SiPM characterization

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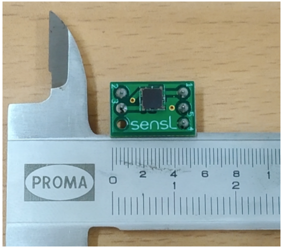
January 26, 2023

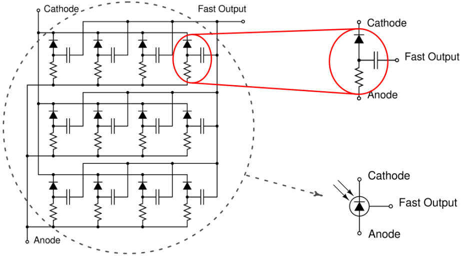
Far-backward meeting

Signal shape and electrical characteristics for a Onsemi SiPM

- Done for MICROFC-SMTPA-30035-GEVB model by Onsemi on a test board
- Active area 3×3 mm^2, 35 µm microcell size (4774 microcells), 64% fill factor
- Picosecond laser is used as a light source, signal is sampled by a fast scope
- Capacitance, resistance and leakage current is measured by a LCR meter



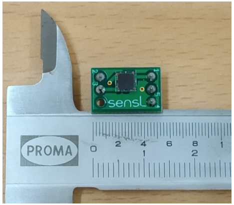
Test board

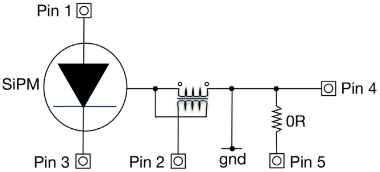


Anode, cathode and capacitive coupling for fast output

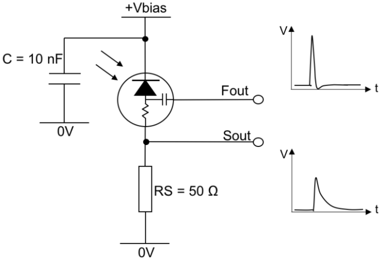
Signal readout for the test board

- Cathode (pin 3) is connected to positive bias voltage, 26.8 V in our case
- Standard signal output (Sout) is read at anode (pin 1) across 50 Ω resistor
- Fast output (pin 2) comes via balance-unbalance transformer (balun) on the back of the test board
- The balun transformer maintains 50 Ω impedance for Fout
- Both Sout and pin 2 are connected by lemo cables to 50 Ω scope inputs





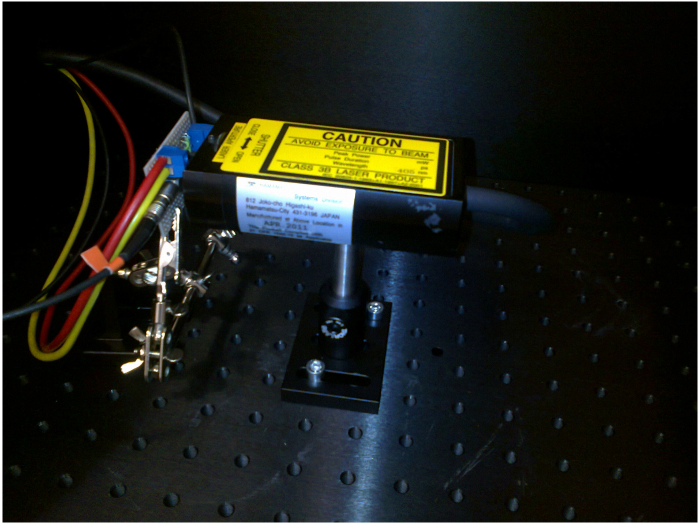
Test board



Biasing and readout

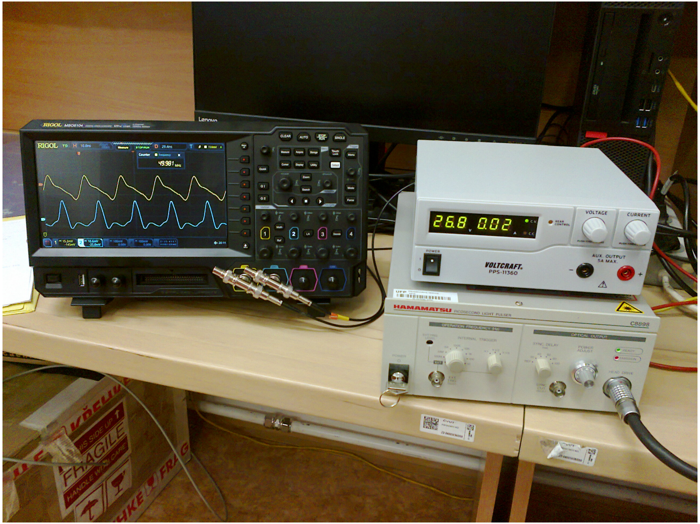
Laser head and SiPM board

- The SiPM board is connected to custom-made connection board providing filtering capacitor for bias voltage and 50 Ω resistor for standard output
- Active area of SiPM is facing directly the laser
- The laser is Hamamatsu 405 nm diode with pulse duration of $\sim$60 ps
- Both the board and laser are placed in a light-tight enclosure



Setup for signal readout

- Signals are sampled by Rigol MSO5104 scope, 100 MHz, 8 GSa/s
- Hamamatsu laser driver supplies the diod for a given frequency of laser pulses
- Laser power was set at a few units above its minimum
- Bias voltage is provided by a standard low voltage power supply

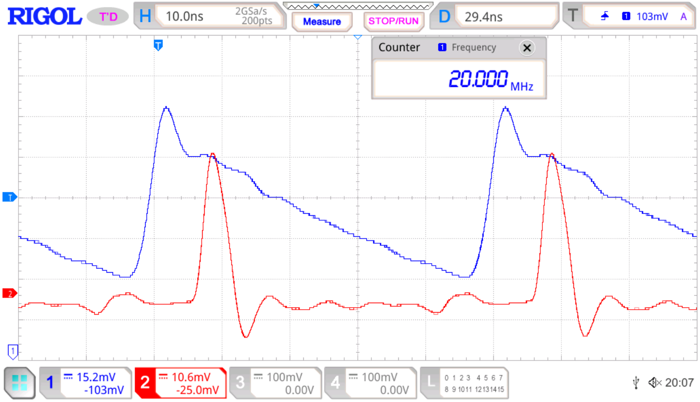


Signal shape for single laser pulses

- Channel 1 (blue) is standard output
- Channel 2 (red) is signal on fast output
- Delay in fast output is caused by longer cable
- Laser frequency is 1 kHz
- Signals are averaged over 1024 triggered samples to reduce the noise
- Nominal performance is achieved even with a very basic setup
- Further investigation is needed for oscillations after the main pulse

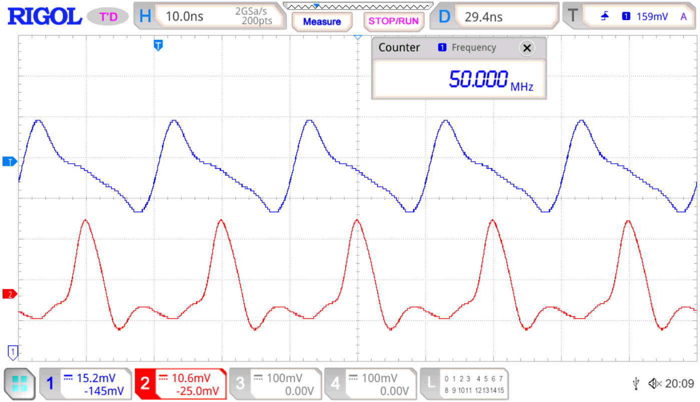
Signals with laser at 20 MHz

- Standard output starts to overlap, a large offset is needed for the waveform
- Frequency of scope triggers (Counter box) is exactly the frequency set on laser driver
- Fast output provides clean separate pulses



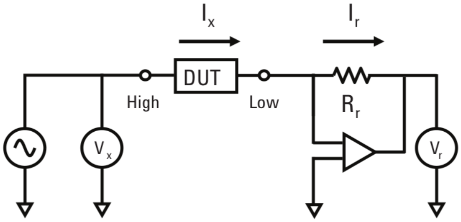
Signals at 50 MHz

- Laser driver is set at 50 MHz, more than we need
- Scope trigger frequency matches the laser
- Still separate pulses for fast output, only reduced in amplitude (laser power is still the same)



Measurement of impedance for SiPM electrical characteristics

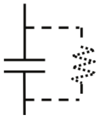
- Complex impedance Z_x is given by voltage V_x of test signal on device under test (DUT) and current I_x flowing through it
- The current is converted to voltage on operating amplifier maintaining 0 V (virtual ground) on Low terminal
- When the bridge is balanced for 0 V at Low, current I_r across opamp feedback range resistor R_r is exactly equal to the current I_x through the DUT
- Both V_x and V_r are vector voltmeters giving two 90° phase components of the voltage
- The procedure is done by Agilent E4980A LCR meter



$$Z_x = \frac{V_x}{I_x} = R_r \frac{V_x}{V_r}$$

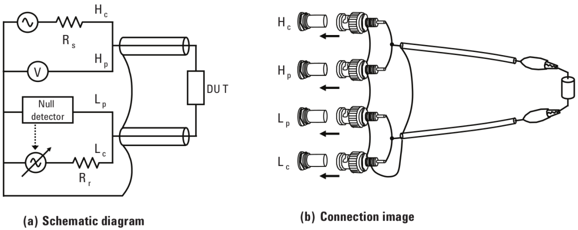
Auto-balancing bridge

SiPM electrical characteristics by impedance measurement



SiPM represented as Cp-Rp

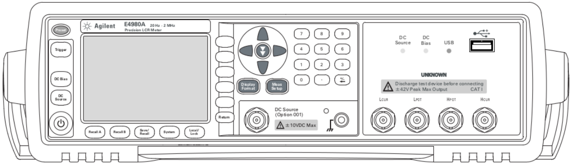
- The DUT is our 30035 Onsemi SiPM connected by its cathode and anode to High and Low terminals of the Agilent LCR meter
- The LCR provides the test signal to measure the impedance and also the bias voltage
- SiPM is represented by parallel capacitor and resistor circuit (Cp-Rp); given the measured impedance, the values of Cp and Rp are algebraically calculated by the LCR meter



Connections used for SiPM characteristics

Automated readout for the LCR meter

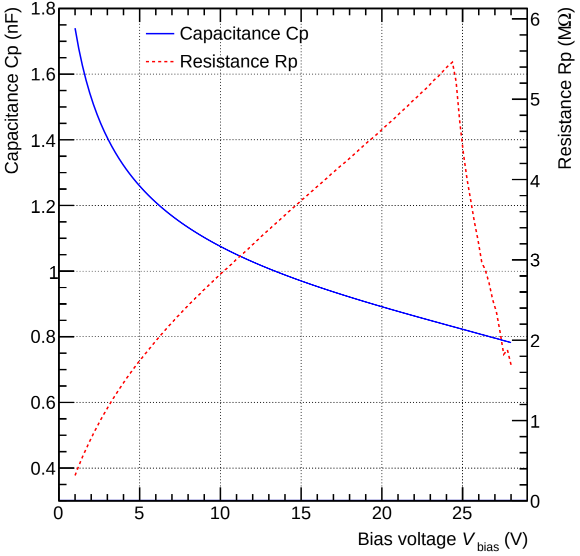
- Amplitude and frequency of test signal were set to 50 mV and 10 kHz
- The SiPM is in a light-tight enclosure during the measurement
- SiPM capacitance, resistance and leakage current were measured for 120 values of bias voltage from 1 V to 28 V
- At each bias voltage, 12 measurements of SiPM quantities were performed and an average was made
- The procedure is automated using telnet connection to the LCR meter, codes are here: github.com/adamjaro/lmon/tree/master/macro/sipm/Agilent



E4980A

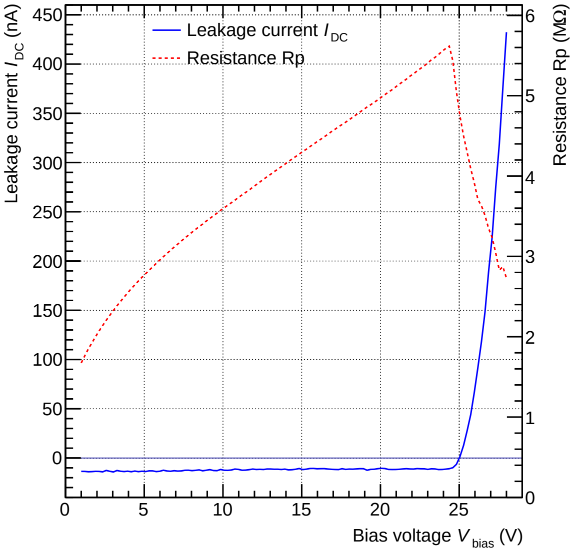
Capacitance and resistance as a function of bias voltage

- Plot shows capacitance Cp and resistance Rp at different values of bias voltage V_{bias}
- Capacitance decreases with voltage as the width of depleted region gets larger
- Resistance has a sharp peak around 24 V where breakdown of individual microcells occurs, consistent with specification
- Signals on the scope were taken at V_{bias} = 26.8 V



Leakage current as a function of bias voltage

- Results of the same measurement as for capacitance
- Resistance is shown again for the position of the breakdown
- Leakage (dark) current I_{DC} starts to develop at 1 V above the breakdown
- Consistent with specification
- Overvoltage (voltage above breakdown) of 1 – 5 V is recommended to use
- Negative offset in I_{DC} is likely caused by not applying specific calibrations to the LCR meter



Some of next steps

- Re-do for more SiPM models
- Multichannel analysis for signal timing and amplitude and with a set of scintillators
- Electrical characteristics at various test signal amplitudes