

1 Problem Statement

An Analog to Digital Converter (ADC) is only as good as its voltage reference, be it internal or external. The ADC depends on voltage references because they perform relative measurements with respect to known good references. The RAD1419 comes with an on-chip, temperature compensated, curvature corrected band-gap reference. In most applications, the internal reference works well, but the RAD1419 is an up-screened commercial device (LT1419) for space applications. While the device performs very well it is possible that the internal reference can move over supply voltage, temperature range, and post radiation because the reference is not characterized as part of the screening process or designed to tolerate the heavy ion environment of space-borne applications.

The RAD1419 internal voltage reference is specified at ambient temperature (25°C) to supply between 2.48V to 2.52V. The temperature coefficient is not bound by a max value. Therefore the output voltage drift over temperature is not limited to +/- 15ppm/°C. The user can solve this unknown by using an external radiation hardened voltage reference such as Cobham's RHD5964 which can guarantee performance in space applications. The device is a radiation hardened external voltage reference and is well suited for use with the RAD1419 and other ADC's requiring 2.5V precision references.

2 Overview

Modern satellite systems require the ability to convert analog signals to digital signals because digital signals can be monitored, processed and stored using solid state processors and memory. The conversion is done using ADCs. The ADCs come in a host of different technologies, topologies, sample rates, and resolutions. Engineers can select ADCs with sampling rates from Kilo (10³), Mega (10⁶), and even Giga (10⁹). The sample rates correlate to sample rates per second (SPS), i.e. KSPS, MSPS, and GSPS. This allows sampling of signals from GHz frequencies to DC using the vast array of ADC's available on the market. Resolution for ADC's generally varies from 8-bits up to 24-bits. The output resolution, also referred to as "number of bits", defines the associated voltage per least significant bit (LSB) from the digital output. For example, an 8-bit converter working on a 5V signal means LSB will equate to:

Equation 1.

$$\frac{5}{2^8} = \frac{5}{256} = 19.5mV \text{ per step}$$

As the bit resolution increases, the voltage per LSB shrinks. In the case of a 14-bit ADC working on a 5V signal, the result is:

Equation 2.

$$\frac{5}{2^{14}} = \frac{5}{16384} = 305\mu V \text{ per step}$$

By moving from 8-bits to 14-bits of resolution, the voltage per LSB drops from 19mV to 305μV, which is nearly 2 orders of magnitude.

Signal conversion is the fundamental purpose of an ADC, and it is imperative that the conversion has a known good voltage reference. It is also important for the voltage reference to be stable over operational environment factors such as temperature and voltage fluctuations. Many ADCs come with built in voltage references. Some are based on an internal trimmed band gap or Zener diode. Even ADCs that come with a built in reference usually have the option of using an external voltage reference. An external voltage reference can be more accurate over the variety of operational characteristics. The accuracy of a voltage reference is limited to its design and many characterize the variations in parts per

million (PPM) over temperature, process, voltage, and radiation. This white paper explores the use of two complimentary Cobham parts: the 14-bit ADC RAD1419 and the 2.5V Series Band Gap Precision Voltage Reference, RHD5964.

2.1 Operation of RAD1419

Cobham offers several standard product ADC solutions, one of which is the RAD1419. The RAD1419 is based on the Linear Technology LT1419 die and is up-screened for space applications. The RAD1419 is a 14-bit sampling ADC, which can convert at 825 KSPS and draws approximately 150mW from dual +/-5V supplies. The ADC includes high dynamic range sample-and-hold, single-ended, or differential inputs and two digitally selectable power shutdown modes that provide flexibility for low power systems.

The RAD1419 has a full-scale input range of +/-2.5V with excellent AC performance, which includes 80dB Signal-to-Noise and Distortion Ratio (SINAD) and 86dB Total Harmonic Distortion (THD) at the Nyquist input frequency of 390kHz. The device can acquire input signals up to 20MHz bandwidth. The ADC is microcontroller compatible with a 14-bit parallel output, and no pipeline delay in the conversion results. The RAD1419 has an internal +2.5V reference with a series resistor into a high impedance amplifier. The series resistor also goes to an output pin allowing for the optional use of an external reference.

2.2 Operation of RHD5964

The RHD5964 Precision Voltage Reference is designed for harsh space environments providing long life with high accuracy and stability. The voltage reference is RadHard-by-Design (RHD) with radiation hardness levels exceeding 1Mrad(Si) at a dose rate of 50-300 rads(Si)/s. The device is CMOS, making it immune to Enhanced Low Dose Rate Sensitivity (ELDRS). The RHD5964 has a Single Event Latch (SEL) up value of >100MeV-cm²/mg, making it essentially immune to single event latch-up.

The RHD5964 comes in small 3-pad SMD 0.5 package and requires only 5mW of power. The RHD5964 uses 0.63mA typical at an input voltage from 3.0V to 5.0V and maintains long-term stability of 100ppm over a 1000hr life test.

Electrically, the RHD5964 exhibits stable output voltage over the full military temperature range. The output of the voltage reference varies from 2.505V to 2.502 over temperatures from -55 °C to +125 °C, peaking at a little over 2.51V near ambient, see Figure 2. Additionally the device will draw no more than 1mA maximum, has a 35ppm/ °C temperature coefficient maximum, and long term stability of 100ppm after a 1000hr life test.

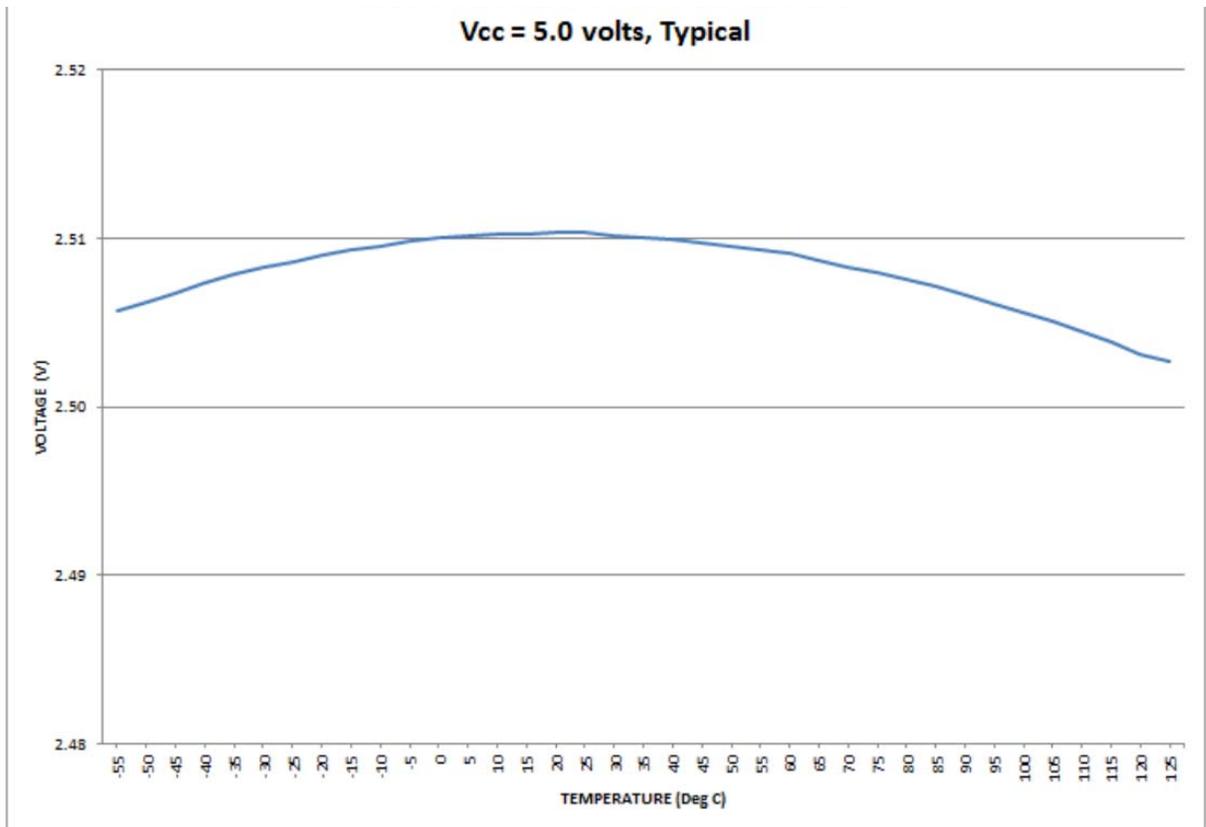


Figure 1 Output Voltage vs Temperature

3 Pairing Up The RAD1419 to RHD5964

In harsh environments like those encountered in Low Earth Orbits (LEO), Geosynchronous Earth Orbits (GEO) and deep space missions, providing a stable reference to the ADC helps guarantee accurate operation throughout the mission. Mating the RHD5964 to the RAD1419 provides a reliable long-term space solution capable of maintaining accurate ADC performance over mission life and under harsh heavy-ion bombardment.

The RAD1419 ADC has an internal reference connected through a 2.0k Ω resistor to a reference amplifier. The amplifier provides a gain of 1.625V, which creates a reference output value of 4.0625V. The 4.0625V is output on the REFCOMP pin. Along with being placed on an output pin, the 4.0625V is driven by a 14-Bit capacitive Digital to Analog Converter (DAC) within the ADC itself. The reference amplifier gains up any significant variations in the original 2.5V internal reference. Errors from the reference amplifier cause errors in the capacitive DAC and external 4.0625V reference. Using a voltage reference that is stable over temperature, process, voltage, and radiation enables continued accuracy from the ADC.

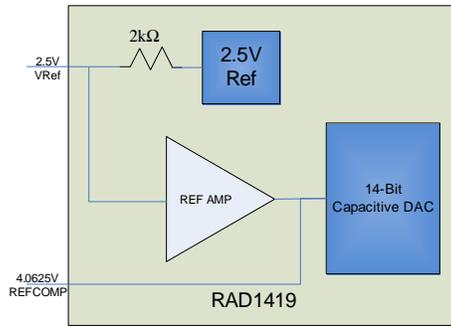


Figure 2 ADC Schematic for 2.5V Reference Input and 4.0625V output

Using an external reference with an ADC is straightforward. The devices connect directly to one another with the RHD5964 Vref output driving the RAD1419 Vref input. The interconnection between the two devices is shown in Figure 3.

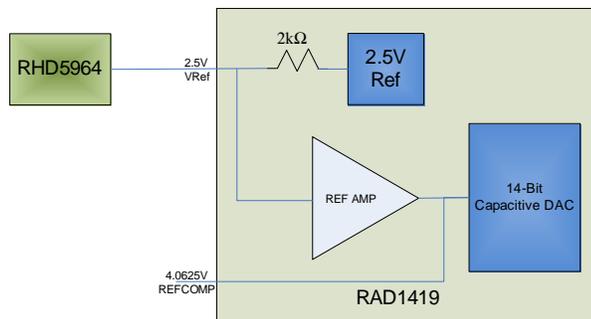


Figure 3 RHD5964 to RAD1419

Some voltage references require a trim resistor and capacitor. The RHD5964 does not require a trim resistor or a capacitor. However, using an optional capacitor C_{opt} will help settle any noise ripple that may transition through or from the device. The use of an external capacitor for improved noise stability is shown in Figure 4. Even though the output capacitor is optional, the capacitor can provide energy for transient load currents as presented by some ADC's. It is up to the designer to verify, when using the RHD5964 with other ADC's via the datasheet, to determine the capacitive loading the circuit can support.

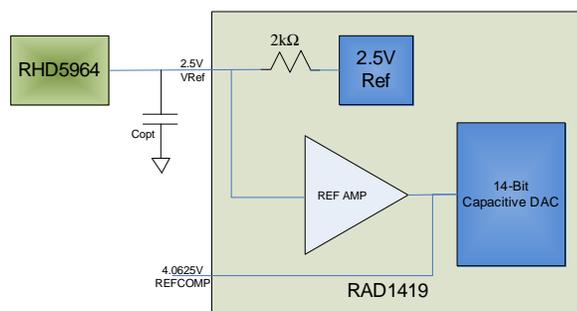


Figure 4 RHD5964 with Capacitor to RAD1419

4 Summary

The RAD1419 is a good choice for space applications that require a mid-speed ADC. The RHD5964 is an excellent companion to provide a stable, radiation hardened, external voltage reference for precision ADC's. This pairing works well to provide a stable voltage reference for the 14-bit ADC to perform signal conversion in a harsh operational environment.

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