White Paper

Radiation Tolerant Multiplexers Move to Low Voltage Rails for Space Flight

Introduction

When a satellite is launched into space, it's accompanied with a multitude of sensors that read out various telemetry signals and statuses for mission critical systems. Because digital microprocessors have a limited number of input/output (I/O) pins, they interface with these sensors using multichannel analog multiplexers that output telemetry signals through an analog-to-digital converter.

The analog multiplexers take up only one I/O pin for reading sensors and are only limited by the number of available input channels. Following the trend of the semiconductor industry, power voltage rails have fallen and thus the need for a low voltage multiplexer that can work in radiation prone environments has emerged.

This white paper discusses the challenges of using low voltage 5V analog multiplexers for spaceflight applications that must withstand the effects of radiation exposure. We'll examine the tradeoffs of switch on resistance, switch input leakage, and propagation delays, including their impact on power consumption and system performance.

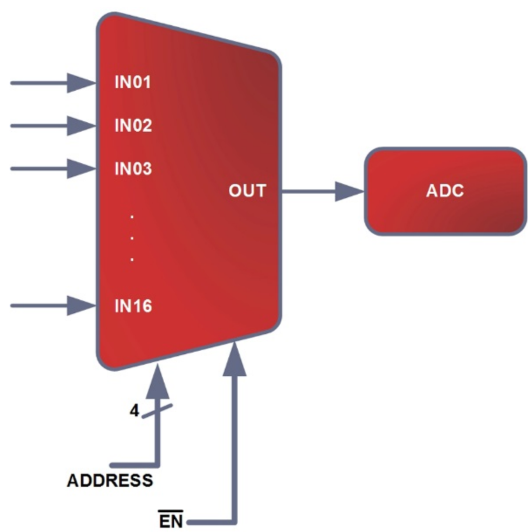

Figure 1. 16-channel multiplexer typical application diagram

Current Multiplexer Tradeoffs

There are options currently available to fulfill the needs for analog multiplexers in the satellite industry, but none is particularly an ideal solution. One option available is to use a high voltage multiplexer because its input range would more than encompass the needs of a low voltage sensor, but this option would require a negative power supply rail just for the multiplexer alone.

This option is in fact being used in many low voltage applications today, but the extra negative voltage rail is undesirable. The other option is to get a multiplexer that's meant to work at lower voltages. There are 5V options, but almost all of them make the satellite design engineer choose between lower switch on resistance or lower switch input leakage. Making this choice is a tradeoff every engineer has to make: when the switch is on, the on resistance distorts the input signal, and while the switch is off, the switch's leakage provides a constant drain on the batteries. Choosing one or the other is a choice between getting more precise sensor readings and getting longer battery life, both of which are critical to satellites.

As with other lower voltage devices, propagation delays get smaller, so having a multiplexer that can keep up is an advantage. The high voltage multiplexer options generally have much longer delays because of the larger devices they use. Faster address transition times translate to getting data closer to real-time and this is key because the reaction of backup or countermeasure systems can occur much faster when sensors report a critical condition.

Radiation Exposure

However, just being fast is not good enough. In space, integrated circuits (ICs) are exposed to radiation in ways that can prevent them from working in full order. Having a multiplexer that is fast might not mean much if it cannot handle single event effects (SEE) or total ionizing dose (TID). TID results in threshold shifts for CMOS devices while SEE becomes more of an issue as the feature size decreases with low voltage devices. Sometimes a multiplexer malfunction can be a minor glitch, but other times the result could be catastrophic.

If the analog multiplexer cannot withstand single event transients (SET), its output could momentarily transition to another channel without the knowledge of the microprocessor and the microprocessor could read the data as a malfunction. After the output returns back, the system reads normal again. An error like this is a minor annoyance and can be programmed out just by making sure the signal persists longer than some predefined time before reading it as valid data--this increases reaction time by adding propagation delay.

If an analog multiplexer has ways to handle SEE, this would all but eliminate the need for a programmed delay and the microprocessor could treat all incoming data as valid. Single event burnout (SEB) and single event latch-up (SEL) can interrupt the normal function of an analog multiplexer. SEB results in a non-functioning multiplexer where SEL may be reversed with a power cycle, but can lead to immediate or latent damage. TID's threshold shifting nature could also cause a multiplexer to stop working altogether, but thankfully lower voltage devices are less prone to threshold movement due to their thinner gate oxides.

No Room for Failure

Another point that is not particularly unique to low voltage multiplexers is reliability. Satellite manufactures want to ensure that these parts last for their mission duration with some margin on top with extremely low levels of risk. They do this by selecting multiplexers that are robust, and by adding redundancy on the system level and on the integrated circuit level. Redundancy on an IC level can be tricky because a redundant multiplexer can load the inputs of an active multiplexer. If done right, a "cold spare" redundant multiplexer can come online in the event the primary multiplexer is non-functional, keeping the system working as planned.

Satellites are multi-million dollar investments that have very little room for failure because there's no chance to perform any repairs while in flight. Thus, it is important to address the effects of TID and SEE while trying to attain the many benefits of low voltage integrated circuits. One tempting solution is to up-screen commercially available multiplexers for radiation tolerant environments. This option has potential advantages from a time-to-market standpoint as the ICs are readily available and they are very cost effective. However, often times it can be a gamble as to whether a part can successfully pass all qualification and radiation tests. Sometimes the availability of these parts can be a hurdle as commercial IC life cycles are much shorter than satellite lifetimes.

The next solution, which is often the most cost-effective, is to purchase low voltage radiation tolerant analog multiplexers as they are designed from the ground up with high reliability in mind. A couple examples include the ISL71830SEH 5V 16-channel multiplexer and the ISL71831SEH 5V 32-channel multiplexer, as shown in Figure 2. These ICs deliver industry-leading performance with low on resistance (120Ω max), low switch input leakage (120nA max), fast address transition times (50ns typ) and SEB resistant to a LET of 60MeV•cm²/mg. Both multiplexers provide cold spare redundancy capability, allowing the connection of 2-3 additional unpowered multiplexers to a common data input line. This is an especially important feature for mission-critical space flights lasting up to 20 years.

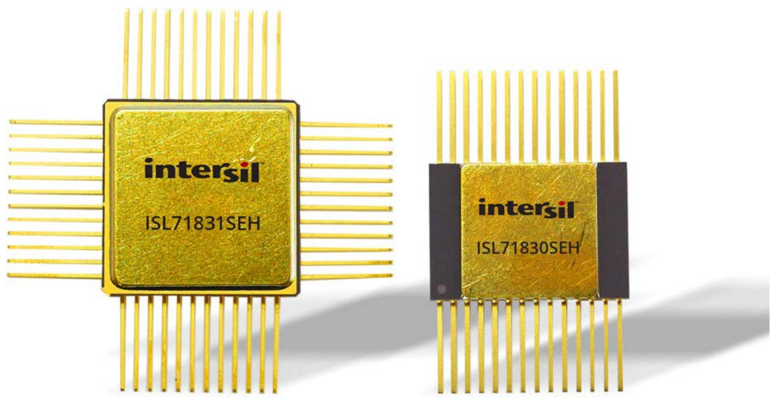

Figure 2. ISL71830SEH 5V 16-channel multiplexer and ISL71831SEH 5V 32-channel multiplexer

Conclusion

Because analog multiplexers are integral in any satellite or deep space flight system, as well as other high reliability systems, it's important to consider the device with the best performance and one that can maintain the performance under the harsh effects of radiation. A non-functional multiplexer can potentially cripple an entire satellite. To ensure no mission fails, having a cold spare redundant capable multiplexer is mandatory for long duration space flights. If for any reason a multiplexer fails, a redundant multiplexer can be immediately activated.

Next Steps

- Learn more about the ISL71830/31SEH
- Get the datasheet
- Download the test reports
- Watch a demo video

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