable of the highest precision, stability and dynamic range. The additional features and performance of this groundbreaking voltage reference, combined with manufacturing quality, make it ideal for many application circuits.