Template for submitting comments/inputs on draft GR on “Single Photon Avalanche Diode (SPAD) Detector”

Name of the Manufacturer/ Stakeholder:

Organization:

Contact details:

Clause No.	Clause	Comments	Other Remarks, if any

Note: The comments/inputs on the on GR on “Single Photon Avalanche Diode (SPAD) Detector” via email to adgqt.tec-dot@gov.in with CC to ddgqt.tec-dot@gov.in

वर्गीय आवश्यकताओं के लिए मानक

दस्तावेज़ सं: टी.ई.सी. ९१०३०: २ ० २ ५

STANDARD FOR GENERIC REQUIREMENTS

No. TEC 91030:2025

सिंगल फोटॉन एवलांच डायोड (एसपीएडी) डिटेक्टर

Single Photon Avalanche Diode (SPAD) Detector

ISO 9001:2015

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FOREWORD

Telecommunication Engineering Centre (TEC) is the technical arm of Department of Telecommunications (DOT), Government of India. Its activities include:

- Framing of TEC Standards for Generic Requirements for a Product/Equipment, Standards for Interface Requirements for a Product/Equipment, Standards for Service Requirements & Standard document of TEC for Telecom Products and Services
- Formulation of Essential Requirements (ERs) under Mandatory Testing and Certification of Telecom Equipment (MTCTE)
- Field evaluation of Telecom Products and Systems
- Designation of Conformity Assessment Bodies (CABs)/Testing facilities
- Testing & Certification of Telecom products
- Adoption of Standards
- Support to DoT on technical/technology issues

For the purpose of testing, four Regional Telecom Engineering Centers (RTECs) have been established which are located at New Delhi, Bangalore, Mumbai, and Kolkata.

ABSTRACT

Single-photon Avalanche Diode (SPAD) detector is a single photon detector which is critical component in quantum communication system, enabling the detection of stream of single photons with high precision and reliability. This document outlines the generic requirements and specifications for the Single Photon Avalanche Diode (SPAD) Detector.

CONTENTS

HISTORY SHEET

Sl. No.	Standard No.	Title	Remarks
1.	TEC No. 91030:2025	Generic Requirements of Single Photon Avalanche Diode (SPAD) Detector	First Issue

REFERENCES

Sl. No.	*Document No.*	*Title/Document Name*
[1]	TEC 11016:2016	Electromagnetic Compatibility Standard for Telecommunication Equipment
[2]	ISO 9001:2015	Quality management system
[3]	IEC 60825-1	Safety of laser products - Part 1: Equipment classification and requirements
[4]	IEC 60825-2	Safety of laser products - Part 2: Safety of optical fibre communication systems (OFCSs)
[5]	CISPR 32:2015+A1:2019	Electromagnetic compatibility of multimedia equipment - Emission requirements
[6]	CISPR 11 {2024}	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
[7]	IEC 61000-4-2 {2008}	Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test
[8]	IEC 61000-4-3 (2020)	Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
[9]	IEC 61000- 4- 4 {2012}	Electromagnetic compatibility (EMC) - Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test

[10]	IEC 61000-4-5 (2014)	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques – Surge immunity test
[11]	IEC 61000-4-6 (2023)	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
[12]	IEC 61000-4-11 (2020)	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests
[13]	IEC 61000-4-29:2000	Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests

Note: Unless otherwise explicitly stated, the latest approved version of the standards/documents referred above, with all amendments in force shall be applicable.

CHAPTER-1

Technical Requirements

1.1 Introduction

SPAD detector is an ultra-sensitive device designed to detect and count individual photons (the smallest unit of light) by converting the energy from a single incident photon into a measurable electrical signal. They are critical in applications like quantum communication, LiDAR, and time-resolved spectroscopy.

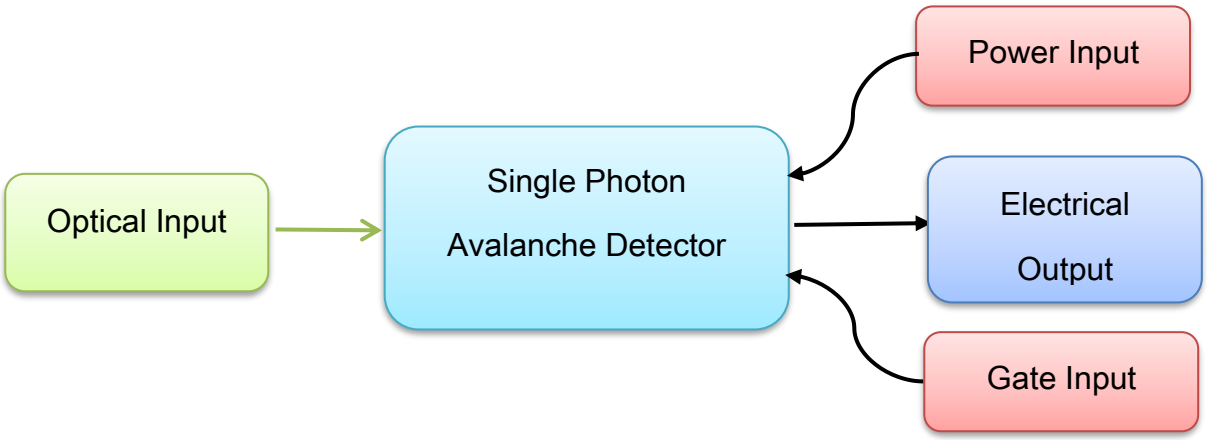

Figure 1: High Level Diagram of SPAD detector

The incident photon leads to impact ionization in a SPAD biased over breakdown voltage. This is further detected by change in the diode V/I characteristics and processed over to generate a photon out pulse.

1.2 Classification of Single Photon Avalanche Diode (SPAD) Detectors:

1.2.1 Types of SPAD on the basis of wavelength:

a) **Near Infrared Range SPAD:** Used to detect photons in near infrared wavelength (approx. 900 nm – 1700 nm), generally used in telecommunications. Eg. InGaAs SPAD, InP SPAD, etc.

b) **Visible Range SPAD:** Used to detect photons in the visible and near-infrared (NIR) range (approx. 400 nm – 900 nm). Eg. Ge SPAD, Si SPAD, etc.

1.2.2 Classification based on mode of operation:

a) **Free Running SPADs:** These SPADs operate continuously above the breakdown voltage and then use either active quenching or passive quenching mechanism to control the current of SPAD.

b) **Gated SPADs:** These SPADs operate above breakdown voltage for very short periods of time called gates, which helps in reducing dark counts. In gating process, SPAD is operated in Geiger mode by providing a bias that is combination of DC Voltage and gating voltage. DC voltage biases the SPAD just below the breakdown voltage and gating voltage rides on top of the DC voltage to take SPAD into Geiger mode for very short periods and then forcefully brings it back.

c) **Time-Gated SPAD:** A Time Gated SPAD synchronizes the Detection time with the optical inputs. The time SPAD is in Geiger mode is precisely synchronised with the input pulses incident enhancing the detection rate and photon detection efficiency.

1.3 Functional Block Diagram of SPAD Detector:

The functional block diagram of SPAD using an avalanche photodiode for single photon detection is as below:

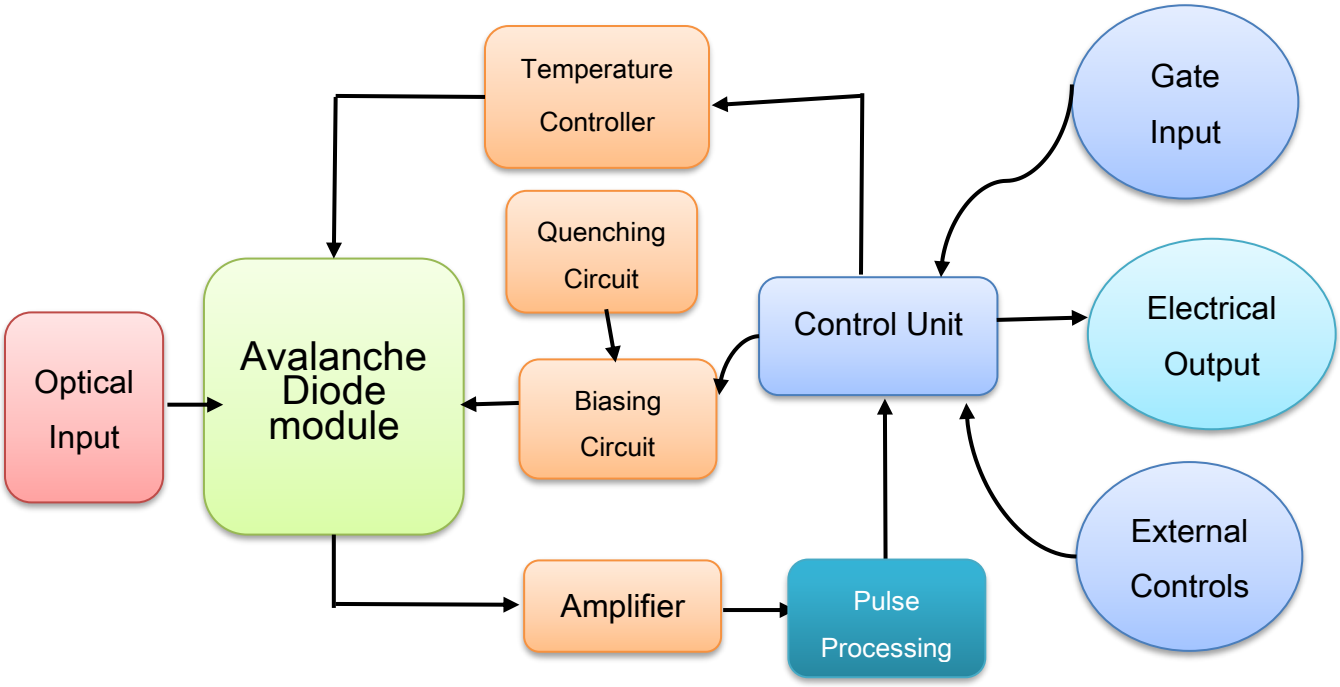

Figure 2: Functional block diagram of SPAD Detector

1.3.1 **Avalanche diode module:** Avalanche diode with internal or external thermo-electric cooler module enabling optimum signal-to-noise performance.

1.3.2 **Biasing Circuit (Bias Voltage Generator Circuit):** This block generates the biasing signal for the SPAD. For free running SPADs, it generates the DC bias and combines DC bias with gating pulse for Gated SPADs.

1.3.3 **Temperature Controller:** Control system for thermo-electric cooler module. It is responsible for maintaining sub-zero temperatures with very high stability.

1.3.4 **Amplifier and Pulse Processing:** It is used to translate the energy of a incident photon leading to impact ionization in the avalanche diode into a detectable photon out pulse.

1.3.5 **Quenching Circuit:** It is responsible to quench/reset SPAD after detection of an avalanche to prevent excessive current flow in the diode and to reduce after-pulsing.

1.3.6 **Main Control Unit:** Control Unit provides access to the user to configure the parameter of the SPAD and for diagnostics. It also makes sure that all the other modules are under specified conditions and ranges.

1.4 Technical Specifications of SPAD Detector

1.4.1 Photon detection efficiency (η): The probability that an incident photon of a specified wavelength will produce a registered electrical output signal. It's the ratio of detected photons to the total number of photons incident on the active area, after accounting for dark counts and after pulsing. It is a key measure of the detector's sensitivity. It's often expressed in terms of percentage.

1.4.2 Dark count rate (P_{dark}): The average rate at which the detector registers a detection event (a "count") even in the complete absence of optical illumination. This is a measure of the detector's intrinsic noise, usually caused by thermal generation of charge carriers within the detector

material. It's typically measured in counts per second (cps or Hz) for free running SPADs and in dark count probability (DCP) per pulse for gated SPADs.

1.4.3 **Afterpulse probability ($P_{afterpulse}$):** The probability that a detector registers a false detection event in the absence of illumination, conditional on a true photon detection event in the preceding avalanche.

1.4.4 **Dead Time (T_{dead}):** It is the controlled time interval immediately following a detection event (either by an incident photon or as dark count) during which the detector is disabled. Its primary purpose is to allow trapped charges to dissipate (releasing them harmlessly) before the detector is again ready for next detection to prevent afterpulsing.

1.4.5 **Timing jitter (t_{jitter}):** The uncertainty in determining the arrival time of a photon at the optical input. This includes the error accumulated by the time-measuring electronics, signal conditioning electronics and intrinsic uncertainty of the SPAD.

1.4.6 **Detector Operating Temperature (T):** Ambient Temperature over which the SPAD operates within the defined specifications.

1.4.7 **Mode of Operation**: Describes how the electrical bias is applied to the detector. The possible modes of operation are Free running mode, and Gated mode.

1.4.8 **Gate Width (W):** For detectors operating in gated mode, this is the nominal duration of the electrical signal applied to turn the detector on.

1.4.9 **Gating Frequency (f):** The frequency of the gating signal applied to the detector, if operating in gated mode.

1.4.10 **DC Bias (V_{dc}):** The DC voltage level applied to the detector.

1.4.11 **AC Bias (V_{ac}):** The peak-to-peak ac voltage level applied to the detector. The ac voltage is defined to vary between 0 and V_{ac}. The total bias applied to the device therefore varies between V_{dc} and (V_{dc} + V_{ac}).

1.4.12 **Discrimination level (V_{disc}):** Voltage threshold above (or below) which the amplitude of an output pulse must overcome to be registered as a detection event.

1.5 Technical Requirements for SPAD Detector:

1.5.1 The photon detection efficiency (η) of the SPAD Detector shall be greater than 10% at the least dark count rate declared by the manufacturer.

1.5.2 The photon detection efficiency (η) of the SPAD Detector of the SPAD detector shall be user configurable.

1.5.3 The dark count rate (P_{dark}) shall not exceed 1000 counts per second for Free Running Mode.

1.5.4 The dark count rate (P_{dark}) shall not exceed 10^{-5} per pulse for Gated Mode.

1.5.5 The afterpulse probability ($P_{afterpulse}$) of the SPAD detector shall be less than 10% at the minimum specified dead time for the free-running mode and less than 3% for Gated mode to ensure low false detection rates and maintain detector fidelity during photon detection.

1.5.6 The dead time (T_{dead}) shall be configurable to achieve the required SNR. However, the maximum dead time of the SPAD detector shall be less than 500 microseconds.

1.5.7 The timing jitter (t_{jitter}) shall be less than 500 ps to provide accurate photon arrival timing and enhance temporal resolution.

1.5.8 SPAD Detector shall incorporate a Quenching Circuit to resect SPAD.

1.5.9 The SPAD detector shall support standard optical connector eg. FC/PC, etc. in case of fiber coupled optical input and optical aperture for a free-space input configuration.

1.5.10 The SPAD detector shall incorporate electrical and optical shielding to minimize susceptibility to electromagnetic interference (EMI), ensuring stable operation in field environments.

1.5.11 **Temperature Stability and Control:** The SPAD detector shall incorporate thermo-electric cooling or equivalent active temperature control mechanism, to maintain performance over the declared operating temperature range.

1.5.12 **Operational Temperature Range:** The SPAD shall operate satisfactorily over an ambient operating temperature range from 0°C to 35°C.

1.5.13 The SPAD detector shall support digital communication interface such as USB, RS-232, Ethernet, etc. for configuration of parameters such as Dead time, efficiency, etc.

1.5.14 The Optical Return Loss for the optical connector shall be greater than 50dB.

1.5.15 The wavelength range of operation shall be 400 nm to 900 nm for visible range SPADs, and 1100 nm to 1700 nm for Near Infrared Range SPADs.

1.5.16 The SPAD detector may optionally include protection circuitry to prevent damage or performance degradation when exposed to optical input levels exceeding the nominal single-photon regime.

1.5.17 The SPAD detector output shall provide standard electrical signal formats (e.g., TTL, NIM, or LVTTL) for easy integration with time-correlated single-photon counting (TCSPC) modules and other readout electronics.

1.5.18 The SPAD detector shall have the provision to securely update the firmware.

1.5.19 The SPAD Detector shall provide the facility for monitoring of the system information and performance parameters.

1.5.20 The SPAD detector shall have command line diagnostic interface and may optionally provide status signals.

1.6 Requirements for SPAD Detector used in Quantum Key Distribution System:

1.6.1 Authentication mechanisms must be used to authenticate an operator accessing the system and to verify that the operator is authorized to access the system.

1.6.2 The SPAD detector shall limit optical back-flash emissions to minimize potential information leakage and prevent side-channel attacks in quantum communication systems.

1.6.3 The configuration for the SPAD parameters shall be secured using a protected interface, such that in a running system, attacker should not be able to change the calibrated parameters.

1.6.4 The SPAD detector shall be protected against Blinding Attack. If the attacker shines a CW light at a SPAD, this act like a DC level and SPAD will go into linear mode and photons cannot be detected. In any such case, the SPAD detector should be able to stop detection event and inform the system about the attack.

1.6.5 The SPAD detector shall be protected against saturation attacks. If the attacker send high speed optical pulses, it will saturate the SPAD since as soon the SPAD comes out of Dead Time, a false click coming at a higher rate than the actual signal with send back the SPAD into Dead time. In any such case the SPD should inform the system about the attack and should stop detection events.

1.6.6 The SPAD detector should be protected against any Thermal Attacks. If the SPAD internal Temperature goes out of calibrated range, SPAD should stop detection events and inform the system about the attack.

CHAPTER-2

General Requirements

2.1 Reference Documents

2.1.1 Anything not specifically stated in this document shall be deemed to be in accordance with the relevant latest global standards.

2.1.2 All references to TEC GRs & other Recommendations/standards imply their latest issues.

2.2 Engineering requirements

2.2.1 The manufacturer shall furnish the actual dimensions and weight of the equipment.

2.2.2 It should be engineered to comply with environmental test requirements as defined in this document.

2.2.3 The external plug-in units shall be of a suitable type to allow their removal/insertion while the equipment is in energized condition.

2.2.4 The mechanical design and construction of each card/unit shall be inherently robust and rigid under all conditions of operation, adjustment, replacement, storage and transport.

2.2.5 Each sub-assembly shall be marked with schematic reference to show its function so that it is identifiable from the layout diagram in the handbook.

2.2.6 Each terminal block and individual tags shall be numbered suitably with a clear identification code and shall correspond to the associated wiring drawings.

2.2.7 All external Interfaces / Controls / Indicators/Switches shall be clearly screen printed/marked on the unit to show their functional/connectivity diagrams and functions.

2.2.8 Important Do's and Don'ts about the operation of the system shall be clearly indicated at a convenient place on the equipment.

2.3 Operational requirements

2.3.1 The equipment shall be designed for continuous operation and shall be tested for 72 hours of continuous working.

2.3.2 The equipment shall be able to perform satisfactorily without any degradation at an altitude up to 4000 meters above mean sea level. A certificate from the manufacturer conforming to this requirement will be acceptable, in case no test facility is available.

2.3.3 The equipment shall provide a user interface for monitoring of system status.

2.4 Quality requirements

2.4.1 The manufacturer shall furnish the MTBF value along with the methodology used for calculation. The minimum value of MTBF shall be 25,000 hrs.

2.4.2 The equipment shall be manufactured in accordance with the international quality management system ISO 9001:2015 or latest issue. A quality plan describing the quality assurance system followed by the manufacturer would be required to be submitted by the manufacturer.

2.5 Maintenance requirements

2.5.1 Maintenance philosophy is to replace faulty units/subsystems after quick analysis through monitoring sockets, alarm indications and Built-in Test Equipment.

2.5.2 The equipment shall have easy access for servicing and maintenance.

2.5.3 The equipment shall have the provision to update the firmware.

2.5.4 Suitable alarms shall be provided for the identification of faults in the system and faulty units. The alarms may be placed on the SPAD Hardware and in the remote monitoring system.

2.5.5 Ratings and types of fuses used are to be indicated by the supplier.

2.6 Power supply requirements

2.6.1 The equipment shall include a power supply to generate the required bias voltages for the SPAD operation.

2.6.2 The equipment shall operate over this range without any degradation in performance.

2.6.3 The equipment shall be adequately protected in case of voltage variation beyond the range mentioned above and also against input reverse polarity in case of DC feeds.

2.6.4 The derived DC voltages in the equipment shall have protection against over-voltage, short-circuit and overload.

2.6.5 The equipment shall be power efficient. The actual power rating/ consumption are to be furnished by the manufacturer of the equipment.

2.7 Accessories

2.7.1 The supplier shall provide a complete set of:

a) All the necessary connectors, connecting cables (including power cord) and accessories required for satisfactory and convenient operation of the equipment. Types of connectors, adapters to be used and

accessories of the approved quality shall be indicated in the operating manuals.

b) Software, along with software version and the arrangement to load the software at site.

2.7.2 The source of the components/ accessories, from where these have been procured, is also to be submitted by the manufacturer.

2.8 Documentation

Technical literature in the English language only shall be accepted. All aspects shall be covered in the manuals. The manuals shall include the following:-

2.8.1 Installation, operation and maintenance manual.

It should cover the following, as applicable to the category of the product:

(i) Safety measures to be observed in handling the equipment;

(ii) Precautions for installation, operation and maintenance;

(iii) Test jigs and fixtures required and procedures for routine maintenance, preventive maintenance, troubleshooting and sub-assembly replacement;

(iv) Illustration of internal and external mechanical parts.

2.8.2 Repair Manual

It should cover the following, as applicable to the category of the product:

(i) List of replaceable parts used to include their sources and the approving authority.

(ii) Detailed ordering information for all the replaceable parts shall be listed in the manual to facilitate the reordering of spares.

(iii) Procedure for trouble-shooting and sub-assembly replacement shall be provided. Test fixtures and accessories required for repair shall also be indicated. A systematic troubleshooting chart (fault tree) shall be given for the probable faults with their remedial actions.

2.9 Operating personnel safety requirements

2.9.1 The Laser product, if used shall meet the Automatic Laser Shutdown (ALSD)/Automatic Power Reduction (APR) procedure of ITU-T Rec. G.664 (latest edition) on Class B laser. The equipment shall have visual warnings and controls ensuring danger-free operation. Laser safety signs and instructions must be mentioned in the equipment.

2.9.2 Protection against short circuits/open circuits in the access points shall be provided.

2.9.3 The equipment shall have a terminal for grounding the rack.

2.9.4 All switches/controls on the front panel shall have suitable safeguards against accidental operation.

2.9.5 The equipment shall be adequately covered to safeguard against entry of dust, insects, etc.

2.10 Environmental Testing Requirements

2.10.1 The instrument shall conform to the requirements for the applicable category as specified in TEC document TEC 14016:2010 {Old Document No: QM-333) {MARCH 2010 issue} "Standard for Environmental Testing of Telecommunication Equipment".

CHAPTER-3

Safety & EMC Requirements

3.1 Safety Requirements

3.1.1 The equipment shall conform to IS/IEC 62368-1:2023 “Audio/video, information and communication technology equipment - Part 1: Safety requirements”.

3.1.2 Laser safety: If the SPAD house active optical devices with optical signal coming out of the enclosure, it should comply with IEC 60825- 1 and IS 14624-2/IEC 60825-2 for optical safety requirements. Note: This test shall be applicable if Laser components are directly mounted in the box.

3.2 Electromagnetic Compatibility (EMC) Requirements:

The equipment shall conform to the EMC requirements as per the following standards and limits indicated therein. A test certificate and test report shall be furnished from an accredited test agency.

3.2.1 Conducted and radiated emission (applicable to telecom equipment):

Name of EMC Standard: “CISPR 32:2015+A1:2019 – Electromagnetic compatibility of multimedia equipment - Emission requirements”

i. To comply with Class B of CISPR 32:2015+A1:2019

ii. For Radiated Emission tests, limits below 1 GHz shall be for measuring a distance of 3m.

OR

Conducted and Radiated Emission (applicable to instruments such as power meter, frequency counter, etc.):

Name of the EMC Standard: " CISPR 11 {2024} - Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics- Limits and methods of measurement"

Limits:

i. To comply with the category of Group 1 of Class B of CISPR 11 {2024}

ii. The values of limits shall be as per clause No. 8.5.2 of TEC Standard No. TEC 11016:2026.

3.2.2 **Immunity to Electrostatic discharge:**

Name of EMC Standard: IEC 61000-4-2 {2008) "Testing and measurement techniques of Electrostatic discharge immunity test".

Limits:

i. Contact discharge level 2 {± 4 kV} or higher voltage;

ii. Air discharge level 3 {± 8 kV} or higher voltage;

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2016.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.

3.2.3 **Immunity to radiated RF:**

Name of EMC Standard: IEC 61000-4-3 (2020) "Testing and measurement techniques-Radiated RF Electromagnetic Field Immunity test".

Limits:

(i) **For Telecom Equipment and Telecom Terminal Equipment with Voice interface(s)**

a. Under test level 2 {Test field strength of 3 V/m} for general purposes in the frequency range 80 MHz to 1000 MHz and

b. Under test level 3 (10 V/m) for protection against digital radio telephones and other RF devices in the frequency ranges 800 MHz to 960 MHz and 1.4 GHz to 6.0 GHz.

(ii) **For Telecom Terminal Equipment without Voice interface (s)**

a. Under test level 2 {Test field strength of 3 V/m} for general purposes in the frequency range 80 MHz to 1000 MHz and protection against digital radio telephones and other RF devices in the frequency ranges 800 MHz to 960 MHz and 1.4 GHz to 6.0 GHz.

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2016.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.

3.2.4 **Immunity to fast transients (burst):**

Name of EMC Standard: IEC 61000- 4- 4 (2012) "Testing and measurement techniques of electrical fast transients / burst immunity test".

Limits:

(i) Test Level 2 i.e., a) 1 kV for AC/DC power lines; b) 0.5 kV for signal / control / data / telecom lines.

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2016.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.

3.2.5 **Immunity to surges:**

Name of EMC Standard: IEC 61000-4-5 (2014) “Testing & Measurement techniques for Surge immunity test"

Limits:

(i) **For mains power input ports:**

a) kV peak open circuit voltage for a line-to-ground coupling

b) 0.5 kV peak open circuit voltage for a line-to-line coupling.

c) 2.0 kV peak open circuit voltage for a line-to-line coupling.

(ii) **For telecom ports:**

a) kV peak open circuit voltage for line to ground.

b) 0.5 kV peak open circuit voltage for line-to-line coupling.

c) 2.0 kV peak open circuit voltage for line-to-line coupling.

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2026.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2026.

3.2.6 **Immunity to conducted disturbance induced by Radio frequency fields:**

Name of EMC Standard: IEC 61000-4-6 (2023) "Testing & measurement techniques-Immunity to conducted disturbances induced by radiofrequency fields"

Limits:

(i) Under the test level 2 {3 V r.m.s.} in the frequency range 150 kHz-80 MHz for AC / DC lines and Signal /Control/telecom lines

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2026.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2026.

3.2.7 **Immunity to voltage dips & short interruptions (applicable to only ac mains power input ports, if any):**

Name of EMC Standard: IEC 61000-4-11 (2020) “Testing & measurement techniques- voltage dips, short interruptions and voltage variations immunity tests”

Limits:

(i) A voltage dip corresponding to a reduction of the supply voltage of 30% for 500ms (i.e., 70 % supply voltage for 500ms).

(ii) A voltage dip corresponding to a reduction of the supply voltage of 60% for 200ms; (i.e., 40% supply voltage for 200ms)

(iii) A voltage interruption corresponding to a reduction of a supply voltage of > 95% for 5s.

(iv) A voltage interruption corresponding to a reduction of a supply voltage of >95% for 10ms.

Performance Criteria shall be as per Table 1 under Clause 6 of TEC Standard No. TEC 11016:2026.

Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2026.

3.2.8 **Immunity to voltage dips & short interruptions (applicable to only DC power input ports, if any):**

Name of EMC Standard: IEC 61000-4-29:2000: Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on DC input power port immunity tests.

Limits:

(i) Voltage Interruption with 0% of supply for 10ms. Applicable Performance Criteria shall be B.

(ii) Voltage Interruption with 0% of supply for 30ms, 100ms, 300ms and 1000ms. Applicable Performance Criteria shall be C.

(iii) Voltage dip corresponding to 40% & 70% of supply for 10ms, 30 ms. Applicable Performance Criteria shall be B.

(iv) Voltage dip corresponding to 40% & 70% of supply for 100ms, 300 ms and 1000 ms. Applicable Performance Criteria shall be C.

(v) Voltage variations correspond to 80% and 120% of supply for 100 ms to 10s as per Table 1c of IEC 61000-4-29. Applicable Performance Criteria shall be B.

Note 1: Classification of the equipment:

Class B: Class B is a category of apparatus which satisfies the class B disturbance limits. Class B is intended primarily for use in the domestic environment and may include:

i. Equipment with no fixed place of use; for example, portable equipment powered by built in batteries;
ii. Telecommunication terminal equipment is powered by telecommunication networks.
iii. Personal computers and auxiliary connected equipment.

Please note that the domestic environment is an environment where the use of broadcast radio and television receivers may be expected within a distance of 10 m of the apparatus connected.

Class A: Class A is a category of all other equipment, which satisfies the class A limits but not the class B limits.

Note 2: The testing agency for EMC tests shall be an accredited agency and details of accreditation shall be submitted.

Note 3: For checking compliance with the above EMC requirements, the method of measurements shall be in accordance with TEC Standard No. 11016:2016 (or latest release) and the references mentioned therein unless otherwise specified specifically. Alternatively, corresponding relevant Euro Norms of the above IEC/CISPR standards are also acceptable subject to the condition that frequency range and test level are met as per the above mentioned sub clauses 3.2.1 to 3.2.9 and TEC Standard No. 11016:2016 (or latest release). The details of IEC/CISPR and their corresponding Euro Norms are as follows:

IEC/CISPR	Euro Norm
CISPR 11	EN 55011
CISPR 22	EN 55022
IEC 61000-4-2	EN 61000-4-2
IEC 61000-4-3	EN 61000-4-3
IEC 61000-4-4	EN 61000-4-4
IEC 61000-4-5	EN 61000-4-5
IEC 61000-4-6	EN 61000-4-6
IEC 61000-4-11	EN 61000-4-11
IEC 61000-4-29	EN 61000-4-29

ABBREVIATIONS

For the purpose of this document the following abbreviations apply:

AC	Alternating Current
ALSD	Automatic Laser Shut Down
APR	Automatic Power Reduction
AQC	Active Quenching Circuit
CISPR	Comité International Spécial des Perturbations Radioélectriques
DC	Direct Current
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
IEC	International Electrotechnical Commission
ISM	Industrial Scientific and Medical
LiDAR	Light Detection and Ranging
LVTTL	Low-Voltage Transistor–Transistor Logic
MTBF	Mean Time Between Failures
NIM	Nuclear Instrumentation Module
NIR	Near Infra-Red
PDE	Photon Detection Efficiency
QKD	Quantum Key Distribution
R.M.S.	Root Mean Square
SPAD	Single-Photon Avalanche Diode
SPD	Single Photon Detector
TCSPC	Time Correlated Single-Photon Counting
TTL	Transistor–Transistor Logic
USB	Universal Serial Bus

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