Flexible electronics for space applications

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Evolution Calculation 3 (3), 220-235 (1999) CrossRefGoogle Let scholars set the stage for this discussion and I can suggest this scenario: Imagine yourself as an astronaut sitting in the crew module of a NASA Orion spacecraft. You expect a final countdown to the ignition of the largest rocket ever designed, stepping through the final equipment checklist for sailing to Mars while sitting at the top of the rocket - nasa space launch system. You are sitting 384 feet in the air on a giant, 130 metric ton configuration, the most competent and powerful projectile in history. When you hear that famous word gentleman, we have ignited, you'll have 9.2 million pounds of thrust propelling you into space. The Orion spacecraft is being designed to take humans to Mars and move into deep space where temperatures can approach more than 2000°C, where radiation is deadly and will travel at speeds of up to 20,000 mph. Now ask yourself what quality electronic component grade is selected for your spacecraft's control system. Devices with high reliability and spatial heritage are key elements in component selection for space-level applications. NASA typically assigns Level 1, a class V (QMLV) device to a list of qualified manufacturers, and they will always ask if there is a high quality level available. You may be sitting on top of this rocket, aware of the extensive selection process NASA uses to identify electronic components for space flight applications. The first obstacle to overcoming the spacecraft's harsh environmental conditions and the hazardous space electrons posed to electronics is the vibrations imposed by the launch car. The demands placed on the rocket and the payload during launch are severe. Rocket launchers generate extreme noise and vibration. There are literally thousands of things that can go wrong and result in a ball of fire. When a satellite separates from a rocket in space, a major shock occurs in the satellite's body structure. A spark shock is a dynamic structural impact that occurs when an explosion occurs in a structure. Pyroshock is a two-stage separation of the reaction or multi-stage rocket of the structure to the high-frequency, high-pitched stress waves propagated throughout the structure as a result of the explosion load, as used for satellite emission. Pyroshok exposure can damage circuit boards, short electrical components, or cause all kinds of other problems. Understanding the firing environment provides a greater audit of impact and vibration requirements and provides inspections imposed on electronic components designed for use in space-level applications. Out-of-the-way is another major concern. Plastics, adhesives and adhesives surpass the gas. Steam from plastic devices can degrade performance by depositing materials in optics. For example, a car plastic dashboard can emit steam that precipitates film on the windshield. This is a practical example from personal experience. The use of ceramics, not plastic parts, eliminates this problem in electronics. The gasification of volatile silicon in low Earth orbit (LEO) causes clouds of pollutants around the spacecraft. Contamination from falls, ventilation, leaks and propellor launches can degrade and modify the outer surface of the spacecraft. High levels of contamination on the surface can contribute to electrostatic discharge. Satellites are vulnerable to charging and discharging. For this reason, spatial applications need parts that do not have floating metal. Satellite charging is an electrostatic pre-electricity fluctuation of a satellite in relation to the surrounding low-density plasma around the satellite. The range of charging depends on the design of the satellite and its orbit. The two primary mechanisms responsible for charging are plasma bombing and photoelectal effects. Discharges of up to 20,000V are known to occur on satellites in geospatial orbits. If no protective design measures are taken, electrostatic discharge by energy accumulated in the space environment can damage the device. The design solution used for geo-motor Earth orbit (GEO) is to coat all the exterior surfaces of the satellite with a material of the channel. Leo's atmosphere consists of approximately 96% atomic oxygen. Oxygen exists in different forms. The oxygen we breathe is O2. O3 occurs in the earth's upper atmosphere, and O (one atom) is an atomic oxygen. Atomic oxygen reacts with organic matter in the exterior of the spacecraft, which can gradually damage it. Material erosion by atomic oxygen has been noted for NASA's first space shuttle mission, where the presence of atomic oxygen caused problems. The space shuttle material actually seemed frosty because it was eroded and textured by the presence of atomic oxygen. NASA solved this problem by developing a thin film coating that is immune to reactions with atomic oxygen. Plastics are quite sensitive to atomic oxygen and ionized radiation. A coating resistant to atomic oxygen is a common method of protection against plastics. Another obstacle is the very high temperature fluctuations caused by the spacecraft. Satellites orbiting the Earth can be divided into two phases. Phase and eclipse phase illuminated by sunlight. In a sunny phase, the satellite is heated by the sun and the temperature can change to 300 °C as the satellite moves around the back of the Earth or around the shadowy side. Because it is close to the sun, the temperature fluctuations of satellites in GEO fixed orbits will be much greater. Temperature changes in LEO's satellites. Note that during the day and night of the lunar calendar, the temperature on the moon's surface can vary from about -200°C to +200°C. It makes you wonder how even a man was able to walk on the moon. Here, too, ceramic packages can withstand repeated temperature fluctuations, provide higher levels of jams, and maintain functionality at higher power levels and temperatures. Ceramic packages offer higher reliability in harsh environments. So how do you dissipate the heat generated by electronics? The accuracy and life expectancy of electronic devices can be degraded by constant high temperatures. There are three ways to pass heat: convecvecing, diffusion, and radiation. In the vacuum of space, no heat convecvecion or ionotherm occurs. Radiant heat transfer is the main way to transfer heat in a vacuum, so satellites release heat into space to cool it. The vacuum of space is a favorable environment for tin beards, so prohibited materials are a concern. Pure tin, zinc and cadmium plating is prohibited in IEEE components and related hardware. Such materials are subject to spontaneous growth of beards, which can cause electric shorts. Tin whiskers are electrically presymedic, crystal structures of tin that sometimes grow on surfaces where tin is used as the final finish. Devices with pure tin leads can suffer from the phenomenon of tin beards, which can cause electric shorts. With lead-based solder, there is no risk of shorts when using the device in a high-response application. Finally, the cosmic radiation environment can have a detrimental effect on spacecraft electronics. There are significant changes in the level and type of radiation a spacecraft can cause. Missions flying in low Earth orbits, highly elliptical orbits, geosym orbits and interplanetary missions have much different environments. And this environment is changing. Radiation sources are affected by the activity of the sun. The solar cycle is divided into two phases: solar minimum and solar maximum. Does the spacecraft mission occur during the solar minimum, the maximum duration of the sun, or both? The important thing here is that the environment in the space is vastly different. The requirements for projectiles vary greatly from that of still-orbit satellites or Mars probes. Each space program must be evaluated in terms of reliability, radiation tolerance, environmental stress, launch date, and the expected life cycle of the mission. Analog devices are highly reliable devices that have supported the aerospace and defense markets for more than 40 years. Areas of focus are electronic warfare, radar, communications, aeront electronics, unmanned systems, missiles and smart ammunition applications. The focus is on the space market. Analog devices have the depth and breadth of technology across the entire signal chain in sensors, amplifiers, RF and microwave devices, ADCs, DACs, and output devices that provide solutions to the demanding requirements of the aerospace and defense industries. Revenue in the satellite industry was $208 billion in 2015. The satellite industry has four segments: satellite manufacturing, satellite launch equipment, ground-based equipment, and satellite services. Satellite services are by far the largest segment and a key driver of the entire satellite industry. So, what have satellites recently did for you? I believe most people will be surprised at how much modern life depends on satellite services. If the 1381 satellites currently in operation were shut down, modern life would be largely disrupted. Global finance, telecommunications, transportation, weather, defense, aviation and many other sectors rely heavily on satellite services. There are three main segments of the satellite services market: satellite navigation, satellite communications, and Earth observation. Navigation satellites are used for global distribution of navigation signals and data to provide positioning, location, and timing services. Examples of available services include traffic management, surveying and mapping, vehicle and asset management, and self-driving technology, where driverless cars and trucks are expected to be the next big thing. Examples of communications satellites or SATCOM are television, telephone, broadband Internet, and satellite radio. These systems can provide un disrupted communications services in the event of a disaster that compromises ground-based communications networks. Both business and commercial aircraft inflight Internet and mobile entertainment are seeing growth in the market. Earth observation satellites are used for the transmission of environmental data. Earth's space-based observations promote sustainable agriculture and help in response to climate change, land and wildlife management, and energy resource management. Earth observation satellites help improve the protection of water resources and weather forecasts, so there is a very wide and increasing range of satellite services. So what kind of electronic systems are used for satellites? The basic elements of the spacecraft are divided into two parts: platforms or buses and payloads. The platform consists of five basic subsystems that support payloads: structural subsystems, telemetry subsystems, tracking and command subsystems, power and distribution subsystems, thermal control subsystems, and attitude and speed control subsystems. Structural subsystems are mechanical structures and provide stress and bearable stiffness. It also provides shielding from radiation for electronic devices. Telemetry, tracking, and command subsystems include sensors for receivers, transmitters, antennas, temperature, current, voltage, and tank pressure. It also provides the status of various spacecraft subsystems. Power and powerion subsystems convert solar power and charge spacecraft batteries. The thermal control subsystem helps to protect electronic equipment from extreme temperatures. And finally, the Attitude and Speed Control subsystem is an orbital control system consisting of sensors that measure vehicle orientation and actuators (reaction wheels, propellor) and apply the torque and force required to steer the vehicle in an accurate orbital position. Common components of attitude and control systems include Sun and Earth sensors, star sensors, momentum wheels, inertia measuring devices (ImUS), and electronic devices needed to process signals and control satellite positions. Payloads are equipment that supports basic missions. GPS navigation satellites include atomic clocks, navigation signal generators, and high-power RF amplifiers and antennas. For communication systems, payloads include antennas, transmitters and receivers, low-sound amplifiers, mixers and local oscillators, demodulators and modulators, and power amplifiers. Earth observation payloads include microwave and infrared sound instruments for weather forecasting, visible infrared imaging radiometers, ozone mapping instruments, visible and infrared cameras, and sensors. The integration of analog devices and hittit micro-wave ranges a few years ago now means we can cover DC on the 110 GHz spectrum. ADI solutions range from navigation, radar, communications systems, satellite communications, electronic warfare, radar systems in the microwave spectrum, radar systems, and satellite imaging of millimeter wave specs below 6 GHz. Analog devices offer more than 1000 components, including all RF and microwave signal chains and applications. Hittite's combination of full spectrum RF function blocks, attenuator, LPGA, PA and RF switches can provide end-to-end system solutions with a portfolio of analog devices in high-performance linear products, high-speed ADCs, DACs, active mixers, and PLL. Natural space radiation environmental impact on electronic devices The radiation effect on electronic devices is a major concern of space-level applications. Outside the protective cover of earth's atmosphere, the solar system is full of radiation. Natural space radiation environments can damage electronic devices and have a range of effects, from degradation of parametric performance to complete dysfunction. These effects may result in reduced mission life and major. System error. The radiation environment close to Earth is divided into two categories: particles trapped in the Van Allen belt and transient radiation. The particles trapped in the Van Allen belt consist of vibrant protons, electrons and heavy ions. Transient radiation consists of galactic cosmic ray particles and particles from solar events (coronary mass emissions and solar flares). There are two main ways radiation can affect satellite electronics: total ionization capacity (TID) and single event effect (SE). TID is an immediate failure mechanism, see-to-long-term failure mechanism. See is expressed as an arbitrary failure rate, whereas A TID is a failure rate that can be described as the average time of failure. The source of ionized radiation in interplanetary space (Image: NASA). A TID is a cumulative charge that varies over time on the device over the life of the mission. Particles passing through transistors generate pairs of electron holes in thermal oxides. Accumulated charging can generate leakage currents, degrade the gain of the device, affect timing characteristics, and in some cases lead to complete functional failure. The total capacity accumulated depends on the trajectory and time. In LEO, the main sources of radiation are from electrons and protons (internal belts) and in GEO, the primary sources are from electrons (outer belts) and solar protons. It is worth noting that the accumulation of TID radiation can be effectively reduced using device shielding. SE is generated by single, high-energy particles that pass through the device and inject a charged power into the circuit. In general, SE is divided into soft errors and hard errors. The Joint Electronics Engineering Council (JEDEC) defines soft errors as nondestructive, functional errors induced by energy ion strikes. Soft errors are a subset of SE and include a single event painter (SE), multi-bit painter (MbUS), single event dysfunction (SEFI), single event transient (SE), and single event latchup (SEL). SEL is where the formation of parasitic bipolar action in CMOS wells induces a low impedance path between the force and the ground, producing a high current state. Therefore, SEL can cause potential and hard errors. An example of a soft error would be a bit flip or change to the state of a memory cell or register. SET is a transient voltage pulse generated by a charge injected into the device from a high-energy particle. These transient pulses can cause SEFIs. SEFI is a soft error that causes a component to reset, lock, or other malfunction in a detectable manner, but does not require power cycling of the device to restore operationality. SEFI is often associated with the painter of a control bit or register. JEDEC defines hard errors as irreversible job changes that are typically associated with one or more permanent damages. Failure is difficult because the component or device is no longer functioning properly, even if data is lost and power resets are occurring. Determine that a hard error can be potentially destructive. Examples of hard errors include single event latchup (SEL), single event gate rupture (SEGR), and single event exhaustion (SEB). SE-under errors can destroy devices, draw down bus voltages, or damage system power supplies. On the satellite payload side, technology trends, radiation effects, and instruments are becoming more complex. At one time, a communication satellite bent the pipe refitter architecture to relay signals by default. Today, they are multibeam and have an on-board processing (OBP) architecture. More complex electronic devices translate into greater risks from radiation effects. Large capacity, small satellite constellations are using more commercial grade plastic components. Commercially available (COTS) devices generally tend to be more sensitive to radiation effects. There is also less structural mass shielding electronics, as small satellites. Thinning fine IC studies and oxides reduces sensitivity to TID radiation effects and improves TID tolerance. SE, on the other hand, increases to IC scaling down. To produce SET and SEU, energy is reduced. Using devices with higher frequencies can cause the SET to switch to more SEUs, increasing the number of SEFIs. Mitigation techniques used to solve faster transient signals can be more challenging. Efforts of analog devices to support space-level applications The Space Products Group leverages the device portfolio of analog devices to support the space industry. We have proprietary silicon in insulator (SOI) processes that provide radiation tolerances for space-level applications. In some cases, we modify the core silicon to improve the radiation tolerance of the device. The design can also be implanted into a radiation-curing SOI process. We integrate the die into a hermetically sealed, ceramic package and characterize the device over an extended military temperature range. We aim for the development and launch of fully qualified Class S QMLV products using the Defense Logistics Agency (DLA) MIL-PRF 38535 system, and MIL-PRF 38534 for Class K hybrid and multi-chip modules. For radiation testing we currently offer high capacity speed (HDR) and low capacity speed (LDR) test models and for new product releases we provide single event effect test data. Analog devices provide commercial, industrial, reinforced products (EP), automotive, military, and space-qualified devices. EP devices are primarily designed to meet mission-critical and high reliability applications in the aerospace and defense markets. Other product classes include military-grade monolithic devices, multi-chip modules, and QMLH devices, space-proven monolithic devices, and multi-chip modules designed to military specifications are used as QMLV and QMLK devices. Analog devices offer space-qualified Class K Die for customers developing hybrid or multi-chip module solutions. Class K qualified die standard aerospace data sheets and customer source control drawings are provided. We offer EP, plastic encapsulated devices and high reliability application requirements designed to meet mission-critical requirements. We are starting a new device product category for space applications defined as enhanced products and (EP+) devices through customer input. Customers need improvements in size, weight, power, higher performance, wider bandwidth, improved operating frequency, payload flexibility, and optimized reliability. Spacecraft designers are increasingly being pressured to use commercial devices to meet high levels of performance in smaller, lower-power, low-cost spacecraft. The internet in the sky is a good example. It is estimated that 60% of the world's population does not have access to the Internet. To address this market, companies plan to deploy large constellations of small, inexpensive satellites circling the Earth that enable access to communications networks around the world. Analog devices are working with customers to define EP+ to address evolving new markets. EP provides COTS solutions for high reliability applications at no additional cost. The EP is a plastic encapsulation device that emits a military temperature range of -55°C to +125°C. In addition to extending the temperature range, EP customers must also have a device that is unpaired and beard-free. You need a device with a controlled manufacturing baseline, a stand-off data sheet, and an EP change notification process. These devices have drawings of V62 vendor items connected from defense logistics agency documentation systems. Currently released EPs are identified by special EP suffixes and have separate standalone data sheets. As mentioned, analog devices are developing space-level application EP and new device concepts for LEO systems and high-high-end applications. Supports EP+ for current source-controlled drawings. ADI wants to provide standard COTS-rated devices for space-level applications. The EP+ approach envisions a device somewhere between a standard EP device and a military Class 883 device, delivering a COTS solution for space-level applications without additional custom upsking costs. The EP+ approach enables you to create COTS devices and provide wafer lot tracking performance and lot-specific radiation inspection data. The main problem is determining the right balance between reliability and cost, as described in the curve in Figure 1. More screenings The higher the unit price. When defining this new product category, the current challenge for the satellite industry and analog devices is to define the optimal screening level and cost point for commercial devices used in space-level applications. Figure 1. Reliability testing and inspection reduces electronic component costs. In summary, the goal of analog devices is to provide a complete product for space-level applications as well as components. We offer the industry's most comprehensive portfolio with industry-leading device reliability We offer single lot date code procurement advanced packaging and feature, providing gold and tin lead hot solder deep lead finish to solve harsh environmental problems, so that we do not provide banned material certification comprehensive conformity certificates to solve tin beards. Material Traceability Comprehensive QMLV Flight Unit Test Report Electrical Performance Production Tests in Extended Temperature Range - 55°C to +125°C We offer fully qualified QMLV devices with 100% screening and quality conformity inspection We offer radiation-qualified devices... The HDR, LDR, see long product lifecycle is a cornerstone of ADI's business strategy We have a dedicated aerospace and defense team for product support and applications currently offer more than 90 standard general space qualified devices with more than 350 models from different grades and packages. Some of the space-certified products with new features are ADA4084-2S, ADA4610-2S, and ADuM7442S devices. The 5962R1324501VXA (ADA4084AF/QMLR) is a new low-sound, low-power, space-proven precision amplifier available as a QMLV spatial qualification device for SMD drawings. The device has a 10MHz integrated gain bandwidth and rail-to-rail inputs and outputs. These amplifiers are suitable for single-supply applications that require both ac and precision DC performance. The 5962R1420701VXA (ADA4610-2BF/QMLR) is a space-proven dual-channel, precision, very low noise, low input bias current wide bandwidth JFET device. Amplifiers are particularly suitable for high impedance sensor amplification and accurate current measurements. The ADuM7442 R703F is a 25Mbps quad-channel digital isoliwriter certified space with three front and one back channels. The device provides two-way communication. Space-verified devices provide galvanized insulation, which means that the input and output circuits are not directly electrically connected. It offers advantages over competitive solutions for size, weight, power and reliability. Solution.

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