
**Space systems — Semiconductor
integrated circuits for space
applications — Design requirements**

*Systèmes spatiaux — Circuits intégrés semi-conducteurs
d'applications spatiales — Exigences de conception*

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Foreword

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The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Normative design requirements of semiconductor integrated circuits for space applications largely determine the reliability of an integrated circuit (IC) and its adaptability to space environment, thereby affecting the reliability of space systems. IC tests and experiments based on product specification only can provide a comprehensive evaluation of its reliability. Once applied to space systems, the design flaws will directly affect the implementation of aerospace engineering. The development of design requirements for semiconductor ICs for space applications can ensure its reliability and space suitability from its very source to meet the space application requirements.

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Space systems — Semiconductor integrated circuits for space applications — Design requirements

1 Scope

This document specifies the basic design requirements for semiconductor ICs for space applications, including its design process, as well as required tasks and requirements of each stage. Requirements of specific circuit design are not included.

2 Normative references

The following documents are referred to in text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61967-2, *Integrated circuits — Measurement of electromagnetic emissions*

IEC 62132, *Integrated circuits — Measurement of electromagnetic immunity*

IEC 62215-3:2013, *Integrated circuits — Measurement of impulse immunity — Part 3: Non-synchronous transient injection method*

IEEE 1149.1, *IEEE standard for test access port and boundary — Scan architecture*

3 Terms and definitions

For the purposes of this document, the terms defined in ISO 10795 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

programmable logic device

PLD

hardware-programmable device

EXAMPLE FPGA, CPLD, etc.

3.2

suitability

degree to which a product meets its requirements

3.3

environment adaptability

ability to achieve the entire product's intended functions, performance and (or) capacity for protecting itself under various environments within its life cycle

3.4

testability

ability to perform function and performance testing of the circuit, position the failure of the circuit and select qualified circuit chip as soon as possible

4 Abbreviated terms

ASIC	application specific integrated circuit
BIST	built-in self test
CMOS	complementary metal oxide semiconductor
DFT	design for test
DRC	design rule checking
EMC	electro-magnetic compatibility
ERC	electrical rule checking
ESD	electrostatic discharge
FPGA	field programmable gate array
IC	integrated circuit
I/O	input/output
IP	intellectual property
JFET	junction field effect transistor
MOSFET	metallic oxide semiconductor field effect transistor
NMOS	N-channel metal oxide semiconductor
RAM	random access memory
RC	resistance capacitance
ROM	read only memory
RTL	register transfer level
SAR ADC	successive approximation register analogue digital converter
SCR	silicon controlled rectifier
SEL	single event latch-up
SET	single event transient
SEU	single event upset
SOI	silicon on insulator
SOS	silicon on sapphire

5 General requirements

General requirements in designing semiconductor ICs for space applications include:

- a) process conducted under a fault-tolerant system with design requirements;

NOTE 1 Special implements are allowed for different types of ICs for space applications.

- b) adherence to existing standards and regulations during the design process;
- c) feasibility and risk analysis of requirements from aerospace customer to validate the rationality of its functional and performance requirements;
- d) conversion of users' requirements into design input, which may involve the following steps:

- 1) derating the design criteria;

NOTE 2 Derate on the basis of nominal stress according to the stress of the circuit. The key is the level and effects. Derating can improve reliability, but takes into consideration issues such as reliability, size, weight and cost.

- 2) applying fault-tolerant design and adopting rational use of redundant technology;
 - 3) ensuring the characteristics of the orbit thermal environment for reliable thermal design;
 - 4) considering radiation hardness to ensure grade requirements, if necessary;
 - 5) taking note of the life of customer's requirements (mean time to failure);
- e) decomposition of the design input requirements to each design stage according to its tasks.

NOTE 3 Implement and validate each step until all objectives and requirements of a semiconductor IC for space applications are achieved.

6 Design process

6.1 Overview

IC designs generally include architecture design, logic design, circuit design and layout design. In order to ensure the validity of the design, computer simulation and verification of its results at each stage are necessary. [Figure 1](#) illustrates the IC design flow.

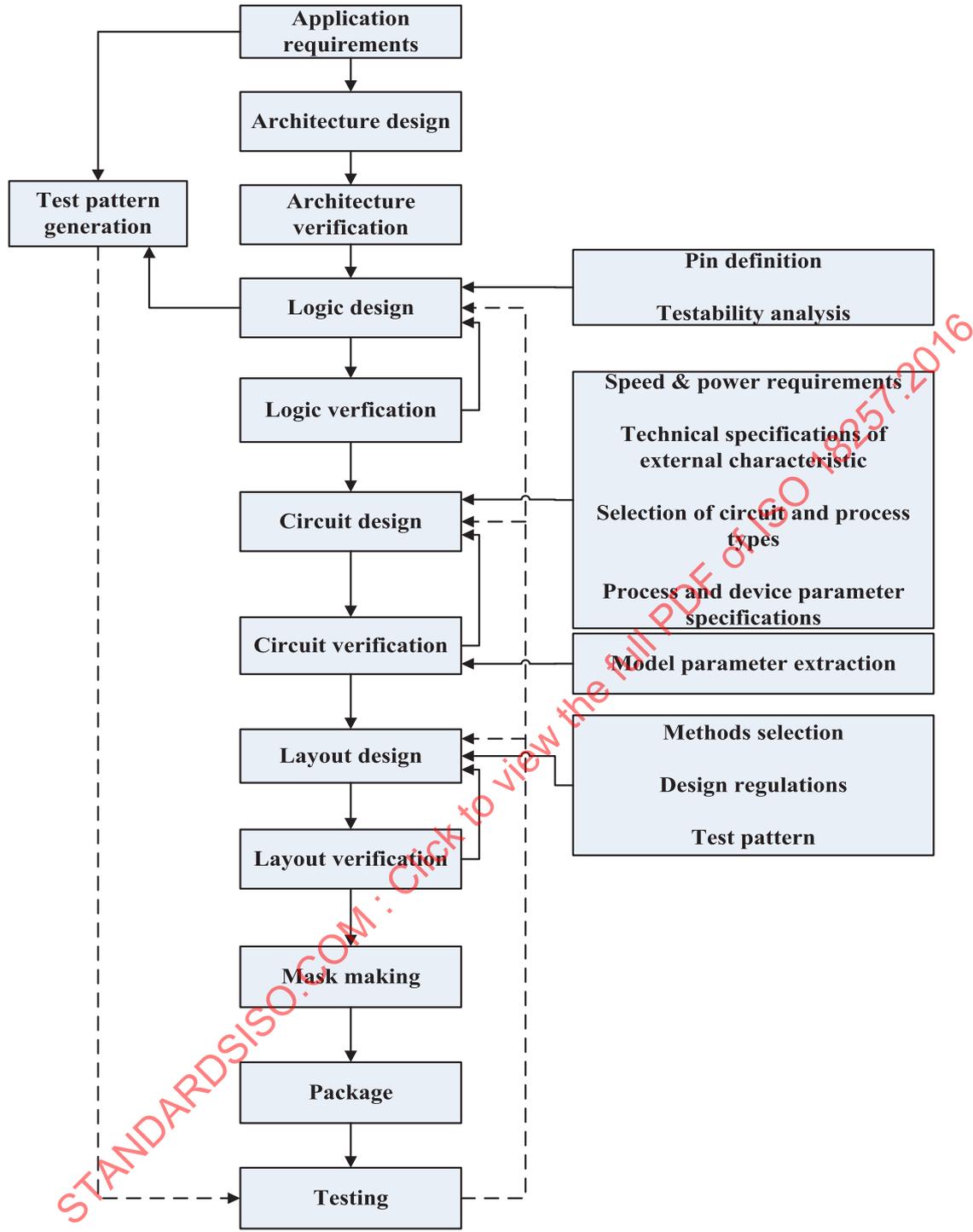


Figure 1 — Integrated circuit design flow diagram

In designing semiconductor ICs for space applications, designers have to follow a general IC design process to convert users’ general and special requirements (i.e. user-oriented features, performance and reliability requirements, etc.) into design input, thereby accomplishing the design goals of each stage to meet the overall requirements. [Figure 2](#) illustrates the decomposition of tasks in the design process of semiconductor IC for space applications.

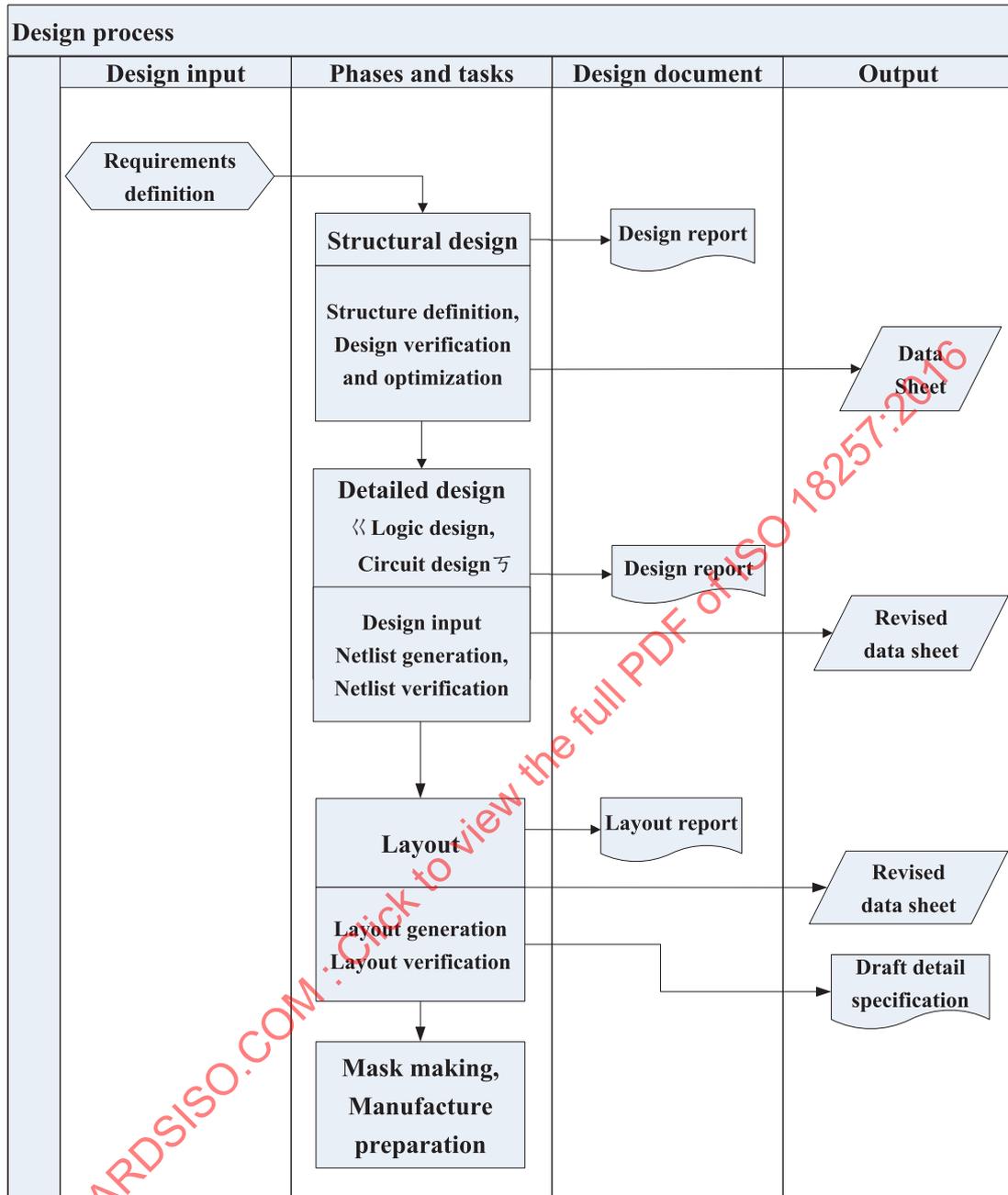


Figure 2 — Decomposition of tasks in designing semiconductor IC for space applications

6.2 Design input

A design input document will be formed after completing the requirements definition. Design input generally includes (modifications are allowed according to specific circuit requirements) the following:

- system division, system configuration and operating mode;
- system interface, external device communication protocols, including memory-mapped register;
- operating frequency range;
- constraints of electrical parameter;
- functional requirements;

- f) application algorithm;
- g) reset and power dissipation requirements;
- h) error handling;
- i) testing mode;
- j) fault coverage requirements of digital circuit testing;
- k) key signal timing;
- l) constraints of the normal working environment;
- m) constraints of the special space working environment, which includes
 - 1) space radiation,
 - 2) heat dissipation in vacuum, and
 - 3) in-space charging effects (i.e. ESD, latch-up);
- n) power dissipation budget;
- o) physical and mechanical constraints include: pin distribution, size, packaging;
- p) reusability and additional features of the product;
- q) new technologies;
- r) intellectual property of design;
- s) IP cores that are necessary and with verification.

6.3 Design phases and tasks

6.3.1 Architecture design

6.3.1.1 Overview

Finding an architecture design that offers efficient functionality at minimal cost, while meeting users' objectives and constraints, is important.

6.3.1.2 Design content

The following is the architecture design process.

- a) Define the chip architecture, verify and record the completion of functions of the basic module, as well as interfaces and interactions.
- b) Select and validate the chip architecture.
- c) Ensure that all definitions and selections are in accordance with the documents made in the definition phase.
- d) Ensure that the output includes:
 - 1) a simulation model,
 - 2) the results verification, and
 - 3) a preliminary datasheet.

The datasheet shall conform to the requirements of [Annex A](#).

Verification: For example, complex digital circuit research and development will be realized through FPGA sample or tested by simulation; digital circuit code coverage requirements; requirements for hardware and software interaction; applications of the code rules.

6.3.1.3 Design verification

The following is the architectural design verification process.

- a) Verify whether the defined architecture meets demands through appropriate simulation and analysis techniques.
- b) Complete independent verification.
- c) Finish the primary placement and routing after the hardware unit is connected, making sure each unit is placed effectively under the given constraints.

NOTE Does not apply to PLD design.

- d) Put in place a back-up plan, in case conflicts occur (i.e. power dissipation and speed, performance, pin number and package size, complexity and area).
- e) Establish a final system design.
- f) Complete the initial datasheet.

6.3.2 Logic design and circuit design

6.3.2.1 Overview

In this stage, the high-level system design is transmitted and transformed to unit-level architecture description with the chosen technology library, and the input information of the next phase, such as layout constraints, placement and routing, and product testing and detailed pin description, etc. are generated. Logic design and circuit design are included. For digital circuits, verified gate-level netlist is generated; while for analogue circuit, verified transistor-level netlist is generated.

6.3.2.2 Design content

The following is the logic design and circuit design process.

- a) Provide complete details of the circuit architecture.
- b) Identify testability description and product testing methods, including extent of fault coverage.
- c) Identify circuit and layout, which are considered together for simulation design.
- d) Test concept of definition during design input and synthesis stage (i.e. scan path, testability logic, test points, test bus and boundary scan).
- e) Identify radiation-hardened concept through design and synthesis stage, when applicable.
- f) Implement step-by-step verification plans and verify the results obtained.
- g) Validate pin leads and connection plans, paying special attention to technical constraints (i.e. power dissipation supply and pin definition).
- h) Select buffers according to I/O requirements.
- i) Ensure that output includes
 - 1) updated datasheet (including output pin), and

- 2) updated design database (including netlist, layout constraints, product testing and testing vectors).

6.3.2.3 Design verification

The following is the logic design and circuit design verification process.

- a) Verify parasitic data and delay data of the assessment layout.
- b) Use the testing method from system design to complete the gate-level simulation, such as formal verification and static timing analysis.

NOTE 1 Does not apply to pure analogue circuits, but applies to digital parts of a hybrid circuit, such as A/D converter and D/A converter.

- c) Verify critical parameters such as bias voltage, operating point, frequency, dynamic, linear range, and modify the timing.
- d) Complete functional verification, including verification of interface.

NOTE 2 It applies to analogue circuit design and analogue part of a hybrid circuit.

- e) If the simulation of the whole mode cannot be completed at the top level (such as operating time limit), simulation of typical mode is allowed.
- f) From the results of simulation of a typical model, verification and analysis can be applied to other models.
- g) Verify the realized testing concepts, such as scan path design, testability design DFT logic, measurement points and test bus.
- h) Verify the radiation-hardened concept at the netlist level.
- i) Verify defined typical power dissipation.
- j) Upload the parameters of the preliminary datasheet according to results obtained.
- k) Generate test vectors and verify the fault coverage requirements.
- l) Complete parameter sensitivity analysis.

NOTE 3 It applies to analogue circuit design and analogue part of a hybrid circuit.

6.3.3 Layout design

6.3.3.1 Overview

Transforming a circuit design into a layout design, as well as its verification, are important parts in the physical realization of an IC design, serving as the transition from the design phase to its manufacture.

6.3.3.2 Design content

The following is the layout design process.

- a) Determine chip placement.

NOTE 1 This does not apply to PLDs.

- b) Complete the placement and routing, ensuring that all constraints are considered.
- c) Complete netlist optimization according to timing and design rules.

NOTE 2 Only applies to digital ASIC design.

d) Generate power dissipation distribution.

e) Generate clock distribution.

NOTE 3 Does not apply to analogue ASIC design.

f) Insert core and pad power, as well as other testing pins.

g) Determine the size of die.

NOTE 4 Does not apply to PLD design.

h) Generate a bonding diagram, ensuring that constraints of package wire are considered.

NOTE 5 Does not apply to PLD design.

i) Ensure that the output contains

- 1) an updated datasheet,
- 2) an updated design database (including layout imitation netlist of the target requirements and related parasitic information), and
- 3) a draft detail specification.

6.3.3.3 Design verification

The following is the layout verification process.

a) Perform a design rule checking (DRC).

b) Perform an electrical rule checking (ERC) if user requests and crosstalk sensitivity shall be checked as well.

c) Extract the netlist from the layout.

d) Verify the consistency between the gate-level netlist and the layout by comparing the layout and the circuit schematic.

e) Verify the functional consistency between the pre-layout netlist and the post-layout netlist through simulation and formal methods.

f) Extract parasitic information.

g) Complete the comprehensive layout verification through anti-standard simulation and timing analysis.

h) Check clock jitter and delay.

NOTE 1 Does not apply to PLD design.

i) Check I/O-related timing.

j) Check chip power dissipation.

NOTE 2 Does not apply to PLD design.

k) Describe timing performance of the circuit (i.e. maximum clock frequency, clock duty factor, input set-up and its holding time, output propagation delay).

l) Update the data table.

6.4 Mask making, package and testing

Once the design is complete, prototype manufacturing begins. It involves mask making, package and testing. The following is the prototype manufacturing process.

- a) Transform correct layout data into data format that is acceptable to the mask system.
- b) Submit basic device electrical parameters and process parameter documents according to design requirements for manufacturers to produce and package.
- c) Test circuit function and its performance parameters by conducting irradiation tests and reliability tests according to requirements of the detail specification to ensure that the product meets the requirements.

7 Detailed requirements

7.1 Architectural design requirements

The detailed architectural design requirements are provided in the list below, while the design guidance is provided in [Annex B](#).

Architectural design requirements include:

- a) semiconductor chips subdivided into basic functions or modules, with each interface, function and interaction identified and recorded;
- b) architecture definition divided into process definition, transistor-level or gate-level mapping;
- c) algorithm and schematics, including realization of functional parameters;
- d) independent chip modules at different positions with each sub-function identified;
NOTE Sub-functions can be compiled as core against other designs.
- e) clock reset program to ensure correct data transmission of clock domains and asynchronous clock part;
- f) generated model as input for subsequent detailed design.

7.2 Logic design and circuit design requirements

Code design shall meet the following specifications when designing digital circuits.

- a) Initial ports state shall be stable and informed.
- b) Comprehensive design principles shall
 - 1) avoid level-sensitive transparent latches and combination of feedback loops when describing combinational logic,
 - 2) have individual temporal logic blocks that can only be triggered by one clock transition within each timing logic block, and
 - 3) employ synchronous design when describing the design.
- c) Asynchronous logic shall be avoided when designing register transfer level (RTL) code. If asynchronous logic has to be employed, synchronizer among asynchronous interfaces is needed to ensure reliability of the design.

- d) An internal logic unit clock generated by employing independent clock management unit, which supports independent reset unit to synchronize the reset input signal in generating the required reset signal of the internal logic unit.
- e) Internal logic unit shall prohibit the use of tri-state bus and combined ring to ensure higher testing coverage of DFT design and circuit reliability.

7.3 Layout design requirements

Layout design requirements include:

- a) a reliable circuit with the smallest footprint;
- b) layout design that meets process design regulations from technology vendors;
- c) die corner design, die seal ring design, wide metal slotting and other design criteria with the following specifications:
 - 1) die corner with a 45° metal wiring in chip corner;

NOTE 1 The size of the die corner is determined by chip size.

 - 2) die seal ring (from substrate to pdiff, contact, metal1, via1 until the highest level of metal) to protect the chip against the blade when cutting;
 - 3) wide metal slotting with 45° corner to alleviate the pressure caused by current density in the metal (slotted placement shall be consistent with current direction);
- d) placement and routing that addresses signal harassment;

NOTE 2 Follow the principle of reducing parasitic parameters.
- e) overall chip power design that employs vertical and horizontal grid wiring to ensure that every memory bit could obtain V_{DD} and V_{SS} from the power grid;

NOTE 3 Design the power cord width of the word line direction according to the array stored number to achieve the supply capacity when all units operating line are open at the same time.
- f) trace width spacing, through-hole diameter and hole line spacing that minimize trace lengths and number of through-holes.

7.4 Package design requirements

7.4.1 Package structure design requirements

Package structure design requirements include:

- a) an adhesive or bonding surface on the package, the size of which is determined according to the chip size;

NOTE 1 Ensure that there is enough space so that the bonding process does not affect the chip's electrical performance.
- b) bonding wires configured according to pad size, pitch and pin orientation;

NOTE 2 Ensure that functional pads can be smoothly extracted and step width between bonding wires meet bonding requirements.
- c) melt seal ring that matches the size of the case and meets requirements;
- d) case thickness that ensures mechanical strength.

7.4.2 Packaging technology design requirements

Packaging technology design requirements include:

- a) bonding wires that meet requirements on thickness, length and bonding strength;

NOTE 1 Avoid cross phenomenon when arranging bonding wires.

- b) melt seal ring with sufficient space left inside and outside to avoid short circuit caused by solder splash;

NOTE 2 Take full account of solder overflow when designing the melt seal ring.

- c) a technology design verified through technology experiments, ensuring the feasibility of the design when necessary.

7.4.3 Packaging electrical simulation analysis requirements

Packaging electrical simulation analysis requirements include:

- a) simulation software to extract important electrical performance parameters to meet device performance requirements;

- b) optimized layout design to make sure parasitic parameters meet design requirements;

NOTE 1 Take full account of the effects of placement and routing on R, L, C parasitic parameters.

NOTE 2 Adjust placement and routing design to reduce parasitic parameters when some of them are high.

- c) simulation software for three-dimensional bonding simulation analysis to ensure the feasibility of bonding technology, when necessary.

NOTE 3 Take full account of the effects of the thickness and length of bonding wire on circuit performance when necessary.

7.4.4 Packaging thermal simulation analysis

Packaging thermal simulation analysis requirements include:

- a) thermal simulation software for a full assessment of the thermal performance of a package;

- b) junction temperature not exceeding allowable value;

NOTE 1 Consider adding a heat sink at the back when the chip's power dissipation is high to improve the cooling capacity of the shell.

- c) an optimized shell structure to improve thermal performance when thermal performance is insufficient.

7.5 Reliability design requirements

7.5.1 Overview

ICs for space application require high reliability. The aim of reliability design is to guarantee circuit functionality and performance parameters, improve circuit's capacity of antistatic, anti-latch up, anti-interference, and resistance to adverse environment, extend life of product, and reduce failure rate. Increase the design margin when it could affect reliability.

7.5.2 Reliability design requirements

Reliability design shall employ an optimized design technology and efficient maintenance to reduce product failure, as well as achieve objectives at minimal cost while meeting functional requirements.

Reliability design requirements include:

- a) technologically mature design to meet overall technical performance requirements;
- b) simplified design, taking into consideration relevant standards and regulations;
- c) derating design and redundant technology criteria;
- d) fault-tolerance approach and anti-transient stress design to ensure the stability and reliability of the product;
- e) thermal design suited for space environment;
- f) protection against harsh environment (which should include overload, vibration, shock, temperature, humidity, vacuum, fungus, salt atmosphere, dust and electrostatic, electromagnetic radiation, etc.) that meets environmental standards;
- g) design rules according to the features of a circuit application software;
- h) a microchip supporting several functions which can make the failure rate of the entire system lower;
- i) packaging designed to minimize failure rate.

7.5.3 Antistatic design requirements

Antistatic design shall comply with the following requirements when applicable.

- a) The aim of antistatic is to provide low resistance discharge path for electrostatic charge. Discharge resistor shall be as low as possible to withstand highest possible instantaneous power.
- b) Antistatic protection circuit shall occupy the smallest area possible on the chip. Antistatic design on full chip is necessary, including at least ESD clamp circuit between power and ground, ESD protection circuit between input and output pads.
- c) On the promise that the operation of circuit is guaranteed, selected trigger voltage should be relatively low to be triggered easily.
- d) ESD rating shall be tested to guarantee the required value.

7.5.4 Low-power design requirements

Low-power design could be developed in the system level, logic level, board level, layout and process level. From its source, power dissipation can be mainly divided into two parts, dynamic power and static power dissipation. Low-power design shall meet the following requirements:

- a) low power dissipation to ensure functionality and performance;
- b) low dynamic power dissipation.

To ensure functionality, performance and reliability, reduce power dissipation by using lower supply voltage, reducing circuit load capacitance and circuit average flip rate, as well as clock frequency. Lower supply voltage can sometimes reduce the hardness against interference, so it shall be balanced.

7.5.5 Parameter modification and design margin optimization requirements

In parameter modification and design margin optimization:

- a) take into account the impact on the circuit performance under worst conditions when the negative and positive of the operating voltage and temperature pull partial;
- b) take into account the impact on circuit performance when device parameters scatter during manufacturing process;
- c) select the design parameters through analysing the worst conditions of analogue circuit (increase margin when reliability could be affected).

7.5.6 Electromagnetic compatibility design requirements

Electromagnetic compatibility design requirements include:

- a) interference sources, sensitive sources and coupling paths;

Pay attention to interference sources such as high-speed logic circuits, high-speed clock circuits, as well as sensitive circuits such as microprocessors and low-level analogue circuits. Any factor which influences EMC should be minimized.

- b) separation between digital and analogue circuits;
- c) controlled capacitance coupling and inductive coupling;
- d) mode of signal grounding in the ground plane design;
- e) connection to the shield enclosure and heat sink;
- f) conducted emission and conducted immunity that meet requirements;
- g) radiated emissions and radiated immunity that meet requirements.

EMC verification and test shall follow IEC 62215-3:2013, IEC 61967-2, and IEC 62132.

7.5.7 Radiation-hardened design requirements

To meet the requirements of circuit functionality and performance, design hardening aims to realize a radiation-hardened circuit design without any design complexity and power dissipation. Hardening activities shall be undertaken during the circuit design process, as well as at system level, circuit level and layout to enhance the radiation hardness of the circuit.

The radiation-hardened assurance design of semiconductor ICs for space applications can meet circuit requirements through design hardening and technical hardening. Follow these steps.

- a) Verify the radiation-hardened requirements of the customer and determine whether to adopt technical hardening.
- b) Verify the technical library if technical hardening is preferred.

Design hardening programs shall take full account of the feasibility of the technical process.

- c) Evaluate the circuit radiation hardness by performing an irradiation test when necessary:
 - 1) Establish or use scientific, faultless single particle test, as well as total dose testing method.
 - 2) Verify the particle type and dose of tests according to circuit application environment and radiation hardness.
 - 3) Establish test data calculating systems and evaluation models of SEU, SET and SEL.

- 4) Accomplish tests according to requirements and obtain the estimated target.

7.6 Testability design requirements

Testability design requirements include:

- a) pre-inserted dedicated test architectures in key parts or peripheral interface of the chip during the design process;

An automatic test equipment will evaluate the inserted test architectures or scan chains for their functionality and performance, as well as carry out testing coverage analysis and failure orientation and detect the defects and failures during layout design and prototype production to ensure the correctness.

- b) a test architecture and dynamic detection point inserted during the design process to ensure testability of local design and internal circuit;

- c) test vectors of circuits automatically generated according to testing rules, methods, as well as fault models;

NOTE 1 Evaluate the testing coverage to assist in the improvement of the test architecture.

- e) boundary scan design (compliant with IEEE 1149.1);

NOTE 2 Clock and reset pins need a boundary scan cell (at least an observe cell), while power and ground pins do not need a boundary scan design.

- f) built-in memory in the self-testing design;

NOTE 3 Choose the appropriate algorithm according to the memory type to cover as many types of fault as possible. Take note that testing coverage and testing area need compromise.

- g) scan chain design;

NOTE 4 Determine the number of scan chains according to circuit scale and ensure that the testing coverage meets requirements.

Annex A (normative)

Datasheet

A.1 Goals and objectives

Gather all technical data from system design to final design verification as input for application and procurement.

A.2 Scope and content

The scope and content of the datasheet includes:

- a) circuit name, number and release date on each page;
- b) description of all the features and constraints of the circuit such as detailed interface description, register definitions and memory map;
- c) system overview of the circuit, and the description of its application under typical system environment, including application block diagram;
- d) detailed description of all features and modes of operation;
- e) detailed description of the signal interface, including definition of all signals, tests and power pins, as well as signal and functions of its signal polarity;
- f) description of signals in groups according to their functions;
- g) definition of all electrical data and mechanical data, as well as related application conditions:
 - 1) absolute maximum range includes reliability index of storage temperature, operating temperature, supply voltage, maximum pin input current, total dose, SEU, latch-up electrostatic discharge, etc.;
 - 2) DC parameters include voltage, leakage current, pin capacitance and output current;
 - 3) typical value of static and dynamic power dissipation in lower frequency operation;
 - 4) AC parameters include set-up and hold time, cycle time, output delay, tri-state delay, and relevant waveform;
 - 5) evidence of related timing characteristics of reference signal edge;
 - 6) package description includes pin configuration, package diagram with pin number and signal name including mechanical drawing of package thermal characteristics such as thickness of the material and heat transfer coefficient.

Annex B (informative)

Guidance

B.1 Architectural design guidance

The topology architecture is designed according to the function and parameter requirements of the circuit. Typical topology architectures of semiconductor ICs are as follows:

- a) complementary bipolar amplifier architecture is recommended for high-speed broadband amplifying;
- b) high-impedance input architecture (i.e. JFET) is recommended for weak signal process amplifying;
- c) PN junction isolation amplifier architecture is recommended for low-speed, low-accuracy and low-power amplifying;
- d) linear regulator architecture is recommended for low-noise and ripple power supplying;
- e) switching regulator architecture is recommended for high-efficiency power supplying;
- f) Flash ADC architecture is recommended for high-speed analogue-to-digital conversion;
- g) Σ - Δ ADC architecture is recommended for high-precision analogue-to-digital conversion;
- h) SAR ADC architecture is recommended for medium speed and accuracy, low-power consumption and no transmission delay analogue-to-digital conversion.

These architectures are recommended but not required. With the development of new technologies, new architectures can be used.

B.2 Logic and circuit design guidance

Based on the understanding of the design requirements and the existing conditions, fully consider the logic design principles, and take into account the following guidance.

- a) A trade-off between area and speed means to achieve the minimum area in the guarantee speed premise. The main design methods include “ping-pong” operation, pipeline operation, time division multiplexing, logic multiplexing, serial-parallel conversion operation, asynchronous clock domain data synchronization, reset operation.
- b) The top-down system design is suggested.
- c) Adopt a synchronous design. The main signal is caused by trigger. Divide the clock domain in the whole system well, then try to use the clock in the same clock domain as the time-driven, take in account these clock lines, interferences and delays.
- d) Code comments must be concise and clear and explanatory notes should be extensive.
- e) Too many levels within the module design of code should be avoided. At the same time, the excessive detail function description in the top-level documents should be avoided.

B.3 Layout design guidance

The following are the layout design guidelines.

- a) Aluminium lines should be short and wide, and could not have cross connections.
- b) Grounding holes should be as large as possible.
- c) The overlap between the aluminium line and the connector hole shall be proper.
- d) Connection mode shall be reduced with diffused strip, as much as possible.
- e) Units with similar parameters should be placed in adjacent areas; geometric architecture should be as symmetrical as possible, the symmetry should not be sacrificed for a more convenient wiring.
- f) Hierarchical design guidance

The layout should be designed according to the hierarchical model. According to the repeatability and functional unit, the layout is divided then each unit layout is designed and the general drawing is generated.

- g) Minimization design guidance

It is important to use the silicon area fully, and increase the rate of finished products within the process conditions permission. The layout area should be as small as possible and close to the square, in order to reduce the occupied area of each circuit.

- h) Reduce the number of isolation zone

The isolation frame takes up a lot of chip area for PN junction isolation zone. The number of the isolation zone should be reduced, whenever possible.

- i) Prevent the parasitic effect

- 1) The epitaxial layer of the resistance island should be connected to the highest potential, and the isolation tank should be connected to the lowest negative potential, which is necessary for guaranteeing the PN isolation effect.
- 2) The input and output terminals should be separated away as far as possible.
- 3) The exothermic unit or the position where the most power is consumed (i.e. resistance) should be placed in the centre of the chip to make the temperature distribution uniform.

B.4 Package design guidance

The following are the package design guidelines.

- a) The reliability design of bonding, including the bonding wire and the bonding solder joints should be considered, especially the effects of the high temperature aging on the brittleness of the bonding.
- b) The adhesion strength of the chip, especially the shear stress on the chip with the elevated work temperature, should be considered. So the thermal shock and mechanical vibration should be done.
- c) Hermetic seal is preferred. For hermetically sealed devices, a vacuum test should be considered.
- d) The residual gas and water vapour content should be considered, and no harmful gases exist in the cavity.
- e) Take full account of the heat dissipation requirements of the power circuit.
- f) Take account of the solderability of the pins and the corrosion of the pins and package.

- g) Unless otherwise specified, the following architectures, materials and processes are prohibited:
- 1) use of pure tin or silver, as well as use of zinc, chromium and electroless nickel as a final finish;
Pure tin is prohibited on leads and cases as a final finish. Unless specified, zinc and chromium is prohibited on leads and cases as a final finish. Electroless nickel shall not be used as the undercoat on flexible or semi-flexible leads and shall be permitted only on rigid leads or package elements other than leads.
 - 2) tin welding seal;
 - 3) use of organic or polymeric materials in sealed components for mounting heat conduction or conformal;
 - 4) beam lead structure;
 - 5) use of desiccant in components;
 - 6) non-hermetic and vacuum package process;
 - 7) thermal diffusion bonding for aluminium-silicon bonding wires;
Bonds should not be covered by gel.
 - 8) laser inscribing.
Laser inscribing from the back of SOS (silicon on sapphire) is allowed.
- h) Unless otherwise specified, caution is needed for the following processes:
- 1) when using ultrasonic cleaning processes;
Power time and other parameter should be tested and verified fully.
 - 2) when the bond process wire metal is different from the die pad area;
If the wire metal for the bonding process is different from the die pad area, this process should be qualified. The qualification test shall contain at least a high-temperature stock, SEM inspection and bond strength. The samples after high-temperature storage should fulfil the requirements of the bond strength specification.
 - 3) when using fritted glass to mount dies.

B.5 Antistatic design guidance

Antistatic design guidelines include:

- a) Guidelines for the design of the whole chip ESD protection circuit:
- 1) Analyse the circuit characteristics
Analyse how to supply power for the digital source, simulation source, and the connection between analogue module and the digital module. Analyse the characteristics of each I/O unit to confirm whether there is a special port.
 - 2) Master the process
After process analysis (including the device breakdown voltage and so on), determine the ESD design window. Be familiar with the maximum current density of polysilicones, metals, contact holes, through holes, parasitic resistance and parasitic capacitance of the metal, contact holes, through holes, the metal thickness, square resistance, current density and other parameters.
 - 3) Choose the suitable ESD protection device