Template for submitting comments/inputs on draft Test Guide for GR on "Single Photon Avalanche Diode (SPAD) Detector"

Name of the Manufacturer/ Stakeholder:

Organization:

Contact details:

Clause No.	Test No.	Comments	Other Remarks, if any

Note: The comments/inputs on the on Draft Test Guide for GR on "Single Photon Avalanche Diode (SPAD) Detector" via email to adgqt.tec-dot@gov.in and adgtc2-tec-dot@gov.in with CC to ddgqt.tec-dot@gov.in

परीक्षण निर्देशिका

टीईसी ९१०३१:२०२६

TEST GUIDE

TEC 91031:2026

for

सिंगल फोटॉन एवलांच डायोड (एसपीएडी) डिटेक्टर

Single Photon Avalanche Diode (SPAD) Detector

(TEC 91030:2026)

ISO 9001:2015

दूरसंचार अभियांत्रिकी केंद्र

खुर्शीदलाल भवन, जनपथ, नई दिल्ली-110001,भारत

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Release 1: _____, 2026

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

This Test Guide of testing pertains to detailed provisional test schedule and test procedure for evaluating conformance/functionality/requirements/ performance of standard on Single Photon Avalanche Diode (SPAD) Detector as per standard no. TEC 91030:2026.

CONTENTS

A. HISTORY SHEET

Sl.No.	***Standard/document No.***	***Title***	***Remarks***
1.	TEC NO. 91031:2026	Test Guide for Single Photon Avalanche Diode (SPAD) Detector	First Issue ……, 2026

B. INTRODUCTION

This document describes the test schedule and procedures for evaluating the requirements of functionality /performance /operational /interface /interoperability /quality/ safety /Electromagnetic compatibility and security services of the product Single Photon Avalanche Diode Detector against the Generic requirements as per the TEC GR No.: 91030:2026.

The manufacturer shall offer the system for type evaluation along with the following documents:

i. System specifications of the equipment containing features, facilities, and physical description,
ii. Installation, System and Operation & Maintenance manual of the equipment,

iii. Hardware, Software, and firmware details of the equipment,

iv. Bill of material,

v. Block schematic diagram and physical configuration of the equipment,

vi. Test Results as per the TEC Test Guide for the GR.

All the necessary set-ups & measuring instruments duly calibrated by an authorised lab shall be provided by the manufacturer for testing. The manufacturer shall provide proper operating environment required for testing.

Note: Though every care has been taken to cover all the parameters of the GR correctly in this Test Guide, yet to avoid any inadvertent error/ misprint, the testing officer shall ensure that all the parameters of the GR have been tested & verified in accordance with the provisions of the GR, same will be reflected on the report.

C. General Information

Sn	General Information	Details (to be filled by testing team)	
1.	Name and Address of the Applicant		
2.	Date of Registration		
3.	Name and No. of TEC Standard /Applicant's		

	Spec. against which the approval sought		
4.	Details of Equipment		
	Type of the Equipment	Model No.	Serial No.
(i)			
(ii)			
5.	Any other relevant information:-		

D. Testing team

S. no.	Name	Designation	Organization	Signature
1.				
2.				

E. List of the test instruments:

S. no.	Name of the test instrument	Make/Model *(to be filled by team)*	Validity of calibration *(to be filled by testing team)*
1.			_ _/_ _/_ _ _
2.			
3.			
4.			
5.			
6.			
7.			
8.			

F. Equipment Configuration Offered:

a) ..... Configuration

S. No.	Item	Details	Remarks

Relevant information like No. of cards, ports, slots, interfaces, size etc. may be filled as applicable for the product

b) …….. Configuration

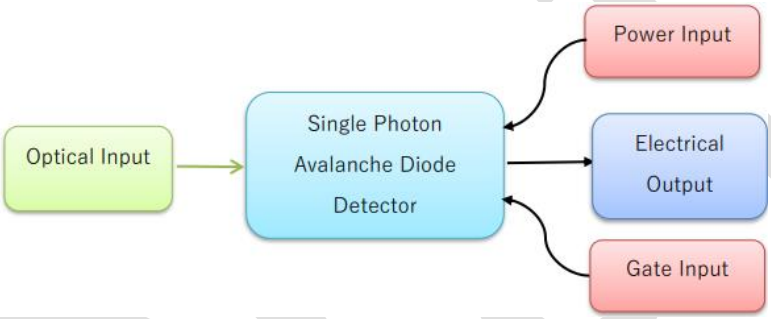
S. No.	Item	Details	Remarks

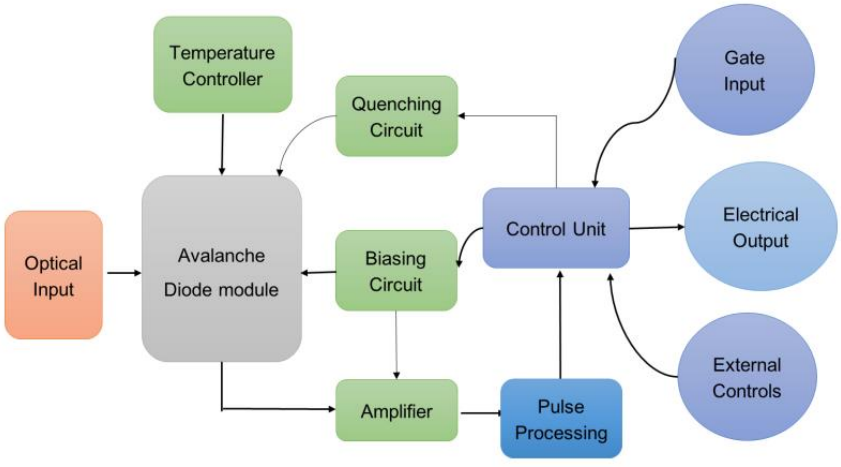
Relevant information like No. of cards, ports, slots, interfaces, size etc. may be filled as applicable for the product

G. Equipment/System Manuals:

*Availability of Maintenance manuals, Installation manual, Repair manual & User Manual etc. (**Y/N**)*

H. Clause-wise Test Type and Test No.:

Clause No.	Clause	Type of Test/Test No. etc.
	CHAPTER-1	
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.	This is for information purpose.
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 (approx. 400 nm – 900 nm). Eg., Si SPAD, etc. **Note:** The specifications of Visible Range SPAD Detector are not included in the scope and will be covered in future releases	Record the wavelength range of SPAD declared by the manufacturer.

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.	Note the type of SPAD submitted for certification by the manufacturer.
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**	The block diagram of the SPAD detector shall be provided by the Manufacturer along with the details of various functional blocks.

1.3.1	**Avalanche diode module:** Avalanche diode with internal or external thermo-electric cooler module enabling optimum signal-to-noise performance.	This is for information purpose.
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.	This is for information purpose.
1.3.3	**Temperature Controller:** Control system for thermo-electric cooler module. It is responsible for maintaining sub-zero temperatures with very high stability.	This is for information purpose.
1.3.4	**Amplifier and Pulse Processing:** It is used to translate the energy of an incident photon leading to impact ionization in the avalanche diode into a detectable photon out pulse.	This is for information purpose.
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.	This is for information purpose
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.	This is for information purpose.
1.4	**Technical Specifications of SPAD Detector** The manufacturer shall provide the values for the following parameters of the 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.	The value/range for the parameter may be specified by the manufacturer.
1.4.2	**Dark count rate (Pdark):** 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	The value/range for the parameter may be specified by the manufacturer.

	(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.	The value/range for the parameter may be specified by the manufacturer.
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.	The value/range for the parameter may be specified by the manufacturer.
1.4.5	**Timing jitter (tjitter):** 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.	The value/range for the parameter may be specified by the manufacturer.
1.4.6	**Detector Operating Temperature (T):** Ambient Temperature over which the SPAD operates within the defined specifications.	The value/range for the parameter may be specified by the manufacturer.
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.	The mode of operation(s) may be specified by the manufacturer.
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.	Test Case No. 1
1.4.9	**Gating Frequency (f):** The frequency of the gating signal applied to the detector, if operating in gated mode.	Test Case No. 2
1.4.10	**DC Bias (V_{dc}):** The DC voltage level applied to the detector.	The value/range for the parameter may be specified by the manufacturer.
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 Vac. The	The value/range for the AC Bias voltage

	total bias applied to the device therefore varies between V_{dc} and (V_{dc} + V_{ac}).	may be specified by the manufacturer.
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	The value/range for the Discrimination level may be specified by the manufacturer.
1.5	**Technical Requirements for Near Infrared Range SPAD Detector:**	
1.5.1	The photon detection efficiency (η) of the SPAD Detector shall be greater than 10%, as declared by the manufacturer.	Test Case No. 3
1.5.2	The photon detection efficiency (η) of the SPAD Detector of the SPAD detector shall be user configurable.	Test Case No. 4
1.5.3	The dark count rate (P_{dark}) for 10% Photon Detection Efficiency (PDE) shall not exceed 800 counts per second.	Test Case No. 3
1.5.4	The afterpulse probability ($P_{afterpulse}$) of the SPAD detector for 10% Photon Detection Efficiency (PDE) shall be less than 1% at the maximum specified dead time for the free-running mode and less than 0.5% for Gated mode to ensure low false detection rates and maintain detector fidelity during photon detection.	Test Case No. 3
1.5.5	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 100 microseconds.	Test Case No. 5
1.5.6	The timing jitter (t_{jitter}) shall be less than 200 ps at the maximum Photon Detection Efficiency declared by the manufacturer.	Test Case No. 6
1.5.7	SPAD Detector shall incorporate a Quenching Circuit to reset SPAD.	Test Case No. 7
1.5.8	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.	Visually inspect the optical input interface of the SPAD detector and and record the type of optical connector provided.
1.5.9	The SPAD detector shall incorporate electrical and optical shielding to minimize susceptibility to electromagnetic interference (EMI), ensuring stable operation in field environments.	Covered in EMI/EMC Testing

1.5.10	**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.	Covered in Environment Testing.
1.5.11	**Operational Temperature Range:** The SPAD shall operate satisfactorily over an ambient operating temperature range from 0° C to 35° C.	Covered in Environment Testing.
1.5.12	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.	Test Case No. 8
1.5.13	The Optical Return Loss for the optical connector shall be greater than 50dB.	Test case no. 9
1.5.14	The wavelength range of operation shall support 1100 nm to 1600 nm for Near Infrared Range SPADs or the range as specified by the manufacturer.	Test Case No. 10
1.5.15	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.	Test Case No. 11
1.5.16	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.	Test Case No. 12
1.5.17	The SPAD detector shall have the provision to securely update the firmware.	Test Case No. 13
1.5.18	The SPAD Detector shall provide the facility for monitoring of the system information and performance parameters.	Test Case No. 14
1.5.19	The SPAD detector shall have command line diagnostic interface and may optionally provide status signals.	Test Case No. 15
1.5.20	Authentication mechanisms must be used to authenticate an operator accessing the system and to verify that the operator is authorized to access the system.	Covered in Test Case No. 8
1.6	**Requirements of SPAD Detector for Highly Secure Applications [Optional]:** For highly-secure applications, the procurer based on their use case may optionally specify additional requirements from the requirements below:	

1.6.1	The SPAD detector shall limit optical back-flash emissions to minimize potential information leakage and prevent side-channel attacks in quantum communication systems.	Manufacturer shall provide details of the implemented measures for limiting optical back-flash emissions and submit supporting test reports/measurement results demonstrating compliance with the specified requirement.
1.6.2	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.	Covered in Test Case No. 8
1.6.3	All network enabled interfaces shall implement secure authentication and encrypted communication protocols Default credentials shall not be permitted. Strong password policies and account lockout mechanisms shall be enforced.	Test Case No. 16
1.6.4	The SPAD detector shall be protected against Blinding Attack. If the attacker shines a Continuous Wave (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.	Test Case No. 17
1.6.5	The SPAD detector shall be protected against saturation attacks. If the attacker sends 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 SPAD should inform the system about the attack and should stop detection events.	Test Case No. 18
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.	Test Case No. 19
1.6.7	Firmware images shall be digitally signed by the manufacturer. The device shall verify cryptographic signature prior to installation.	Test Case No. 20

	Firmware update events shall be logged with timestamp and operator identity.	
1.6.8	There shall be provision for maintaining tamper-evident logs for security-relevant events including authentication attempts, configuration changes, firmware updates, and interface access.	Test Case No. 21
1.7	**General Requirements**	
1.7.1	**Reference Documents**	
1.7.1.1	Anything not specifically stated in this document shall be deemed to be in accordance with the relevant latest global standards.	This is for information purpose.
1.7.1.2	All references to TEC GRs & other Recommendations/standards imply their latest issues.	This is for information purpose.
1.7.2	**Engineering requirements**	
1.7.2.1	The manufacturer shall furnish the actual dimensions and weight of the equipment.	Record the dimensions and weight of the equipment.
1.7.2.2	It should be engineered to comply with environmental test requirements as defined in this document.	Covered in Clause 5.10 - Environmental Testing
1.7.2.3	The external plug-in units shall be of a suitable type to allow their removal/insertion while the equipment is in energized condition.	Physically inspect and record the observations.
1.7.2.4	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.	Physically inspect and record the observations.
1.7.2.5	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.	Physically inspect and record the observations.
1.7.2.6	Each terminal block and individual tags shall be numbered suitably with a clear identification code and shall correspond to the associated wiring drawings	Physically inspect and record the observations.
1.7.2.7	All external Interfaces / Controls / Indicators/Switches shall be clearly screen printed/marked on the unit to show their functional/connectivity diagrams and functions.	Physically inspect and record the observations.

1.7.2.8	Important Do's and Don'ts about the operation of the system shall be clearly indicated at a convenient place on the equipment.	Physically inspect and record the observations.
1.7.3	**Operational requirements**	
1.7.3.1	The equipment shall be designed for continuous operation and shall be tested for 72 hours of continuous working.	Test Case No. 22
1.7.3.2	The equipment shall be able to perform satisfactorily without any degradation at an altitude up to 3200 meters above mean sea level.	Test reports shall be submitted by the manufacturer or Testing shall be carried out at an an altitude up to 3200 meters above mean sea level to check whether the system works satisfactorily.
1.7.3.3	The equipment shall provide a user interface for monitoring of system status.	Covered in Test Case No. 16
1.7.4	**Quality requirements**	
1.7.4.1	The manufacturer shall furnish the MTBF value along with the methodology used for calculation. The MTBF of the equipment shall be declared by the manufacturer.	The values shall be submitted by the manufacturer along with the calculation methodology.
1.7.4.2	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.	Declaration/Certificate to be submitted for ISO 9001:2015 compliance. The Quality plan describing the quality assurance system shall be submitted by the manufacturer along

		with the quality check report of the finished product.
1.7.5	**Maintenance requirements**	
1.7.5.1	Maintenance philosophy is to replace faulty units/subsystems after quick analysis through monitoring sockets, alarm indications and Built-in Test Equipment.	The details shall be provided by the manufacturer.
1.7.5.2	The equipment shall have easy access for servicing and maintenance.	Physically inspect and record the observations.
1.7.5.3	The equipment shall have the provision to update the firmware.	Covered in Test Case No. 15
1.7.5.4	The alarms shall be provided for the identification of Power related, Temperature related and Fan related faults in the system. The alarms may be placed on the SPAD Hardware and in the remote monitoring system.	Test Case No. 23
1.7.5.5	Ratings and types of fuses used are to be indicated by the supplier.	Physically inspect and record the observations.
1.7.6	**Power supply requirements**	
1.7.6.1	The equipment shall work using AC power supply of 100-240 VAC, 2A, 50-60 Hz or DC supply: 12V, 2A.	Inspect and Record the Power supply details of the system including Make and Ratings: voltage, current, frequency (if applicable).
1.7.6.2	The equipment shall operate over this range without any degradation in Performance.	Test Case No. 24
1.7.6.3	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.	Test Case No. 24

1.7.6.4	The derived DC voltages in the equipment shall have protection against over-voltage, short-circuit and overload.	The details shall be provided by the manufacturer.
1.7.6.5	The equipment shall be power efficient. The actual power rating/ consumption are to be furnished by the manufacturer of the equipment.	The power consumed by the equipment in idle state and in the operating state shall be noted.
1.7.7	**Accessories**	
1.7.7.1	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.	The details shall be provided by the manufacturer.
1.7.7.2	The source of the components/ accessories, from where these have been procured, is also to be submitted by the manufacturer.	The details shall be provided by the manufacturer.
1.7.8	**Documentation** Technical literature in the English language including the below details shall be provided in hard copy. Additionally, a soft copy /QR code on the system in respect of technical literature shall also be provided both in Hindi and English.	The details shall be provided by the manufacturer.
1.7.9	**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 subassembly replacement; (iv) Illustration of internal and external mechanical parts.	Check whether the Installation, operation and maintenance manual provided by the manufacturer covers the required aspects.

1.7.10	**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.	Check whether the Repair manual provided by the manufacturer covers the required aspects.
1.7.11	**Operating personal safety requirements**	
1.7.11.1	Protection against short circuits/open circuits in the access points shall be provided.	The details shall be provided by the manufacturer.
1.7.11.2	The equipment shall have a terminal for grounding the rack.	Physically inspect and record the observations.
1.7.11.3	All switches/controls on the front panel shall have suitable safeguards against accidental operation.	Physically inspect and record the observations.
1.7.11.4	The equipment shall be adequately covered to safeguard against entry of dust, insects, etc.	Physically inspect and record the observations.
1.7.12	**Environmental Testing Requirements**	
1.7.12.1	The instrument shall conform to the requirements for the category 'A' as specified in TEC document TEC 14016:2010 {Old Document No: QM-333) {MARCH 2010 issue} "Standard for Environmental Testing of Telecommunication Equipment".	Report from TEC designated test lab to be submitted.
1.8	**Safety Requirements**	

1.8.1	The equipment shall conform to IS/IEC 62368-1:2023 "Audio/video, information and communication technology equipment - Part 1: Safety requirements".	Report from TEC designated test lab to be submitted.
1.8.2	**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.	Report from TEC designated test lab to be submitted, if applicable.
1.9	**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.	Report from TEC designated test lab to be submitted.
1.9.1	Conducted and radiated emission (applicable to telecom equipment): **Name of EMC Standards:** "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}	Report from TEC designated test lab to be submitted.

	ii. The values of limits shall be as per clause No. 8.5.2 of TEC Standard No. TEC 11016:2016.	
1.9.2	Immunity to Electrostatic discharge: **Name of EMC Standard:** IEC 61000-4-2 {2025) "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.	Report from TEC designated test lab to be submitted.
1.9.3	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	Report from TEC designated test lab to be submitted.

	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.	
1.9.4	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.	Report from TEC designated test lab to be submitted.
1.9.5	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)** 2 kV peak open circuit voltage for a line-to-ground coupling **b)** 1 kV peak open circuit voltage for a line-to-line coupling. (ii) **For telecom ports:**	Report from TEC designated test lab to be submitted.

	a) 2 kV peak open circuit voltage for line to ground. **b)** 2 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 11016:2016. Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.	
1.9.6	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 11016:2016. Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.	Report from TEC designated test lab to be submitted.
1.9.7	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).	Report from TEC designated test lab to be submitted.

	(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 11016:2016. Applicable Performance Criteria shall be as per Table 3 under Clause 7.2 of TEC Standard No. TEC 11016:2016.	
1.9.8	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:	Report from TEC designated test lab to be submitted.

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 IEC 61000-4-4 IEC 61000-4-5 IEC 61000-4-6 IEC 61000-4-11 IEC 61000-4-29	EN 61000-4-3 EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-11 EN 61000-4-29	
	CHAPTER-2		
2.1	**Information for the procurer of product** This chapter describes the requirements which may be included in the tender by the procurer as per its needs. The following items need to be specified by ordering authority depending upon the actual requirements:		For information of the procurer.
2.1.1	The procurer shall specify the type of SPAD i.e. Near Infrared Range SPAD / Visible SPAD along with the mode (Free-Running/Gated) and wavelength of operation.		For information of the procurer.
2.1.2	The procurer may specify the requirements for Single Photon Avalanche Diode Detector as per the specifications provided in clause 2.0.		For information of the procurer.
2.1.3	The purchaser may specify the dimension of the equipment for any specific requirement.		For information of the procurer.
2.1.4	The procurer may specify the requirement of field-trial. Feedback, if any, may be furnished to TEC for improvement in the GR.		For information of the procurer.
2.1.5	The procurer based on its requirements for highly-secure applications may optionally specify the additional requirements as provided in clause 4.0.		For information of the procurer.
2.1.6	The procurer may specify the protocol for the applicable interfaces of SPAD detector, if required.		For information of the procurer.
2.1.7	The procurer may specify may specify the additional alarms to be extended for remote monitoring over and above the alarms listed in the standard, if required. The procurer may specify the requirement of LED indication regarding health of the equipment.		For information of the procurer.
2.1.8	The procurer may specify the requirements for the surge protection, if required.		For information of the procurer.

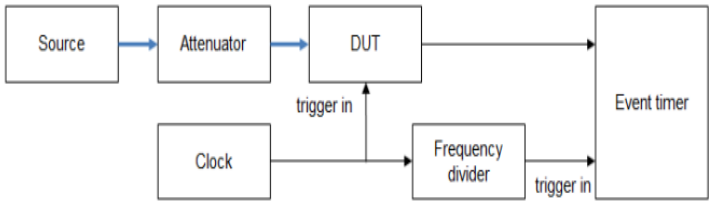
2.1.9	The procurer may specify the MTBF and MTTR requirements.	For information of the procurer.
2.2	**Specific items to be mentioned in the certificate** The following details of SPAD Detector shall be mentioned on the certificate: 1. Model number of the equipment along with the Hardware Version and Software Version (if applicable). 2. Type and Mode of operation of the SPAD Detector.	For information purpose.

I. TEST SETUP & PROCEDURES:

Test Case No. 1

Sl. No.	Test Details	Details
1.	Name of the test case	Gate Width (Only applicable for Gated SPADs)
2.	GR Clause covered	1.4.8
3.	Objective of the test	To verify that the detector operates correctly over the entire gate width (W) range specified by the manufacturer
4.	Test environment/pre-condition	SPAD Detector is biased and operated in gated mode.
5.	Tools required	• Optical input source • Pulse generator (for gate signal)
6.	Test procedure	• Illuminate the detector with optical input. • Configure the pulse generator to apply gating pulses at the minimum specified gate width (W_{min}) to the SPAD detector. In case where gated pulse can be generated internally by the SPD, such SPADs should be tested by providing a clock to the trigger input or the SPAD or by programming it to generate internal trigger and using the GUI/programming interface to program different gate widths. • Record the Detection Count/ Photon Detection Efficiency (PDE) for the gate width. • Increment the gate width in steps (3-4 steps) until the maximum specified gate width (W_{max}) is reached.
7.	Expected Result	The detector shall function properly across the entire range from W_{min} to W_{max}.

Test Case No. 2

Sl. No.	Test Details	Details
1.	Name of the test case	Measurement of Gating frequency (Only applicable for Gated SPADs)
2.	GR Clause covered	1.4.9
3.	Objective of the test	To measure the Gating frequency
4.	Test environment/pre-condition	SPAD Detector is biased in the Gated Mode.
5.	Tools required	• A fibre-coupled CW light source • A fibre-couple attenuator • An event timer, or equivalent • A clock may be required to trigger the DUT, if it does not provide its own externally available trigger signal
6.	Measurement Setup	
7.	Test procedure	As specified in clause 14 of ETSI GS QKD 011 V1.1.1
8.	Expected Result	The measured gating frequency shall be as declared by the manufacturer.

Test Case No. 3

Sl. No.	Test Details	Details

1.	Name of the test case	Measurement of dark count probability, after-pulse probability and detection efficiency
2.	GR Clause covered	1.5.1, 1.5.3, 1.5.4
3.	Objective of the test	• To verify that the photon detection efficiency (η) of the SPAD Detector is greater than 10%. • To verify that the dark count rate (P_{dark}) for 10% Photon Detection Efficiency (PDE) shall not exceed 800 counts per second. • To verify that the afterpulse probability ($P_{afterpulse}$) of the SPAD detector for 10% Photon Detection Efficiency (PDE) shall be less than 1% at the maximum specified dead time for the free-running mode and less than 0.5% for Gated mode.
4.	Test environment/pre-condition	SPAD Detector is biased in the Gated Mode and/or Free-Running Mode as specified by the manufacturer.
5.	Tools required	As per the applicable method specified in clause 15 of ETSI GS QKD 011 V1.1.1
6.	Test procedure	As per the applicable method specified in clause 15 of ETSI GS QKD 011 V1.1.1
7.	Expected Result	• The photon detection efficiency (η) of the SPAD Detector shall be greater than 10% • The dark count rate (P_{dark}) shall not exceed 800 counts per second. • The afterpulse probability ($P_{afterpulse}$) of the SPAD detector shall be less than 1% at the maximum specified dead time for the free-running mode and less than 0.5% for Gated mode.

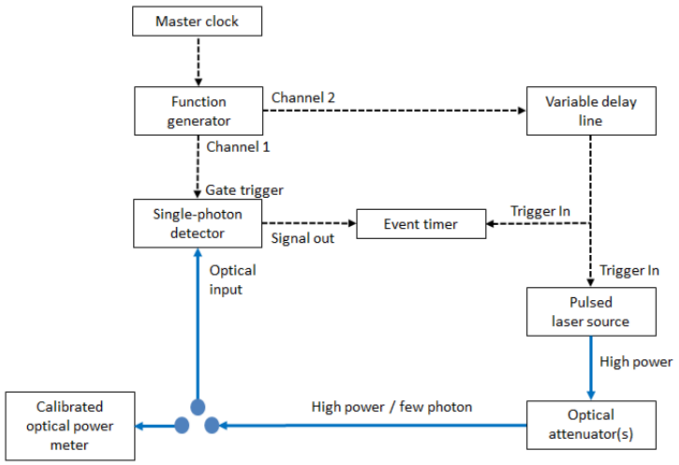
Test Case No. 4

Sl. No.	Test Details	Details

8.	Name of the test case	Configuration of Photon Detection Efficiency (PDE)
9.	GR Clause covered	1.5.2
10.	Objective of the test	To verify that the photon detection efficiency (η) of the SPAD detector is user configurable.
11.	Test environment/pre-condition	SPAD Detector is biased in the Gated Mode and/or Free-Running Mode as specified by the manufacturer.
12.	Tools required	Optical input source
13.	Test procedure	• Illuminate the SPAD detector with an optical input. • Record detection counts over a specified period (T_1) without changing the optical input. • Increase the PDE (η) using the interface/GUI. • Record detection counts over the same period (T_1) without changing the optical input. • Decrease the PDE (η) using the interface/GUI. • Record detection counts again over the same period (T_1).
14.	Expected Result	The photon detection efficiency (η) is user configurable and the detection counts increase with increase in configured PDE and decrease with reduction in PDE.

Test Case No. 5

Sl. No.	Test Details	Details
1.	Name of the test case	Measurement of dead time
2.	GR Clause covered	1.5.5
3.	Objective of the test	To verify that the dead time of the SPAD detector is less than 100 microseconds and is user configurable.
4.	Test environment/pre-condition	SPAD Detector is biased in the Gated Mode and/or Free-Running Mode as specified by the manufacturer.

5.	Tools required	• Function generator. • Pulsed laser. • Tunable delay line. • Calibrated optical attenuator. • Event timer.
6.	Measurement Setup	
7.	Test procedure	**Measurement of Dead Time:** As specified in clause 18 of ETSI GS QKD 011 V1.1.1 **To check whether the dead time is user-configurable:** • The SPAD detector is illuminated using the CW light source. • Record the detection count / Photon Detection efficiency for a period T_1. • Increase the dead time of the SPAD detector using the provided interface/GUI without changing the optical input. • Again Record the detection count / Photon Detection efficiency for a period T_1. • Decrease the dead time of the SPAD detector using the provided interface/GUI without changing the optical input. • Again Record the detection count / Photon Detection efficiency for a period T_1.

8.	Expected Result	• The dead time of the SPAD detector is less than 100 microseconds. • The detection count/ Photon Detection efficiency shall decrease with an increase in dead time and increase with a decrease in dead time.

Test Case No. 6

Sl. No.	Test Details	Details
1.	Name of the test case	Measurement of detector signal jitter
2.	GR Clause covered	1.5.6
3.	Objective of the test	To verify that the timing jitter (t_{jitter}) shall be less than 200 ps
4.	Test environment/pre-condition	SPAD Detector is biased in the Gated Mode and/or Free-Running Mode as specified by the manufacturer.
5.	Tools required	As per the applicable method specified in clause 19 of ETSI GS QKD 011 V1.1.1
6.	Test procedure	As per the applicable method specified in clause 19 of ETSI GS QKD 011 V1.1.1
7.	Expected Result	The timing jitter (t_{jitter}) shall be less than 200 ps

Test Case No. 7

Sl. No.	Test Details	Details

1.	Name of the test case	Functioning of Quenching Circuit to reset SPAD
2.	GR Clause covered	1.5.7
3.	Objective of the test	• To verify that the avalanche diode detects incident photons and produces valid output pulses for detection. • To verify that the SPAD is quenched/reset after detection.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	Optical input source
6.	Test procedure	• Illuminate the detector with optical signal. Input photon rate should not exceed the saturation count rate. • Observe the detection count behavior over time to ensure no continuous increase or saturation under constant input. • Vary optical input and monitor change in counts.
7.	Expected Result	• Detection counts shall be observed for incident optical input. • The detection counts shall increase with increase in optical input and vice-versa. • No continuous runaway or saturation in the detection count.

Test Case No. 8

Sl. No.	Test Details	Details
1.	Name of the test case	Communication Interface and Access Control
2.	GR Clause covered	1.5.12, 1.5.20, 1.6.2
3.	Objective of the test	• To verify that the SPAD detector supports standard digital communication interfaces (USB/RS-232/Ethernet) for parameter configuration. • To verify that authentication mechanisms are implemented to allow only authorized access.

4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical input source • Interface cables (USB/RS-232/Ethernet)
6.	Test procedure	• Connect the SPAD detector to the Laptop/PC using the supported interface. • Attempt to access the system with incorrect credentials and observe behavior. • Verify that the unauthorized access attempt is logged. • Log in using valid user credentials. • Configure parameters such as dead time, efficiency, gate width, etc.
7.	Expected Result	• Users with valid credentials are able to login and configure parameters successfully. • Access with invalid credentials is denied and logged.

Test Case No. 9

Sl. No.	Test Details	Details
1.	Name of the test case	Optical Return Loss
2.	GR Clause covered	1.5.13
3.	Objective of the test	To verify that the optical return loss of the optical connector is greater than 50 dB.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical Time Domain Reflectometer (OTDR) • Standard optical patch cord

6.	Test procedure	• Connect the optical return loss meter (or OTDR) to the SPAD detector's optical connector using a standard patch cord. • Record the optical return loss at the operating wavelength (e.g., 1550nm or 1310nm).
7.	Expected Result	The optical return loss of the optical connector shall be greater than 50 dB.

Test Case No. 10

Sl. No.	Test Details	Details
1.	Name of the test case	Spectral Responsivity
2.	GR Clause covered	1.5.14
3.	Objective of the test	To verify the wavelength range of operation supported by the SPAD detector.
4.	Test environment/pre-condition	As per Test Case No. 6
5.	Tools required	As per Test Case No. 6
6.	Test procedure	The spectral wavelength, λ (nm), of the incident optical pulses is varied in 3-4 steps across the range declared by the manufacturer, and the detection efficiency, η, is measured at these values.
7.	Expected Result	The photon detection efficiency (η) of the SPAD Detector shall be greater than 10%.

Test Case No. 11

Sl. No.	Test Details	Details
1.	Name of the test case	Protection against high optical input levels
2.	GR Clause covered	1.5.15
3.	Objective of the test	To verify the operation of protection circuitry against high optical input levels.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Variable optical input source • Optical power meter
6.	Test procedure	• Gradually increase the optical input power from nominal single-photon level to higher levels. • Monitor detector response (detection counts, status, alarms). • Observe any protective behavior such as saturation control, shutdown, attenuation, or warning indication. • Reduce optical input back to nominal level and observe recovery of normal operation.
7.	Expected Result	• If protection circuitry is implemented, the detector shall exhibit protective behavior at high optical input levels. • Normal operation shall resume upon returning to nominal input levels.

Test Case No. 12

Sl. No.	Test Details	Details
1.	Name of the test case	Output Signal Format
2.	GR Clause covered	1.5.16

3.	Objective of the test	To verify that the SPAD detector provides output in standard electrical signal formats (TTL/NIM/LVTTL)
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical input source • Oscilloscope
6.	Test procedure	• Illuminate the detector with optical signal. • Observe the output signal on an oscilloscope along with the signal characteristics such as voltage levels, and polarity. • Compare the measured signal characteristics with standard formats (TTL/NIM/LVTTL specifications) as declared by the manufacturer.
7.	Expected Result	The output signal shall conform to the standard format as declared by the manufacturer.

Test Case No. 13

Sl. No.	Test Details	Details
1.	Name of the test case	Secure Firmware Update
2.	GR Clause covered	1.5.17
3.	Objective of the test	To verify that the SPAD detector supports secure firmware update.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical input source • Valid firmware update package.
6.	Test procedure	• Verify current firmware version via system command.

		• Initiate update using a valid, digitally signed firmware package. Check if authentication mechanisms are implemented. • Verify that the firmware version is updated correctly after successful installation. • Verify that the SPAD detector operates normally after the firmware update.
7.	Expected Result	• The system shall correctly display the firmware version. • The user shall be authenticated before initiating the firmware update. • The firmware is successfully updated.

Test Case No. 14

Sl. No.	Test Details	Details
1.	Name of the test case	Monitoring of System Information and Performance Parameters
2.	GR Clause covered	1.5.18
3.	Objective of the test	To verify that the SPAD detector provides facility for monitoring of system information and performance parameters.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	Optical input source
6.	Test procedure	• Access the monitoring interface/GUI provided by the manufacturer. • Observe and note the displayed system information and performance parameters. The system information may include product details HW/SW version, and parameters such as operating mode, alarms, temperature, detection count, photon detection efficiency (PDE), dark count rate (DCR), dead time, etc.

7.	Expected Result	SPAD detector shall successfully provide monitoring of system information and performance parameters through the provided interface/GUI.

Test Case No. 15

Sl. No.	Test Details	Details
1.	Name of the test case	Configuration & Diagnostics
2.	GR Clause covered	1.5.19
3.	Objective of the test	• To verify that the user can configure SPAD parameters through the GUI/interface. • To verify that the control unit monitors system conditions and generates appropriate alarms/indications.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	Optical input source
6.	Test procedure	• Observe the system performance parameters on GUI eg. Detection count / photon f, dark count rate (DCR), dead time. Temperature, etc. • Using the provided interface/GUI, configure the system parameters viz. dead time, efficiency, etc. • Observe and record corresponding changes in detector behavior via GUI. • Simulate or induce any failure conditions (Power related, Temperature related and Fan related)
7.	Expected Result	• User is able to configure SPAD parameters through the interface/GUI. • The alarms shall be generated in case of failure.

		• The system displays real-time status and diagnostic information.

Test Case No. 16

Sl. No.	Test Details	Details
1.	Name of the test case	Secure Authentication and Encrypted Communication
2.	GR Clause covered	1.6.3, 1.7.3.3
3.	Objective of the test	To verify that all network-enabled interfaces implement secure authentication, encrypted communication protocols, and security mechanisms against unauthorized access.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical input source • Network protocol analyzer/software tools (eg. Wireshark)
6.	Test procedure	• Connect to the SPAD detector through the supported network-enabled interface. • Check that authentication mechanism is implemented and access using invalid credentials is denied. • Check whether secure password policy is implemented. The password policy may include minimum password length, alphanumeric/special character requirements, etc. • Specify the communication/security protocols implemented. • Perform packet capture using Wireshark or through a protocol analyzer or other software as provided by the manufacturer, verify the use of encrypted communication protocols.

7.	Expected Result	• Strong password policy is enforced. • Network-enabled interfaces are secured through authenticated and encrypted communication protocols.

Test Case No. 17

Sl. No.	Test Details	Details
1.	Name of the test case	Protection Against Blinding Attack
2.	GR Clause covered	1.6.4
3.	Objective of the test	To verify that the SPAD detector detects and responds to blinding attacks caused by continuous wave (CW) optical illumination.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• CW optical source • Variable optical attenuator • Optical power meter
6.	Test procedure	• Operate the SPAD detector under normal conditions. • Gradually increase CW optical input power to simulate a blinding attack condition. • Observe detector response; mode of the operation, detection events, alarms, notifications, or protective actions generated by the system. • Remove the CW light source and verify if the detector can be reset to a normal operating state.
7.	Expected Result	The SPAD detector shall detect the blinding attack condition caused by CW illumination and take appropriate protective action and generate an alarm.

Test Case No. 18

Sl. No.	Test Details	Details
1.	Name of the test case	Protection Against Saturation Attack
2.	GR Clause covered	1.6.5
3.	Objective of the test	To verify that the SPAD detector detects and responds to saturation attacks caused by high-speed optical pulses.
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• High-speed pulsed optical source • Optical attenuator • Pulse generator
6.	Test procedure	• Apply high-speed optical pulses at a rate higher than the normal operating signal rate to simulate a saturation attack condition. • Observe detector response; mode of the operation, detection events, alarms, notifications, or protective actions generated by the detector/system. • Verify whether the detector stops or disables detection events during the attack condition and generates an alarm.
7.	Expected Result	The SPAD detector shall detect the saturation attack condition, take appropriate protective action and generate an alarm.

Test Case No. 19

Sl. No.	Test Details	Details
1.	Name of the test case	Protection Against Thermal Attack
2.	GR Clause covered	1.6.6

3.	Objective of the test	To verify that the SPAD detector is protected against Thermal Attacks
4.	Test environment/pre-condition	Detector is operated under normal conditions (gated/free-running as applicable)
5.	Tools required	• Optical input source • Controlled heating source
6.	Test procedure	• Gradually vary the detector internal/environment temperature beyond the calibrated operating range specified by the manufacturer. • Observe detector response; mode of the operation, detection events, alarms, notifications, or protective actions generated by the detector/system. • Verify whether the detector stops or disables detection events during the attack condition and generates an alarm.
7.	Expected Result	The SPAD detector shall detect abnormal thermal conditions beyond the calibrated operating range, take appropriate protective action and generate an alarm.

Test Case No. 20

Sl. No.	Test Details	Details
1.	Name of the test case	Secure Firmware Signature Verification and Logging
2.	GR Clause covered	1.6.7
3.	Objective of the test	To verify that firmware images are digitally signed by the manufacturer, cryptographic signature verification is performed prior to installation, and firmware update events are logged.

4.	Test environment/pre-condition	-
5.	Tools required	• Valid digitally signed firmware package • Modified/unsigned firmware package
6.	Test procedure	• Login with valid credentials. • Attempt to upload a modified or unsigned firmware image to the detector. • Check for an Invalid Signature or Verification Failed error. • Upload the valid digitally signed firmware image provided by the manufacturer and verify successful installation. • Check the system logs whether firmware update events are recorded with timestamp and operator identity.
7.	Expected Result	• Firmware images with invalid or missing cryptographic signatures gives error. • Only valid digitally signed firmware images are successfully installed. • Firmware update events are logged with timestamp and operator identity.

Test Case No. 21

Sl. No.	Test Details	Details
1.	Name of the test case	Tamper-Evident Security Event Logging
2.	GR Clause covered	1.6.8
3.	Objective of the test	To verify that the SPAD detector maintains tamper-evident logs for security-relevant events including authentication attempts, configuration changes, firmware updates, and interface access.

4.	Test environment/pre-condition	-
5.	Tools required	Laptop/PC
6.	Test procedure	• Access the SPAD detector through the supported interface & GUI. • Perform events such as login attempts (failed/successful), configuration changes. • Access and review the generated system logs. • Verify whether the logs contain timestamp, user/operator identity, and event details. • Check whether unauthorized modification or deletion of logs is prevented or detectable.
7.	Expected Result	• The events including authentication attempts, configuration changes, firmware updates, etc. access shall be recorded in logs. • Logs shall contain timestamp, user/operator identity, and event details. • Unauthorized modification or deletion of logs shall not be permitted and shall be detectable.

Test Case No. 22

Sl. No.	Test Details	Details
1.	Name of the test case	Continuous Operation Test
2.	GR Clause covered	1.7.3.1
3.	Objective of the test	To verify that the SPAD detector is capable of continuous operation without malfunction or performance degradation.

4.	Test environment/pre-condition	Detector is operated under normal operating conditions (gated/free-running as applicable).
5.	Tools required	Optical input source
6.	Test procedure	• Operate the SPAD detector continuously for 72 hours under normal operating conditions. • Monitor Photon Detection Efficiency, alarms generated (if any) and other relevant performance parameters made available by the manufacturer using the GUI/logs during the test duration.
7.	Expected Result	• The Photon Detection Efficiency (PDE) shall be greater than 10% during the test duration and no unexpected failures shall occur during the continuous operation.

Test Case No. 23

Sl. No.	Test Details	Details
1.	Name of the test case	Alarm Indications
2.	GR Clause covered	1.7.5.4
3.	Objective of the test	To verify that alarms are generated for faults in the SPAD detector system.
4.	Test environment/pre-condition	Detector is operated under normal operating conditions (gated/free-running as applicable).
5.	Tools required	Optical input source
6.	Test procedure	• Simulate the fault conditions.

<table>
<tr><td></td><td></td><td>

Observe and verify the alarm indications generated on the SPAD hardware and/or monitoring system.
Record the details as below:

<table>
<tr><th>Alarm Type</th><th>Failure Simulated (Y/N)</th><th>Alarm generated (Y/N)</th><th>Monitoring (GUI/Hardware)</th></tr>
<tr><td>Power related</td><td></td><td></td><td></td></tr>
<tr><td>Temperature related</td><td></td><td></td><td></td></tr>
<tr><td>Fan related</td><td></td><td></td><td></td></tr>
<tr><td>Any other alarm present in the system</td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>7.</td><td>Expected Result</td><td>

The SPAD detector shall generate alarms in case of failure.
The alarms shall be indicated on the SPAD hardware and/or remote monitoring system.

</td></tr>
</table>

Test Case No. 24

Sl. No.	Test Details	Details
1.	Name of the test case	Voltage Variation and Reverse Polarity Protection for DC feeds
2.	GR Clause covered	1.7.6.2, 1.7.6.3
3.	Objective of the test	To verify that the SPAD detector operates without performance degradation over the specified voltage range and is protected against voltage variation beyond the range and input reverse polarity (DC feed).

4.	Test environment/pre-condition	-
5.	Tools required	• Variable DC/AC power supply • Optical Input Source
6.	Test procedure	• Operate the SPAD detector within the specified nominal voltage range. • Vary the input voltage within the allowable operating range declared by the manufacturer and observe system performance. • Apply voltage beyond the specified range (±15%) and verify that the system is protected and no damage or malfunction occurs. Check normal operation shall resume when correct voltage within the allowable range is restored. • Apply reverse polarity to the DC input (where applicable) and verify that the system is protected and no damage or malfunction occurs.
7.	Expected Result	• The equipment shall operate over the specified voltage range without any performance degradation. • The equipment shall be protected against voltage variations beyond the specified range. • The equipment shall be protected against reverse polarity connection in case of DC feeds, without damage or malfunction.

J. SUMMARY OF TEST RESULTS

TEC Standard No. TEC 91030:2026

TEC Test Guide No. TEC 91031:2026

Equipment name & Model No. _____

Clause No.	***Compliance*** *(Complied /Not Complied / Submitted/Not Submitted / Not Applicable)*	***Remarks / Test Report Annexure No.***

Date:

Place: **Signature & Name of TEC testing officer/**

***Signature of Applicant/ Authorized Signatory**