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Prototype of LED control card for SNDICE

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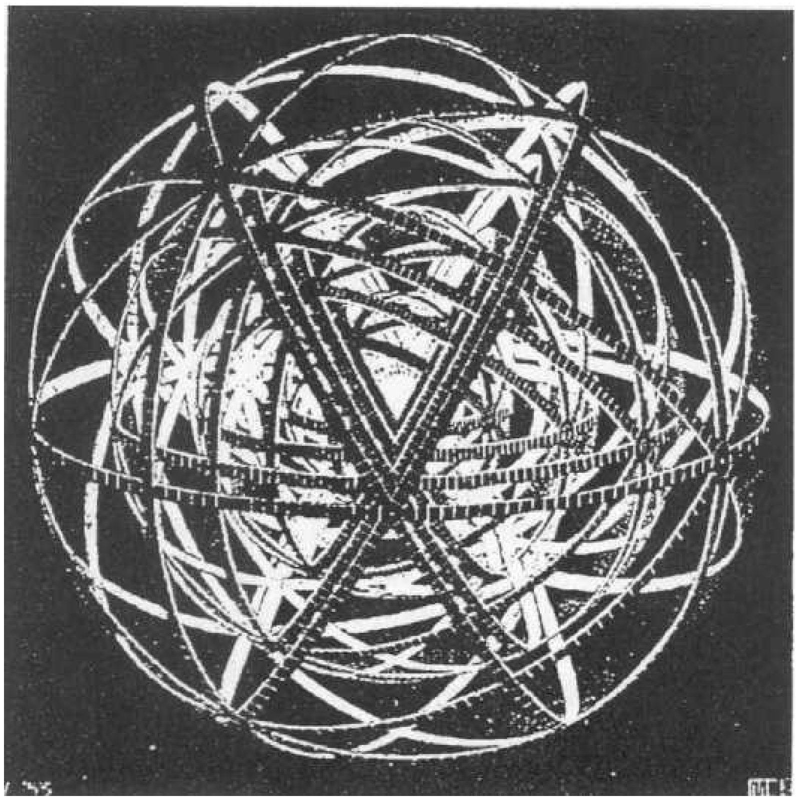

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Abstract

Introduction

The final card for controlling the LED source of SNDICE will generate currents for 24 calibration LEDs, plus one LED for the 'artificial planet'. It will read the 25 LED currents, and also 24 photodiode currents from the monitoring photodiodes placed at 25 cm from each calibration LED.

The value of the feedback resistor for the measurement of photodiode currents must be as high as possible, while ensuring that the amplifier output voltage stays below the ADC maximum (± 2.5 V). The table 1 gives an expected photocurrent of 1.42 μA for the selected photodiode at 25 cm with 300 mA current. We can extrapolate to 2.4 μA with a 500 mA current. We must also take into account the pinhole size (0.6 mm in diameter), which is smaller than the LED emitting surface (a 0.7x0.7 mm square). This gives a geometrical factor of 57 % on the maximum photocurrent, and a value of 1.4 μA. With an additionnal safety factor for better LED efficiency and photodiode quantum efficiency at other wavelengths, we find that a 1 MΩ feedback resistor is a good value.

	Agilent LED	**OSRAM LED**
Measured current in LED (near full scale)	35.5 mA	300 mA
Measured current in 5.7mm^2 PD at 90 cm	25.4 pA	19.2 nA
Photocurrent on 33.6 mm^2 PD at 25 cm (same QE)	1.87 nA	1.42 μA
Photocurrent on 1 cm^2 PD at 13.5 m (same QE)	1.98 pA	1.50 nA
Photons/s/pixel (size 13.5 μm) at 13.5 m	27	20,200

Table 1: Comparison of luminous power between an Agilent LED and an OSRAM Golden Dragon LED (LY W57B): evaluation of the expected photocurrent from measurements on the first test bench. Both LEDs are emitting around 590 nm.

The goal of the montoring with off-axis photodiode is to compensate for variations in the luminous flux. Those are most likely to be thermic variations, so the timescale should be comparatively slow, not faster than a tenth of a second. Since we are planning for exposures lasting at least a few seconds, monitoring at the millisecond scale gives a comfortable accuracy. This gives us a target readout rate of 1 kHz for each channel, so a total readout rate of 50 kHz. Currently the readout performs at around 34 kHz (30 μs per reading), which is close enough to our goal. This readout rate is also appropriate to oversample and eliminate any line noise (50 or 60 Hz depending on the location) that we might pick up.

1 Setups

op amp AD549JH: typical differential input capacitance 1 pF, minimal slew rate 2 V/μs, Input Bias Current ?

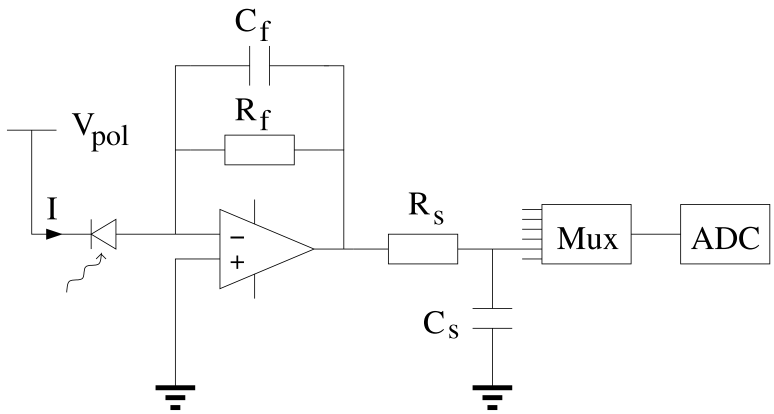

Figure 1: One photodiode readout channel with feedback resistor and capacitor, and with output filter.

For studies on the photodiode current amplifier, a feedback resistor of 997 kΩ was used.

1.1 Input

50 kΩ resistor for current pulses, pulses of 20 mVpp (peak-to-peak), 0.40 μApp

330 pF to simulate photodiode (see measure of capacitance) and for charge pulses (also with 82 pF for smaller pulses)

pulser: rise time 5 ns, checked to be negligible at the scales of amplifier rise time

photodiode: selected for LED source: Centronic OSD35-7CQ, 5.8x5.8 mm = 33.6 mm^2

20 pA typical dark current at ambient temperature for 10 mV reverse voltage (should be negligible if this is true: 20 μV, lower than LSB)

detector capacitance varies with voltage : 1000 pF nominal at 0 V, around 430 pF at 2 V, 300 pF at 5 V

1.2 Measurements

oscilloscope: active probe, compensated by oscilloscope, checked no effect on circuit stability or noise

limited to 10 mV/div because of factor 10 in probe, 8-bit ADC : 313 μV LSB

acquisition with LabView: 16-bit ADC (measurement time : 2 μs after 1 μs delay, plus readout), Altera FPGA, DIO card

± 2.5 V, 76 μV LSB

This conversion factor was roughly checked by parallel measurements on the oscilloscope and ADC. The acquisition frequency is measured by the acquisition program. A first calibration was also done with room light (100 Hz half-sinusoids, checked with oscilloscope). With a calibration on 50 Hz harmonics, we measured $f_e = 34343 \pm 30$ Hz. However, there are slight variations (a few Hz) in the displayed frequency from one burst of acquisition to another, which is either an artifact in the evaluation method or a real (but small) source of error on frequency measurements.

2 Measurement of intrinsic parameters

current pulses

check gain roughly : 400 mVpp for example

parasitic capacitance : current pulse: exponential rise time τ_r =5.5 μs

slew rate : same rise time up to 4.0 Vpp (0.72 V/μs)

not limited by slew rate, will always be slower when adding feedback capacitance

charge pulses: instability, also seen in noise : frequency 16.7 kHz (period 60 μs) with 330 pF as input, goes up to 28.6 kHz (35 μs) with 82 pF

identical to pseudo-periods obtained in charge pulses

with photodiode as input: 13.3 kHz (75 μ) (find the same on Fourier diagram)

3 Selection of a feedback capacitor

starts with 4.7 pF (allowing for at least 10 % error)

current pulses: τ =11 μs,compatible with addition of C_f and C_p

charge pulses with C_{in} = 330 pF and 82 pF: still oscillating, dampening much stronger (less than 2 pseudo-periods)

with 33 pF

charge pulses: no oscillation

330 pF: rise time 3.1 μs, fall time : 32 μs (approx)

current pulses: τ_f =38 μs, matches $C_f + C_p$

The minimum C_f value should be above 10 pF for safety, which gives a minimal time τ_f of around 15 μs, and a settling time (5τ) of around 75 μs.

4 Effects of output filtering

The possible positions for additional filtering are at the output of the amplifier ($R_s C_s$) or between the multiplexer and ADC ($R_m C_m$). With C_f at 33 pF, the settling time is 190 μs without any other filter, and the cut-off frequency is 4.2 kHz. If we add another filter that is faster than the feedback filter, its only use will be to cut high-frequency pick-up noise that might be added after the amplifier output.

If we put a filter between the multiplexer and ADC, it must not be fast enough to allow switching between channels. For example, if we decide to wait 1 μs between the command to the multiplexer and the conversion (as is done currently), the filter must be faster than $R_m C_m = 0.2\mu$s. This is much faster than what we have already with the feedback characteristic time τ_f, so the only use of such a filter would be to cut high-frequency pick-up noise added to the signal between the multiplexer and ADC.

effect of multiplexer switching ?

On the other hand, on the output of the amplifier, the settling time is well below the time between measurements (1 ms), so we have some margin for additional filtering. We want too keep the settling time below 1 ms, which gives an upper limit for the filter values. We have tested briefly a fast filter ($R_s = 30\Omega$,$C_s = 100$ nF, so $\tau_s = 3\mu$s) and found that it did not change high-frequency noise, as expected if there is no noticeable pick-up on the output.

The 'baseline' values of the filter for tests are $R_s = 330\Omega$ and $C_s = 100$ nF, giving τ_s of the same order as τ_f. In that case we expect the circuit to act as a second-order low pass filter, with the cut-off worth approximately 1.5 times the cut-off time of one of the filters (when they are equal).

charge pulses with 330 pF: rise time 15 μs, fall time : approximately 50 μs as expected $(1.5\tau_f)$

After additional work on grounding, the amplitude of the 50 Hz component was reduced to 10 ADU peak-to-peak. Figure 4 shows the distribution of values in the baseline configuration with 3 different values of input capacitor.

5 Crosstalk between photodiode channels

6 Readout of LED current channels

Currently the current in four LED channels (LED0 to LED3) is measured by the voltage on a resistance of 2.5 Ω, and the other four on 12.5 Ω. In this test (figure 5), the LED0 channel was connected to a Golden Dragon LED. We can estimate the current in the LED thanks to the increase in current consumption (approximately 120 mA), and check that we obtain a similar value from the measured voltage (4000 ADU, for a maximum of 32768 ADU at 2.5 V):

$$4000/32768 * 2.5(\mathrm{V})/2.5(\Omega) = 122 \text{ mA}$$

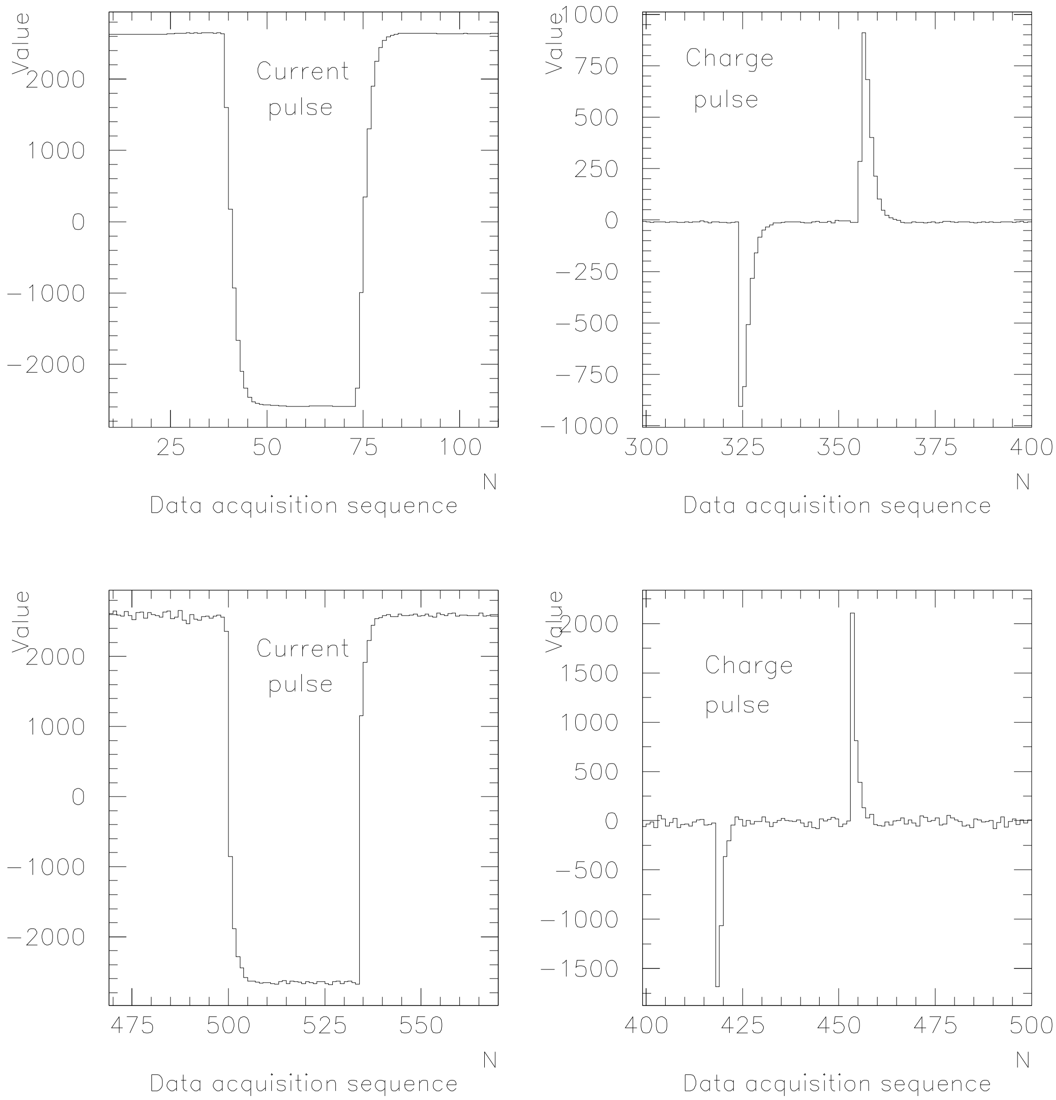

Figure 2: Measurements of response to current and charge pulses in 'baseline' configuration (top) and with no output filter (bottom) with Labview acquisition. 1 ms pulses of 20 mVpp on 50 kΩ (left) and 330 pF (right). The no-filtered output is clearly faster, and more noisy.

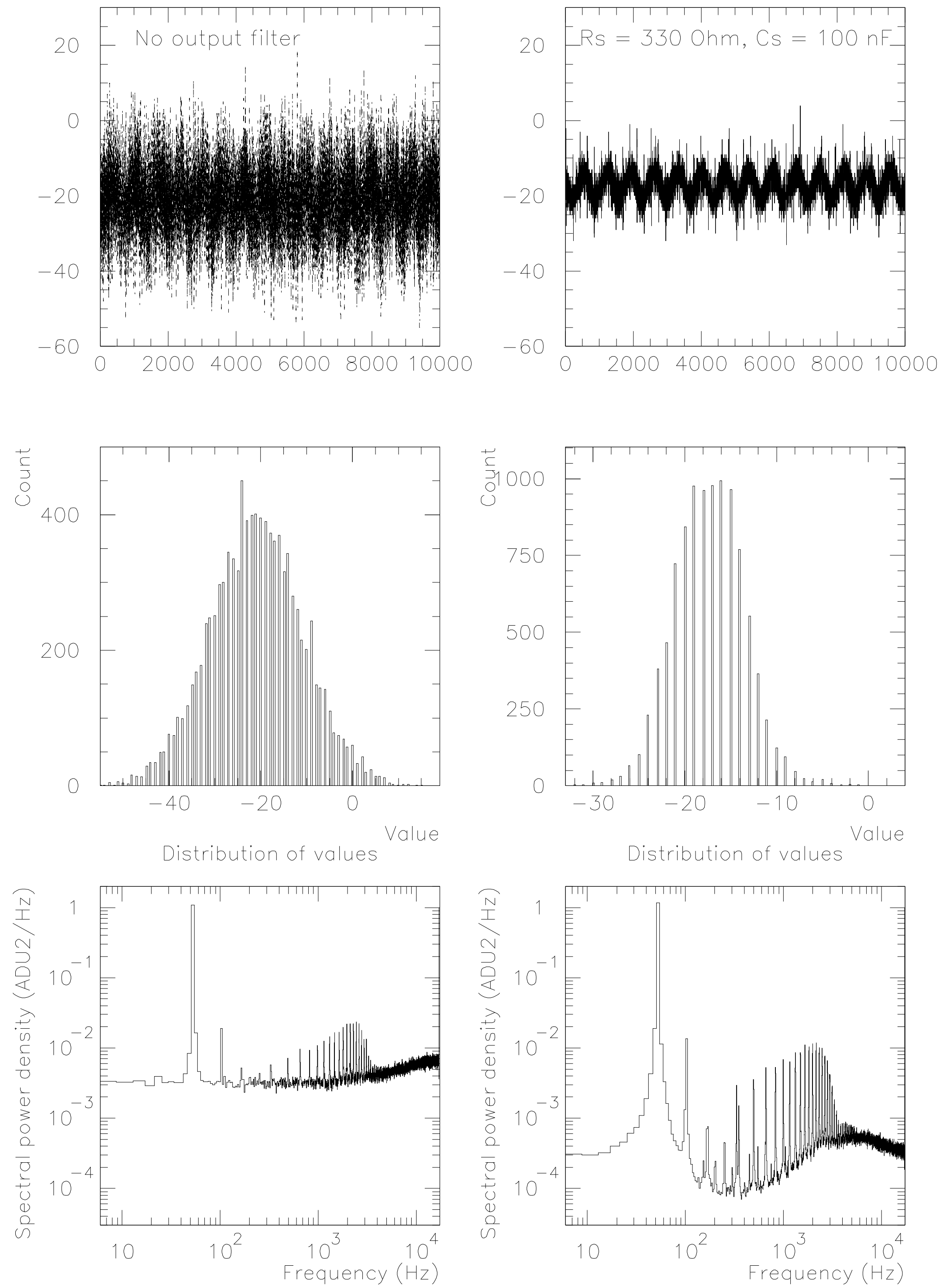

Figure 3: Effect of the 'baseline' output filter on one run of 10,000 points (top and middle), and on the power spectra built from 100 bursts of 10,000 points (bottom). The 50 Hz component remains logically unaffected by the filter.

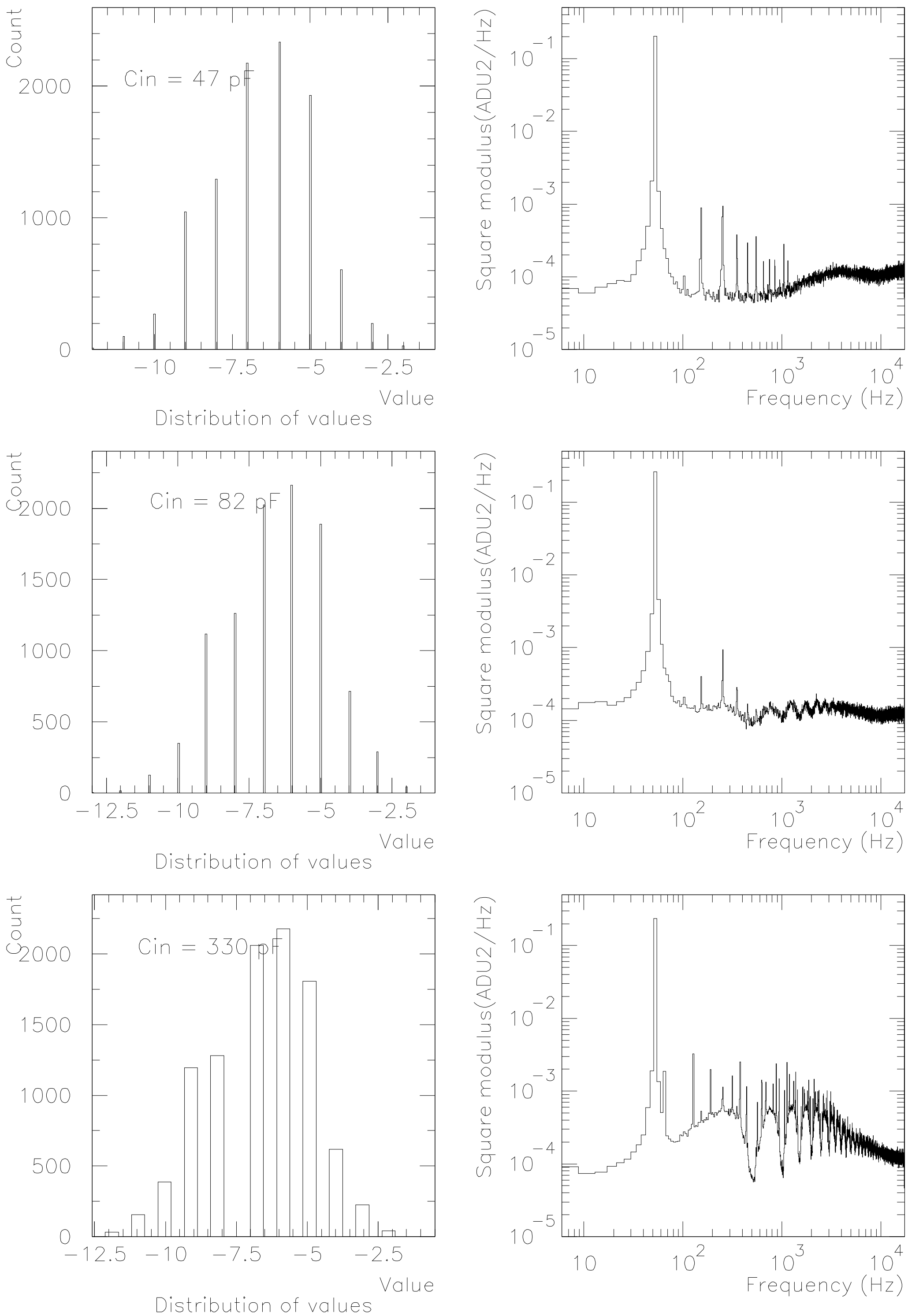

Figure 4: Effect of the input capacitance (placed between the input and the ground) on the noise. The distributions of values on one burst (left) do not vary with the input capacitance, because it is dominated by 50 Hz pick-up noise. On the other hand, there is a clear relation between the input capacitance and the bump around 1 kHz in the power spectrum (right).

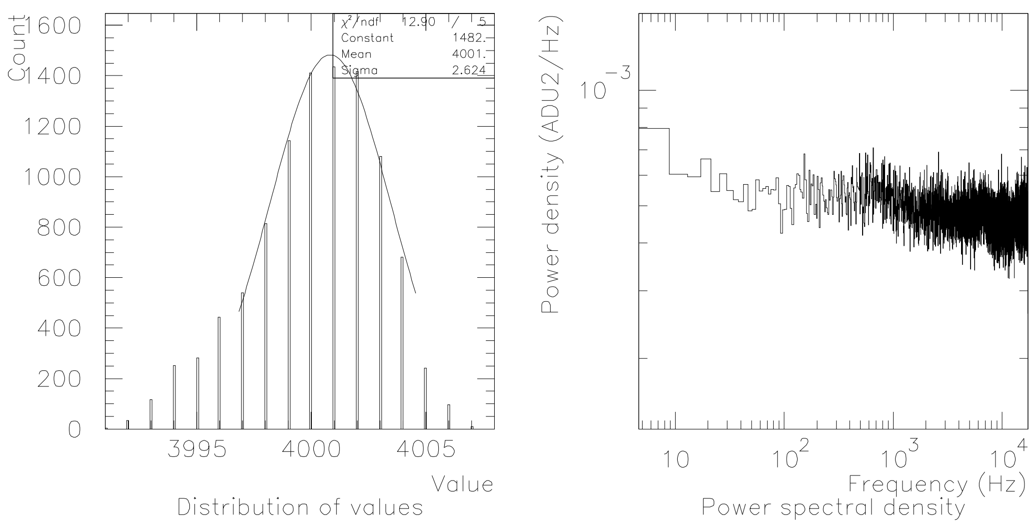

Figure 5: Distribution of values for one burst and noise spectrum averaged on 100 bursts for a LED current measurement channel with 120 mA current. Most notable is the lack of 50 Hz component.