

UDC 383

EDN: VVRYXU

PACS: 42.79.Pw, 85.60.Gz, 07.57.Kp

The stand for conducting resource tests in forced modes of a photosensitive element from a space-based photodetector device

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Received 25.08.2025; revised 22.09.2025; accepted 20.10.2025

A stand has been designed for carrying out resource tests in forced modes of a photomodule (FM) of the infrared range (IR) with a temporary hold and accumulation mode (VZN) from a space-based photodetector. A feature of the development is the possibility of obtaining experimental data on failures that occur during prolonged operation of the FM, which affect the threshold characteristics of the device. The stand allows us to confirm the sufficiency of measures to ensure the durability and reliability of the photomodule, as well as to assess the reliability of all equipment used in the whole. The stand will be tested through scheduled tests.

Keywords: stand; photodetector device; photosensitive element.

DOI: 10.51368/2949-561X-2025-5-79-83

Introduction

During development of the Earth remote sensing (ERS) equipment intended for operation in space, the design phase includes reliability calculations and assessments, particularly for the cases involving the ultra-long-term operation during about 10–15 years under the constant influence of space ionizing radiation [1]. Based on these reliability calculations and assessments, as well as the requirements for the ERS equipment, schematic-design and structural design solutions for manufacturing are also determined.

A key component of the ERS equipment are photodetectors operating in the infrared (IR) spectral range. The most promising types of IR photodetectors in terms of reliability and radiation hardness are considered to be scanning-type IR photodetectors incorporating the charge time delay and accumulation (TDA) mode, which use digital-output photomodules (DPMs) as a photodetector. The reliability and radiation

hardness of such IR photodetectors is based on the fact that analog-to-digital signal conversion is performed inside the readout large-scale integrated (LSI) circuit which is a part of DPM [2].

The most critical component was identified among the parts of the photodetector under consideration, that is DPM, whose photosensitive elements (PSE) array is composed of HgCdTe (mercury-cadmium-telluride) photodiodes [3]. This paper contains the reliability calculation for the photomodule.

Description of the Measurement Object

The photomodule consists of a Kovar base bearing a multiplexer with 1024 TDA channels. Each channel incorporates a built-in 14-bit analog-to-digital converter connected to a photosensitive element sized (1024×10), topologically organized into four sub-arrays [4, 5]. The photosensitive elements are made of

cadmium-mercury-telluride. Each photomodule generates digital sequences at its outputs, which represent the results of the analog-to-digital conversion of signals from 1024 TDA channels of the multiplexer.

Test Methods

Endurance tests are conducted to develop and verify the reliability of equipment, to identify and eliminate potential design and construction defects that are revealed during long-term operation of the equipment during the service life (assigned lifetime) as per the technical assignment, and to assess (predict) reliability characteristics based on the endurance test results. To shorten the endurance test period for equipment with long mission life of a spacecraft (3 years or more), testing in forced modes is permitted.

Forced endurance test consists of four procedures:

- Procedure 1 – thermal cycling: 1120 hours, consisting of 70 thermal cycles.
- Procedure 2 – low operating temperature exposure test: minus 110 °C, 150 hours, consisting of 3 cycles.
- Procedure 3 – long-term operation of the photomodule at the operating temperature of minus (103±2) °C in "On-Off" mode, 2676 hours, consisting of 2676 "photomodule on" – "photomodule off" cycles.
- Procedure 4 – high temperature exposure test: +35 °C, 604 hours, consisting of 2 cycles.

Test Bench

To perform endurance tests in forced modes of the photomodule being a part of the space-based photodetector, a test bench has been developed that allows evaluating the photomodule's endurance and operational reliability. The bench components (see the figure) include:

- cryostat with a liquid nitrogen cooling system that ensures cooling down the internals to which the photomodule's gauging is attached;
- control and power supply unit consisting of:
 - 1) control unit providing the following:
 - monitoring of set values for supply voltages;

- setting the photomodule's operation modes;

- outputting the analog form (for oscilloscope monitoring) of signals representing the sequences of samples of 512 even or 512 odd channels from photomodule's OUT1 and OUT2 outputs;

- outputting the analog form (for oscilloscope monitoring) of signals representing the sequences of samples from one of 512 even or 512 odd channels of the photomodule;

- setting the synchronization mode between the ambient illumination scanner and multiplexer;

- measuring the total current consumed by the photomodule;

- monitoring the photomodule control pulses;

- managing the communication with the host PC.

2) communication unit that ensures the connection between the photomodule equipped with the gauging and the control unit, and monitors its operability, thus enabling the following checks:

- checking the range of photomodule supply and control voltages;

- checking the channel for measuring the total current consumed by the photomodule;

- checking the time-base diagrams of photomodule control pulses;

- checking the channel for outputting the analog information for oscilloscope monitoring;

- checking the integrity of temperature sensor circuits;

- checking the functionality of the USB channel for transmitting the information from the control and power supply unit to PC.

3) cable connecting the control unit to the communication unit;

4) USB cable connecting the control unit to PC;

5) network cable.

- Thermodat-17E6 TD13303625 (designed for simultaneous temperature measurement and adjustment in several channels);

- MATRIX VPS-3005L-3 laboratory power source (used for heating elements (resistors) and maintaining the temperature in the gauging and communication unit);

- AKTAKOM ATH-3335 laboratory power source (used for heating elements

(resistors) and maintaining the temperature in the communication unit);

- MIT 8.03 multi-channel precision temperature meter (designed for precision temperature measurements and thermal field mapping);

- AKIP B7-78/1 multi-purpose voltmeter (allows highly accurate measurement of AC/DC current, resistance, voltage, frequency, and temperature with external sensors);

- Tektronix MDO4054B-3 oscilloscope (enables the time-correlated recording of analog, digital, and RF signals which allows examining the signal and making measurements in both frequency and time domains simultaneously);

- Agilent TPS-mini dry high vacuum turbo molecular pumping system (creates a vacuum inside the cryostat);

- TELEVAK CC-10 electronic vacuum gauge (designed for precise measurement of absolute pressure);

- M305 blackbody module (serves as a radiation source);

- New Focus modulator with control unit, model 3502 (modulates the radiation flux from the blackbody);

- PC;

- software designed to process information from the photomodule and display information frames along with calculated photomodule characteristics on the PC monitor.

DPM is installed in the gauging, which, together with the communication unit, is placed in the cooled zone of the cryostat. Then the pressure inside the cryostat is reduced to ultra-high vacuum (less than 10^{-5} Pa) using a high-vacuum pump, with the pressure level monitored with a corresponding sensor inside the cryostat. After that DPM is cooled with liquid nitrogen to the operating temperature, which is monitored with a corresponding sensor inside the cryostat. For example, the operating temperature is approximately 80 K for the photomodule whose photosensitive elements are photodiodes made of long-wave infrared CdHgTe. Then, power is applied, and initial configuration of DPM is performed via the control and power supply unit [6].

The communication unit is equipped with a temperature sensor and heating resistors (HF2 and HF3) designed to maintain the positive temperature on the communication unit.

The cryostat has two zones:

- a hermetically sealed, pumpable zone containing the gauging with the photomodule and communication unit (the cooled zone);

- a zone to be filled with liquid nitrogen (nitrogen chamber)

The gauging with the photomodule in the cooled zone is mounted on a copper plate, which is attached to a heat conductor leading to the nitrogen chamber. To adjust the photomodule temperature, a heating resistor (HF1) and a temperature sensor (T1), using a platinum sensitive element, ChEPT-50P, are installed on the plate. By changing the current through the heating resistor (HF1), the specified cooling or heating temperatures for the photomodule are set. The communication unit has no thermal contact with the copper plate. The heat flow from the communication unit to the photomodule travels along the cable that connects them. To maintain the positive temperature on the communication unit during all types of photomodule tests, the unit is equipped with two heating resistors (HF2 and HF3) and LN222Pt100 temperature sensor, which outputs the temperature from the communication unit (T4). Additionally, two LN222Pt100 temperature sensors are integrated into the gauging of the photomodule to provide temperatures T2 and T3. The heating resistor (HF1) is heated by a laboratory source (H1). Control and supply voltages are applied to the photomodule, and its information signals are read off using the communication unit and control unit, which are part of the control and power supply unit. A voltmeter and an oscilloscope connected to the control unit are used to monitor the total consumption current and signals at the photomodule output. In the control unit, the information signals from the photomodule outputs are converted into a single digital stream, which is transmitted via the USB channel to the PC for processing and display. A reduced pressure shall be maintained inside the cryostat for the photomodule ($10^{-6} \div 10^{-4}$ mm Hg), which is created by "Agilent TPS-mini" dry high vacuum turbo molecular pumping system. The pressure inside the cryostat shall be monitored using TELEVAK CC-10 vacuum gauge. The temperature of the communication unit (T4) shall be maintained within the range of $(10 \div 30)^\circ\text{C}$ by

means of heating elements (resistors) HK3, HG3 and two-channel AKTAKOM ATH-3335 source. The operating temperature of the photomodule is monitored with three temperature sensors:

- sensor T1 mounted on the plate equipped with the gauging;
- sensors T2 and T3 of LN222Pt100 type mounted inside the gauging.

The temperature sensors providing data for temperatures T2, ..., T4 are connected to the four-channel temperature controller (meter) Thermodat-17E6. The values of T2, ..., T4 are displayed on the meter's indicator panel and are simultaneously transmitted to the PC via the interface channel created using RS-232/USB converter of MOXA type.

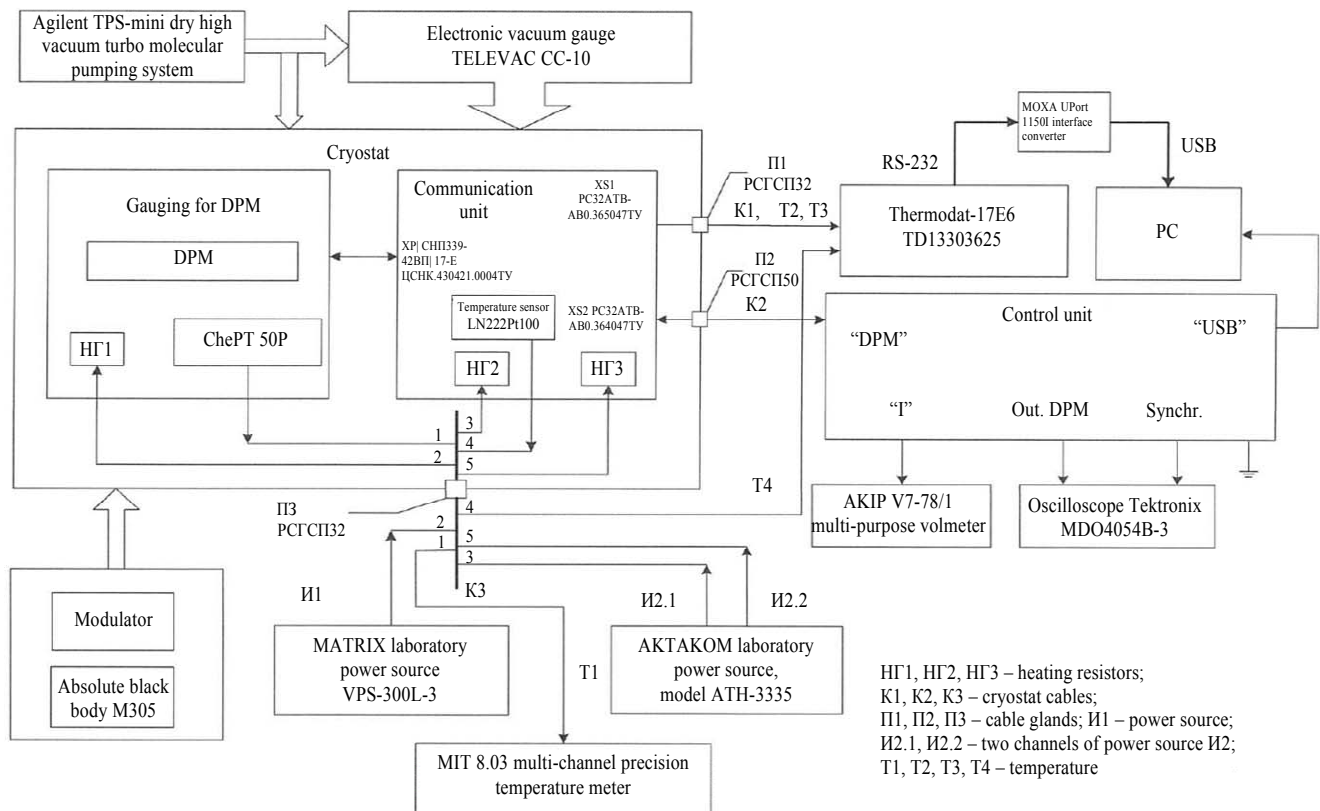


Figure Structural diagram of the test bench

Conclusion

The test bench for forced endurance tests of the photomodule, which is part of the space-based photodetector, enables the detection and elimination of defects and failures during long-term operation of the photomodule, monitoring and verification of sufficient measures to ensure

the specified probability of failure-free operation and assigned service life, which is implemented in the forced mode under exposure factors, as well as confirmation of the non-destructive nature of the electrothermal conditioning of the photomodule. To validate the reliability assessment conducted in paper [3], the forced endurance tests will be performed at this bench.

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