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Automated Multifunction Stand for Mass Measurement of Pin Photodiodes' Characteristics

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Abstract—To control the parameters of PIN photodiodes during their mass production, a high-performance automated multifunctional stand has been developed. The stand provides measurement of dark current, capacitance at operating voltage, and response to a light signal with simultaneous connection of up to 16 photodiodes and successive verification of their characteristics.

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STAND DESCRIPTION

The Budker Institute of Nuclear Physics, Siberian Branch, Russian Academy of Sciences, developed and manufactured an automated multifunctional stand for mass measurement of the characteristics of PIN photodiodes [1]. The stand consists of independent circuits for measuring the current and capacitance of photodiodes (PD). The block diagram of the stand is shown in Fig. 1. The FDs are connected to the board via a PLLD1.27-40R pin connection. For control, a reference FD was installed. A positive bias voltage is applied simultaneously to the cathodes of all PDs from an external power source. All anodes are connected to zero potential through controlled switches on field-effect transistors (Fig. 2). To carry out measurements, the PD anodes are disconnected in turn from the zero potential and connected to the input of the measuring circuit. Such a solution makes it possible to avoid the rapid overflow of charges at the moment of switching since the potential difference across the PD hardly changes. The stand uses a two-stage power supply. The AC–DC power supply operates on 220 V AC and outputs +15 V DC) and the second stage, using DC–DC converters and linear stabilizers, generates the necessary set of voltages to power the controller, amplifiers, and switch (±2.5, ±5, +10 V).

The dark current measurement circuit is connected to the cathode of the diode under study through a 1 MΩ resistor (Fig. 3), and the capacitance measurement circuit is connected through a 1 μF capacitor (Fig. 4). The selected denominations allow one to reliably separate permanent and variable current components. At the output of each measuring circuit, a constant voltage is generated, which is digitized by the built-in ADC in the control controller.

A dark current measurement circuit (see Fig. 3) is assembled on the basis of an AD8602 two-stage operational amplifier (op-amp). The dark current enters the inverting input of the op-amp and is compensated by the current coming from the negative feedback circuit (NFB) through the resistor with resistance 20 MΩ. The second stage of the op-amp further amplifies the signal by 25 times. The dark current to voltage conversion ratio is 500 mV/nA.

To measure PD capacitance (see Fig. 4), a sinusoidal voltage of 1 V with a frequency of 1 MHz is supplied from an external generator. The variable current component, due to the capacitance of the PD, enters the inverting input of the AD8065 op-amp and is compensated by the current coming from the CFO circuit through a capacitor with a capacity of 100 pF. On the second stage, the signal is additionally amplified by a factor of 20 and fed to a linear half-wave rectifier based on the AD829 op-amp and an integrating *RC*-circuit with a time constant of 4.4 ms. DC output voltage is proportional to the PD capacitance with a coefficient of 0.15 V/pF. The capacitance measurement range can be increased by installing a larger capacitor in the AD8065 amplifier's OOS circuit.

A dark current measurement circuit is used to measure the response to a light signal. The studied PD is irradiated by the LED simultaneously with the reference one (in a specific implementation, the PD is used

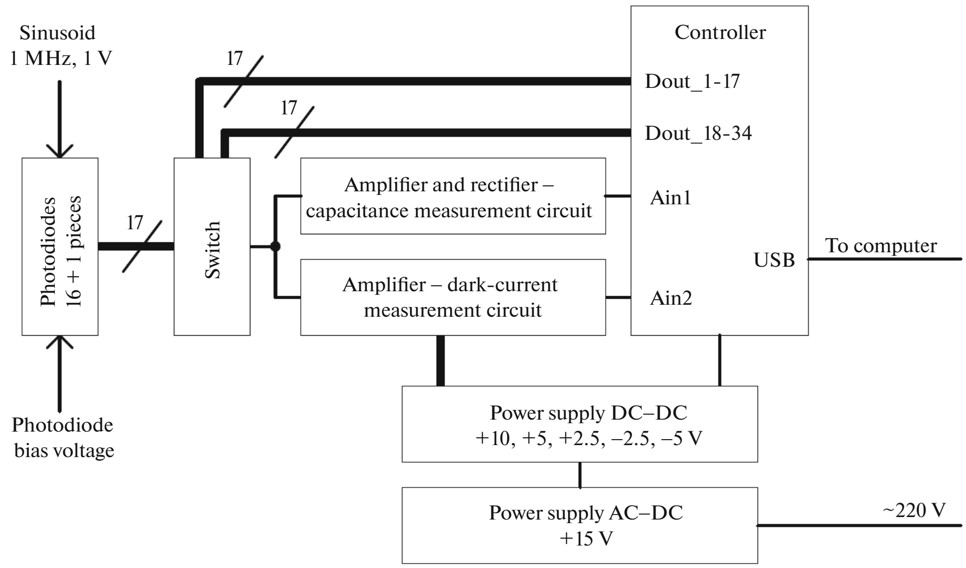

Fig. 1. Block diagram of an automated multifunctional stand for mass measurement of the characteristics of PIN photodiodes.

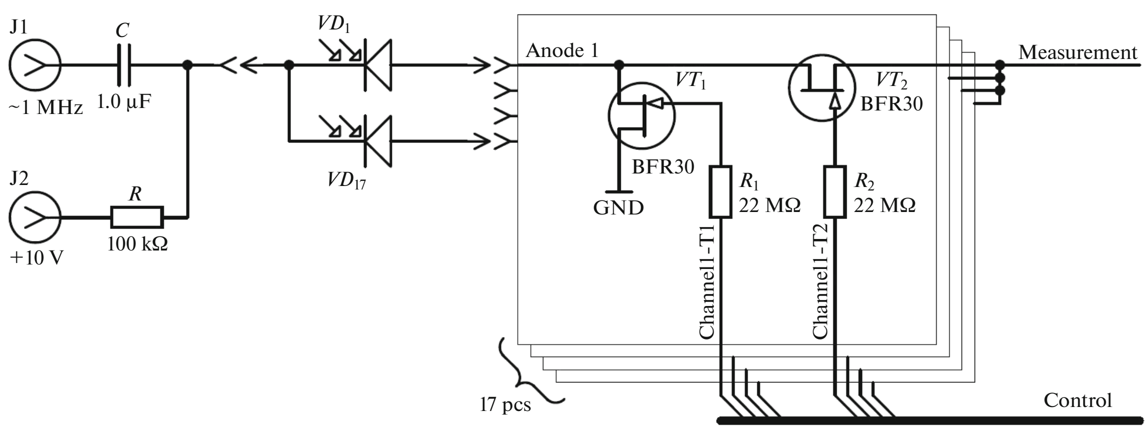

Fig. 2. Photodiode connection diagram and switch.

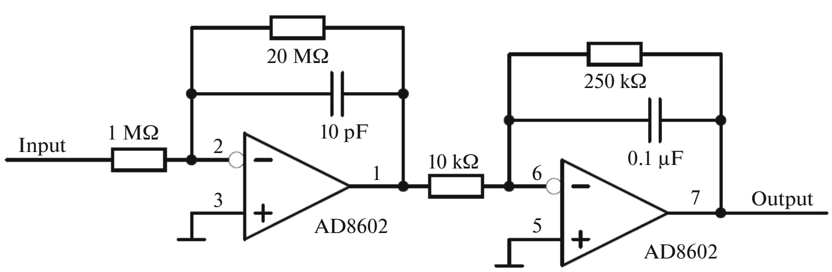

Fig. 3. Scheme of the channel for measuring the dark current of the PD.

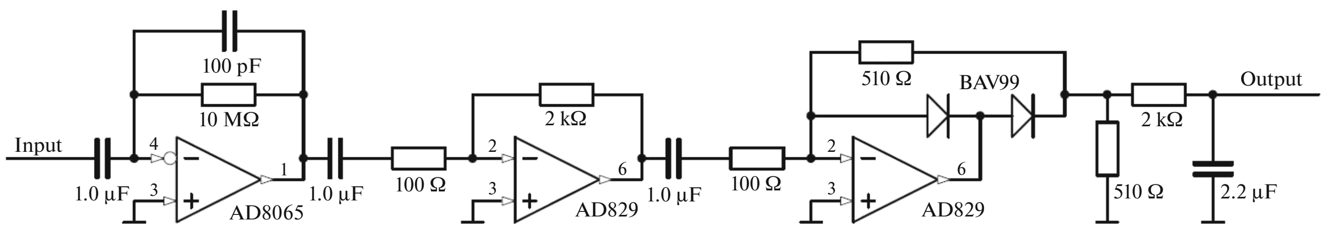

Fig. 4. Scheme of the PD capacitance measurement channel.

Hamamatsu S10993-05GT [2]), and its sensitivity is calculated from the signal ratio. This approach makes it possible to measure the PD sensitivity in the wavelength range from 400 to 1000 nm using LEDs with different emission spectra. Unlike measurements of dark current and capacitance, which are carried out for each PD, the response to a light signal is controlled selectively for several PDs from a batch. Therefore, for ease of operation and the possibility of using large signals, a simplified version of the stand was made without a capacitance measurement circuit and with a sensitivity lower by four orders of magnitude.

STAND CONTROL

The stand is controlled using the built-in controller, which is a ready-made Arduino Mega 2560 board [3]. The board has the required number of digital outputs for controlling transistor switches, a 10-bit ADC with an input voltage range of 0 to 5 V, and several analog inputs. The switch is controlled by digital outputs of the controller board, which set the state of the keys. Signal levels for key management are transmitted to the controller from the computer. The signals from the outputs of the measurement channels arrive at the analog inputs and are switched to the ADC input.

To control the Arduino board, a program was written for the ATmega2560 controller [4]. For the firmware, the programmer built into the board and the Arduino IDE were used. We defined 34 digital outputs to control the FET switch (two outputs for each of the 16 + 1 PD channels) and two analog inputs for measuring capacitance and dark current. Functions for accessing these outputs were written. On digital pins, the state “1” turns on and “0” turns off the corresponding FETs in the switch. Analog outputs are connected to the ADC built into the microcontroller. The measured values are transferred to a personal computer (PC) for parameter calculation. For greater autonomy and universality in connection to different computers, a USB interface is used, through which the operation of a COM port is emulated.

A PC program written in the C++ language [5] controls the stand operation modes: switches it to the capacitance measurement mode or the dark current measurement mode, switches the channel switch. This also allows one to carry out the necessary measurements, calculate the values of the measured quantities using calibration parameters, and save the data to a file. Along with the measured data, marks about the current measurement time and comments are written to the file. In this program, it is possible to change the following settings: the values of the maximum and minimum allowable values, calibration coefficients, the name of the port for connecting the stand to a computer, and the settings for connecting to a PC.

STAND CALIBRATION

To calibrate the channel for measuring the dark current, we measured the dependence of the output voltage on the input current. To do this, a constant voltage was applied to the input of the stand through a resistor with a resistance of 2 GΩ, i.e., 1 V corresponds to a current of 0.5 nA. By changing the input voltage from 0 to 10 V, we obtained a linear dependence and determined the corrected current-to-voltage conversion factor. In the stand designed to test the response to a light signal, the current measurement channel was calibrated in a similar way, only the calibration current was applied through a 200-kΩ resistance.

To calibrate the capacitance measurement channel, four capacitors with known ratings were measured. Based on the results of the calibration, the sensitivity of the bench was determined to be 6.7 pF/V.

In order to test the stand, the parameters of the Hamamatsu S10993-05GT photodiode were measured. The obtained values are consistent with the passport ones within the measurement accuracy.

CONCLUSIONS

Two automated multifunctional benches for mass measurement of PIN-PD characteristics have been created. One stand allows precise measurement of the dark current and capacitance of the photodiode with a reverse bias applied, the second is designed to test the response to a light signal, is designed for a higher input current, and is equipped with an LED with a light filter.

The following characteristics have been achieved:

1. dark current measurement range from 0 to 5 nA with an accuracy of 0.05 nA;

2. capacitance measurement range from 0 to 30 pF with an accuracy of 0.15 pF;

3. relative accuracy of measurement of the response to the light signal 2%;

4. the time for measuring the parameters of 16 PDs is 2 min;

5. the drift is no more than 1 LSD of the ADC in 80 min.

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