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The Calibration System Hardware Manual (PRELIMINAY)

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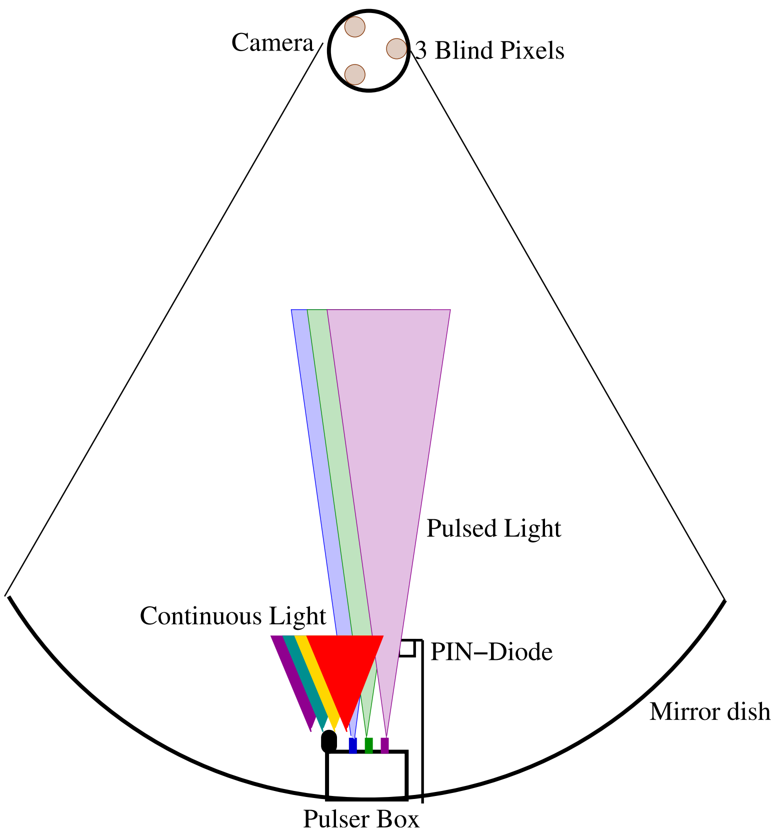
Abstract

The Hardware Manual of the MAGIC Calibration system.



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1 Preface

The MAGIC ***Calibration System*** is designed to provide ultra-fast light pulses from ***Pulsed LEDs*** with intensities variable by a factor >1000 in order to calibrate the whole dynamic range of the camera and the readout chain. The absolute light flux is measured with additional devices: Three blind pixels in the MAGIC ***Camera*** and a calibrated ***PIN-Diode*** situated between ***Camera*** and ***Pulser Box***. At the same time, there is a ***Continuous Light Source*** in four different colours and variable intensities to simulate star and moon light.

The ***Calibration System*** is a rather complex interplay of many parts of the telescope and many people have contributed. Its hardware has been designed mainly by ***Thomas Schweizer*** <tschweiz@physik.hu-berlin.de>, ***Markus Gaug*** <markus@ifae.es>, ***George Blanchot*** <blanchot@ifae.es> and ***Manel Martinez*** <martinez@ifae.es> (with the help of many others, see e.g. chapter 12.2 ...).

Trigger and steering software was written by ***Javi Lopez*** <jlopez@ifae.es> and communication with the ***Camera Control*** by ***Pepe Flix*** <jflix@ifae.es>.

Communcation between ***Central Control*** and ***Camera Control*** and lecture of the and interpretation of the ***Calibration Scripts*** was also written by: ***Juan Cortina*** <cortina@ifae.es> and ***Nuria Sidro*** <nsidro@ifae.es>

A first systematic analysis has been done by ***Michele Doro*** <mdoro@ifae.es>.

For any problems or questions, please contact one of the above named persons or via telephone:

```
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Tel.: 0034-93-5812839
```

For a first understanding of the principles of this system, have a look at:

```
Th. Schweizer et al., The Optical Calibration of the MAGIC Telescope Camera,
in ‘‘Transactions on Nuclear Science TNS’’, IEEE Conf., San Diego, Nov. 2001’’
```

For the software steering part, have a look at:

```
http://www.magic.iac.es/subsystems/caco/
http://www.magic.iac.es/subsystems/caco/howto_calib.html
```

For an analysis of the performance, look at:

```
M. Doro, The commissioning and characterization of the calibration system
of the MAGIC Telescope, Diploma Thesis, Univ. of Padova, July 2004.
available at:

http://www.magic.ifae.es/~mdoro/tesi/totale.ps.gz
```

2 Introduction to the hardware part

The ***Calibration System*** consists of several boxes housing electronic boards with power supplies, connectors, cables and filters. Because different people contributed different parts over several years, there is a big variety of this stuff, don't get confused!

The glossary (chapter 3) gives a short list of the naming conventions used for the main parts of the ***Calibration System***: Boxes, Boards, Hardware parts, External Hardware and People.

The subsequent chapters give a quicklook of the most important characteristics of the ***Calibration System***. They are called "Data Sheets" and you can use them as reference. The numbers listed there have been measured partly in Barcelona, partly at La Palma. Any deviations from what is listed there should be reported to ***Markus Gaug*** <markus@ifae.es> immediately since they then reflect changes in the behavior of the system.

The next parts are introductory chapters to each hardware part.

At the end, listings and figures are given for those who need to exchange or adapt hardware directly.

Figure 1 gives a sketch of the components of the ***Calibration System***. There is hardware in the ***Center of the Mirror Dish*** (the ***Pulser Box***, the ***LV-Box*** and the ***PIN-Diode Box***), inside the ***Camera*** (the ***Blind Pixel***s) and in the ***Control House*** (the ***Trigger Box*** and the ***Camera Control***).

There are one long cable and one optical fibre line connecting the ***Control House*** with the ***Center of the Mirror Dish***: The ***CAN-BUS*** line, the ***Trigger*** line and the ***PIN-Diode*** read-out, where the last two are optical and contained in one same fibre bundle. The ***Pulser Box*** itself is alimented from a 230 VAC power cable starting from the ***Cooling Box***.

The ***Calibration System*** talks to different subsystems of the telescope: The ***L2*** trigger (for external triggering of the ***Pulsed LED*** pulses, the ***Pedestal***s and the ***PIN-Diode*** calibration events) and the ***Digital Module***s (to write the ***Pulsed LED*** pattern directly into the data).

There is ***Spares Boxes*** (fig. 2) in dedicated shelf for the ***Calibration System*** in the rear cupboard of the electronics room. Most of the hardware parts have spares there.

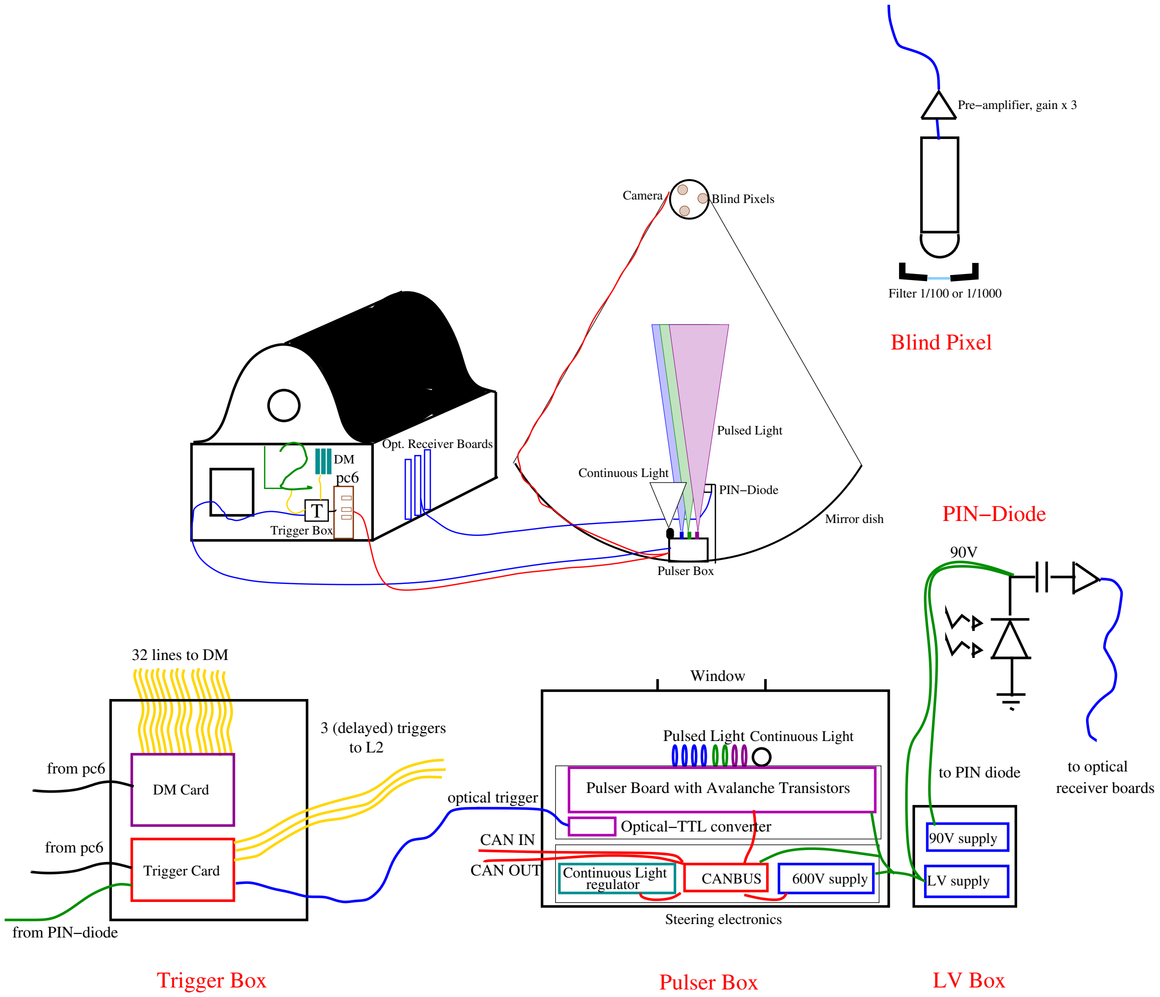

Figure 1: Overview of the ***Calibration System*** Boxes:

- The ***Pulser Box***: Electronics for the ***Continuous Light LED***s and the ***Pulsed LED***s
- The ***Lower Box***: Lower part of the ***Pulser Box*** housing the ***CAN-BUS Board***, the ***600 V Supply Board*** and the ***Shift Register Board*** with the ***Continuous Light LED*** regulator
- The ***Upper Box***: Upper part of the ***Pulser Box*** housing the ***Pulser Board***
- The ***LV-Box***: LV-supply for the ***Pulser Box*** and the ***PIN-Diode Box***
- The ***PIN-Diode Box***: houses and reads out the ***PIN-Diode***
- The ***Trigger Box***: Trigger for the ***Pulsed LED***s, Communication with ***L2*** and ***Digital Modules***

Overview of the ***Calibration System*** Cables:

- Red: ***CAN-BUS***
- Blue: Optical transmission
- Green: Voltage supply
- Yellow: digital lines

Figure 2: The ***Spares Boxes***

3 Glossary of the hardware part

Boxes (see fig. 1 in page 13)

Lower Box*:** The lower part of the ***Pulser Box, housing the steering electronics (***CAN-BUS***,***Shift Registers***,***Continuous Light Source***,***600V Supply***)

LV-Box*:** A smaller black box beside the ***Pulser Box providing the LV for the ***Pulser Box*** and the ***PIN-Diode Box***

PIN-Diode Box*:** An even smaller box situated about 1 m above the ***Pulser Box and housing the ***PIN-Diode***

Pulser Box*:** The main part of the system containing all LEDs and the steering electronics. It is housed at the ***Center of the Mirror Dish, about 18.13 m from the ***Camera*** lids and 18.25 m from the entrance of the light guides.

Spares Boxes*:** Three boxes in the IFAE cupboard in the electronics room of the ***Control House with all the spares.

Trigger Box*:** A part of the computer rack in the ***Control House, situated directly above ***pc6*** and housing the ***Trigger Board***, the ***TTL to Opt. Converter*** and the ***DM-Board***.

Upper Box*:** The upper part of the ***Pulser Box, housing the ***Pulser Board*** with the ***Pulsed LED***s and the ***Continuous Light LED***s

CT1-Pulser*:** The former calibration pulser of the CT1-telescope, installed as a backup in the MAGIC ***Center of the Mirror Dish. It is situated 17 m from the ***Camera*** lids behind the ***PIN-Diode***.

Electronic Boards (see fig. 1 in page 13)

ADC2000*:** A ***CAN-BUS receiver board designed for the ***ATLAS*** experiment and used in the ***MAGIC Camera*** and the ***Calibration System***.

CAN-BUS Board*:** Situated inside the ***Lower Box, it receives the digital ***CAN-BUS*** signal and converts them into serial ones and a ***DAC*** voltage.

DM-Board*:** Situated inside the ***Trigger Box, it creates the bit pattern written into the ***Digital Module***s.

Opt. to TTL Converter*:** Small board in the ***Pulser Box converting the optical pulses into TTL ones.

Pulser Board*:** Situated inside the ***Upper Box, it steers and switches the ***Pulsed LED***s. It is the motherboard of 4 ***Relays Board***s.

Relays Board*:** Small boards adapting the pinning of relays to the ***Pulser Board.

Shift Register Board*:** Situated inside the ***Lower Box, it contains the ***Shift Registers*** steering the ***Pulsed LED***s and creates the current for the ***Continuous Light LED***s from the ***DAC*** voltage.

Trigger Board*:** Situated inside the ***Trigger Box, it creates the optical trigger going up to the ***Pulser Box*** and communicates with the ***L2***.

TTL to Opt. Converter*:** Small board converting TTL signals into optical ones. One is situated in the ***Trigger Box, another in the ***PIN-Diode Box***.

600 V Supply Board*:** Situated inside the ***Lower Box, it creates the 600 V needed by the ***Pulser Board***

90 V Supply Board*:** Situated inside the ***LV-Box, it creates the 90 V counter voltage for the ***PIN-Diode***

Hardware Parts (see fig. 1 in page 13)

Avalanche Transistor*:** Ultra-fast transistors switching in about 1-2 ns. Work in the overdrive regime (>280 V CEO). In each ***Pulser Board slot, two ***Avalanche Transistor***s are switched one after the other.

Blind Pixel*:** Three un-coated PMTs of the size of an ***Inner Pixel, situated outside the Swiss cheese and darkened with 1/100 or 1/1000 filters. Their signals get stronger amplified than the ones of an ***Inner Pixel***, but are further read out like an ***Outer Pixel***. They are connected to one same PMT base and receive the same voltages.

Calibration System*:** Defines the hardware associated with the calibration: The ***Pulser Box, the ***LV-Box***, the ***Blind Pixel***, the ***PIN-Diode***, the ***Trigger Box*** and associated steering and analysis software.

***Continuous Light LED*:** Slow LEDs of high intensity ($5 \cdot 10^7$ photons/ns/sr) used to simulated star light with four different colours and at different intensities.

Continuous Light Source (CL)*:** A circuit producing the different intensities of the ***Continuous Light LED

DAC*:** An 8-bit DAC housed in the ***ADC2000.

Indicator LEDs*:** LEDs in three different colours at the front panel of the ***Trigger Board. They shine whenever a calibration run or a pedestal run or a PIN Diode calibration run is taken.

ME1400*:** An I/O PCB housed in ***pc6 and used to build the pre-stages of the ***Trigger*** and the digital lines to the ***Digital Module***s.

Minimum Load*:** Resistencies needed to fulfil the minimum load requirement of one of the power supplies in the ***LV-Box.

Nano-Second Amplifier*:** The pre-amplifier of the ***PIN-Diode signal.

PIN-Diode*:** A 1 cm^2 PIN diode of HAMAMATSU used to measure the light flux emitted by the ***Pulsed LEDs.

Pulsed LED*:** The central parts of the ***Calibration System. Ultra-fast LEDs (NISHIA, single quantum well, NSPB-310A and NSPG-310A) able to send $10^8 - 10^{10}$ photons/sr within 3–4 ns FWHM. They are used to simulate Cherenkov light flashed with different colours and intensities. Housed in slots of the ***Pulser Board***, each slot can contain maximally 5 ***Pulsed LED***s.

Shift Registers*:** Electronic parts converting a stream of digital information into single bit patterns. 16 bits are used to switch on and off the 16 ***Pulsed LED slots.

Trigger*:** A special trigger steering the ***Pulsed LEDs of the ***Calibration System***.

600V Supply*:** A power supply producing the 600 V needed for the functionning of the ***Avalanche Transistors

90V Supply*:** A power supply producing the 90 V needed as counter voltage of the ***PIN-Diode

External Hardware

ByteBlaster*:** Dedicated connector with internal buffer to program the ***MAX7000S

Camera*:** houses 396 ***Inner Pixels, 179 ***Outer Pixel***s and the 3 ***Blind Pixel***s.

Camera Control*:** Software to control the ***Camera and the ***Calibration System***. Also called "La Guagua".

Central Control*:** Software to control the whole telescope. Talks to the ***Camera Control. Also called "Arehucas".

CAN-BUS*:** The communication protocol for the steering of the ***Calibration System and the ***Camera***. Two ***CAN-BUS*** lines, both going from the ***Control House*** to the ***Camera*** are used independently: CAN-A (∼150 m) and CAN-B (∼200 m), each steering one half of the ***Camera***. The ***Calibration System*** is the first node of the CAN-B line which is therefore longer. The ***CAN-BUS*** is alimented externally with 15 V supplies in the ***Control House***, from which about 10 V arrive at the ***Calibration System***.

Center of the Mirror Dish*:** The place of the central mirror is left free to give free sight for the ***Pulsed LEDs and the ***Continuous Light LED***s. It is accessible from the main access platform: In telescope zenith position by walking on the aluminium paths just below the mirrors towards the center. The ***Pulser Box*** and the ***LV-Box*** are then easily accessible at the height of your belly. In telescope parking position, you have to walk along the other aluminium paths and cross over to the center. The ***Pulser Box*** and ***LV-Box*** are then turned by 90° and cannot be opened and closed easily. You might drop parts or even the whole boxes.

Control House*:** The ***MAGIC Control House houses important parts of the ***Calibration System*** hardware: The ***Trigger Box***, the ***ME1400*** and the ***CAN-BUS*** cards in ***pc6***.

Cooling Box*:** A dedicated electronics box and a refrigator controlling the temperature in the ***Camera. In telescope park position, it is situated just above the telescope rails opposite to the Wuerzburg container.

Digital Module*:** Interfaces of digital information lines and the ***MAGIC DAQ. The ***Calibration System*** has 32 bits located on 2 ***Digital Module***s.

L2*:** The second level trigger of ***MAGIC. It receives three trigger signals from the ***Calibration System***: ***Pulsed LED*** calibration, ***Pedestal*** and ***PIN-Diode*** calibration upon which all channels are read out and stored in the data.

MAX7000S*:** ALTERA chip in the ***Trigger Board used to create the different triggers to the ***Pulser Box*** and the ***L2***

Inner Pixel*:** One of 396 PMTs of the inner part of the ***Camera with an average diameter of $\sim$3.25 cm and a field-of-view of $\sim 0.11°$. The ***Pulser Box*** sees this pixel under a smaller angle of $\sim 0.1°$ because it is situated behind the mirror dish. An ***Inner Pixel*** cover $2.4 \cdot 10^{-6}$ sr seen from the ***Pulser Box***.

Outer Pixel*:** One of 179 PMTs of the outer part of the ***Camera with an effective diameter of $\sim$6.5 cm and a field-of-view of $\sim 0.22°$. The ***Pulser Box*** sees this pixel under an angle of $\sim 0.2°$, covering $8.4 \cdot 10^{-6}$ sr.

pc6*:** The pc housing all hardware for the ***Camera Control in the electronics room of the ***Control House***.

pc39*:** The windows-pc in the control room housing the MAXPLUS-II software to program the ***MAX7000S via the ***ByteBlaster***.

4 Whom to contact

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Figure 3: ***Thomas Schweizer*** (with calculations)

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Figure 4: ***Markus Gaug***

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Figure 5: ***Manel Martinez***

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Figure 6: ***George Blanchot***

***Javi Lopez*:** IFAE: <jlopez@ifae.es>, Tel.: 0034-93-581-2834

Figure 7: ***Javi Lopez***

***Pepe Flix*:** IFAE: <jflix@ifae.es>, Tel.: 0034-93-581-2823

Figure 8: ***Pepe Flix***

***Michele Doro*:** IFAE: <mdoro@ifae.es>, Tel.: 0034-93-581-2839

Figure 9: ***Michele Doro***

5 Quicklook - Specifications of the ***Calibration System***

Calibration System Data Sheet					
Nr	Type	Vcc [V]	Power [W]	Location	Remarks
1	***Pulser Board***	+5, –5 +600	1.1 – 1.8	***Upper Box***	ch. 6.1.1
2	***CL*** LEDs	–5 +(0 – 2.3)	0 – 0.2	***Upper Box***	ch. 6.1.4
	TOTAL ***Upper Box***		1.1 – 2.0	***Upper Box***	
3	***CL*** Circuit	+12, –5 +(0 – 2.5 ***DAC***)	0.7 – 2.1	***Lower Box***	ch. 6.1.4
4	***600V Supply***	+12, +5	5 in 1 out	***Lower Box***	ch. 6.1.2
5	***CAN-BUS*** Receiver	+5, –5, +12	Â> 0.1	***Lower Box***	ch. 6.1.2
6	***Shift Registers***	+5	1.5	***Lower Box***	ch. 6.1.2
	TOTAL ***Lower Box***		$\gtrsim$6.3 – 7.7	***Lower Box***	
7	***Minimum Loads***	+12, +5	3.1	***Pulser Box***	ch. 6.2
8	***Opt. to TTL Converter***	+12, +5, –5	0.15	***Pulser Box***	ch. 6.5
	TOTAL ***Pulser Box***		$\gtrsim$10.6 – 12.9	***Pulser Box***	
9	LV-Supply 1	230 AC	$\gtrsim$19 in $\gtrsim$13 out	***LV-Box***, bottom	ch. 6.2
10	***90V Supply***	+12	1 in, 0.2 out	***LV-Box***, top	ch. 6.2
11	***TTL to Opt. Converter***	+12, –12	0.8	***Trigger Box***	ch. 6.5
12	***PIN-Diode*** readout	+12, –12 +90	1.1	***PIN-Diode Box***	ch. 6.4
13	LV-Supply 2	230 AC	5 in, 3 out	***LV-Box***, top	ch. 6.2
	TOTAL ***LV-Box***		$\lesssim$ 25	***LV-Box***	
14	***TTL to Opt. Converter***	+5, –5	0.2	***Trigger Box***	ch. 6.5
15	***Trigger Board***	+5, –5	3.5	***Trigger Box***	ch. 6.5
16	LV-Supply 3	230 AC	7	***Trigger Box***	ch. 6.5
17	***DM-Board***	+5, –5	$\lesssim$ 4.3	***Trigger Box***	ch. 6.5.4
18	LV-Supply 4	230 AC	$\lesssim$ 3.5	***Trigger Box***	ch. 6.5
19	LV-Supply 5	230 AC	$\lesssim$ 3.5	***Trigger Box***	ch. 6.5
	TOTAL ***Trigger Box***		$\lesssim$ 14	***Trigger Box***	
19	***ME1400*** I/O card	+5 Standard PCI	$\gtrsim$2	***pc6***	ch. 6.5
20	***Blind Pixel***	+12, –12 HV,D5,D6		***Camera***	ch. 6.3

Table 1: Data Sheet of the ***Calibration System***

5.1 The ***Pulsed LED*** s

Pulsed LED s Data Sheet			
Symbol	Parameter	value	comments
	type green type blue type UV	NSPG-310A NSPB-310A NSHU550E	
A_{pk}(bg)	Pk Current blue/green LED slots [A]	2.0	during 1 ns
A_{pk}(uv)	Pk Current UV LED slots [A]	6.7	during 0.5 ns
V_{pk}(bl1)	Pk Voltage 1 blue LED slots [V]	44	
V_{pk}(bl1)	Pk Voltage 3 blue LED slot [V]	42	
V_{pk}(bl5)	Pk Voltage 5 blue LED slots [V]	39	
V_{pk}(gr5)	Pk Voltage 5 green LED slots [V]	39	
V_{pk}(uv5)	Pk Voltage 5 UV LED slots [V]	90	distinct circuit
P_{pk}(bl1)	Pk Power 1 blue LED [W]	88	during 1 ns
P_{pk}(bl5)	Pk Power 5 blue LEDs [W]	78	
P_{pk}(bl43)	Pk Power all blue LEDs [W]	650	
P_{pk}(gr5)	Pk Power 5 green LEDs [W]	78	
P_{pk}(bl20)	Pk Power all green LEDs [W]	310	
P_{pk}(uv5)	Pk Power 5 UV LEDs [W]	595	during 0.5 ns
P_{pk}(uv20)	Pk Power 20 UV LEDs [W]	2380	during 0.5 ns
A_{pk}(bl1)	Area under Peak 1 blue LED [V ns]	44.5 ± 0.5	
A_{pk}(bl2)	Area under Peak 2 blue LEDs [V ns]	43.0 ± 0.5	
A_{pk}(bl5)	Area under Peak 5 blue LEDs [V ns]	37.0 ± 1.0	
A_{pk}(gr5)	Area under Peak 5 green LEDs [V ns]	37.5 ± 0.7	
A_{pk}(uv5)	Area under Peak 5 UV LEDs [V ns]	52 ± 1.2	
t_{el}(bg)	El. Pulse Width blue/green LEDs (FWHM) [ns]	3[a]	prepulse
t_{el}(uv)	El. Pulse Width UV LEDs (FWHM) [ns]	2.5[a]	prepulse
t_{opt}(bl1)	Opt. Pulse Width 1 blue LED (FWHM) [ns]	4.5±1[b]	afterpulse
N_{ph}(bl1)	Photons/***Inner Pixel*** 1 blue LED att.	70–85	
N_{ph}(bl1)	Photons/***Inner Pixel*** 1 blue LED	165–180	
N_{ph}(bl5)	Photons/***Inner Pixel*** 5 blue LEDs	650–700	
N_{ph}(bl23)	Photons/***Inner Pixel*** all blue LEDs	∼3000	
N_{ph}(gr1)	Photons/***Inner Pixel*** 1 green LED att.	45	
N_{ph}(gr1)	Photons/***Inner Pixel*** 1 green LED	220	
N_{ph}(gr5)	Photons/***Inner Pixel*** 5 green LEDs	420	
N_{ph}(bl20)	Photons/***Inner Pixel*** all green LEDs	∼1000	
N_{ph}(uv1)	Photons/***Inner Pixel*** 1 UV LEDs	12	
N_{ph}(uv5)	Photons/***Inner Pixel*** 5 UV LEDs	70–90	
N_{ph}(all)	Photons/***Inner Pixel*** all LEDs	200	
$\overline{\lambda}$(bl)	Mean wavelength blue LEDs [nm]	460	still to be measured
continued on next page			

[a]prepulse starting at -10 ns (see fig. 28)
[b]afterpulse lasting 8 ns (see fig. 33)

continued from prev. page			
	***Pulsed LED**s Data Sheet*		
Symbol	Parameter	value	comments
			in pulsed mode
σ_λ(bl)	Spectral Width blue LEDs [nm]	30	
$\overline{\lambda}$(gr)	Mean wavelength green LEDs [nm]	520	still to be measured in pulsed mode
σ_λ(gr)	Spectral Width green LEDs [nm]	40	
$\overline{\lambda}$(UV)	Mean wavelength UV LEDs [nm]	370	still to be measured in pulsed mode
σ_λ(UV)	Spectral Width UV LEDs [nm]	25	
$f_{max}(1)$	max. ***Trigger*** frequency one slot [Hz]	4.000	
f_{max}(all)	max. ***Trigger*** frequency all LEDs [Hz]	4.000	
d_{min}	min. dist. from camera lids [m]	18.128±0.003 [a]	telescope in zenith
d_{max}	max. dist. from camera lids [m]	18.142±0.003 [a]	telescope in park position
D_{min}	min. dist. from light guides [m]	18.244–18.253±0.005 [b]	telescope in zenith: first number: central pixel last number: outmost ring
D_{max}	max. dist. from light guides [m]	18.258–18.268±0.005 [b]	telescope in park pos.: first number: central pixel last number: outmost ring

[a]Distance measured with Razmik's DISTO from ***Pulser Box*** window to camera lid (accuracy: 3 mm), plus 3 mm distance diffuser window to ***Pulser Box*** window (including window thickness).

[b]Thickness camera lids: 40 mm, dist. lids to plexiglass: 49±3 mm at 10 km focus, dist. plexiglass to light guides: 27 mm incl. 2 mm thickness of plexiglass.

Table 2: Data Sheet of the ***Pulsed LED**s*

5.2 The *Continuous Light Source* (*CL*)

Continuous Light Source Data Sheet						
Symbol	Parameter	0° C	5 sec	5 min	1 hr	with HV ON
$I_{av}(0)$	Av. Current through LEDs @ 0 [mA]	0.0	0.2	0.2	0.3	1.8
$P_{av}(0)$	Av. Power through LEDs @ 0 [mW]				1.5	4.6
$I_{av}(50)$	Av. Current through LEDs @ 50 [mA]	5.0	5.1	5.0	5.3	6.6
$P_{av}(50)$	Av. Power through LEDs @ 50 [mW]				31.8	40.3
$I_{av}(100)$	Av. Current through LEDs @ 100 [mA]	10.0	10.2	10.1	10.6	11.8
$P_{av}(100)$	Av. Power through LEDs @ 100 [mW]				67.8	76.7
$I_{av}(150)$	Av. Current through LEDs @ 150 [mA]	15.0	15.1	15.3	15.7	16.9
$P_{av}(150)$	Av. Power through LEDs @ 150 [mW]				106.8	116.6
$I_{av}(200)$	Av. Current through LEDs @ 200 [mA]	20.1	20.2	20.4	20.9	21.95
$P_{av}(200)$	Av. Power through LEDs @ 200 [mW]				148	156
$I_{av}(250)$	Av. Current through LEDs @ 250 [mA]	24.2	24.3	24.4	24.6	26.1
$P_{av}(250)$	Av. Power through LEDs @ 250 [mW]				177	193
$\overline{\lambda}$(red)	Mean wavelength red LEDs [nm]	615				
σ_λ(red)	Spectral Width red LEDs [nm]	17				
$\overline{\lambda}$(amber)	Mean wavelength amber LEDs [nm]	590				
σ_λ(amber)	Spectral Width amber LEDs [nm]	17				
$\overline{\lambda}$(green)	Mean wavelength green LEDs [nm]	524				
σ_λ(green)	Spectral Width green LEDs [nm]	47				
$\overline{\lambda}$(blue)	Mean wavelength blue LEDs [nm]	470				
σ_λ(blue)	Spectral Width blue LEDs [nm]	35				
$\overline{\lambda}$(UV)	Mean wavelength UV LEDs [nm]	370				
σ_λ(UV)	Spectral Width UV LEDs [nm]	25				

Table 3: Data Sheet of the ***Continuous Light Source*** (see also fig. 35 in page 54)

5.3 The Voltage Supplies

600V Supply Data Sheet						
Symbol	Parameter	0° C	5 sec	5 min	1 hr	10 hr
$U_{out}(0)$	Voltage no load [V]	605± 2	604± 2	612± 1	614 ± 1	616
$U_{out}(all)$	Voltage full load [V]				616	
$\Delta U_{out}(0)$	Voltage ripple no load [V]	0.03	0.03	0.03	0.03	0.03
$\Delta U_{out}(all)$	Voltage ripple full load [V]				1.4±0.1	

Table 4: Data Sheet of the ***600V Supply*** (see also fig. 19 in page 39)

90V Supply Data Sheet (at ***PIN-Diode Box*** entry)						
Symbol	Parameter	0° C	5 sec	5 min	1 hr	10 hr
$U_{out}(0)$	Voltage no load [V]		88.4	90.1	91.3	91.7
$U_{out}(all)$	Voltage full load [V]		88.1	89.6	91.1	
$\Delta U_{out}(0)$	Voltage ripple no load [V]			0.02	0.02	
$\Delta U_{out}(all)$	Voltage full load [V]			0.025		
$\Delta + 12\,\mathrm{V}$	Voltage ripple ***Nano-Second Amplifier*** [V]				0.035	
$\Delta - 12\,\mathrm{V}$	Voltage ripple ***Nano-Second Amplifier*** [V]				0.03	

Table 5: Data Sheet of the ***90V Supply*** (see fig. 19 in page 39)

5.4 The *Trigger*

Trigger Data Sheet				
Parameter	rise/fall time [ns]	duration [ns]	Amplitude [V]	remarks
TTL (ALTERA) Jitter @ 1V	2.8 0.2	130	3.0 0.3	neg. pulse
Opt.receiver (cal.box) Jitter @ 1V	1.7 0.3	140	4.5 0.1	fast component neg. pulse
After comparator After comparator Jitter	8.0 2.0 0.3	120 3.5	3.5 120	HV OFF HV ON pos. pulse

Table 6: Data Sheet of the ***Trigger***

5.5 The *Blind Pixels*

Blind Pixels Data Sheet			
Nr.	Parameter	value	comments
1,2,3	Voltage 1.-2. dynode: [V]	440	2 Zeners of 220V
1,2,3	Nominal Voltage [V]	1300	
1,2,3	Connected pins at base:	12V, GND, HV, D5, D6	DC not read out
1,2,3	Pixel Numbers	1911,1611,1613	
1,2,3	Sectors	1,3,5	
1,2,3	Filters	0.01,0.001,0.1	1: Oriel, 2: Edmunds, 3: Diaphragm
1,2,3	Camera sector	1,3,5	
1,2,3	Readout channel	560,561,???	
1,2,3	Coll. Effiency	0.91±0.01	from [7]
1,2,3	Diameter	25 mm (1")	same as ***Inner Pixel***

Table 7: Data Sheet of the ***Blind Pixel***s

5.6 The ***PIN-Diode***

PIN-Diode Data Sheet			
Symbol	Parameter	value	comments
$A_{PinDiode}$	Effective area [mm^2]	63.517	
$U_{sat.}$	Saturation voltage out [V]	2.25	
$U_{max.}$	Maximal voltage out (all LEDs) [V]	0.4	
t_r	Signal rise time [ns]	50 ± 5	
t_f	Signal fall time [ns]	150 ± 10	
d_{min}	Min. distance from ***Pulsed LED***s [m]	1.098±0.004	at min. view angle
d_{max}	Max. distance from ***Pulsed LED***s [m]	1.102±0.004	at max. view angle
θ_{min}	Min. view angle of ***Pulsed LED***s [deg.]	2.7	
θ_{max}	Max. view angle of ***Pulsed LED***s [deg.]	4.0	
channel	Receiver Board	66 Pixel 0	recognizable from outside by the LEMO-connector
channel	FADC Board	82 Pixel 0	

Table 8: Data Sheet of the ***PIN-Diode***

Voltage supply ***PIN-Diode*** Data Sheet (at ***Nano-Second Amplifier*** entry)			
Symbol	Parameter	value	comments
$\Delta + 12\,\mathrm{V}$	Voltage ripple ***Nano-Second Amplifier*** [V]	0.006	140 kHz switches pk-to-pk
$\Delta + 12\,\mathrm{V}$	Voltage ripple ***Nano-Second Amplifier*** [V]	0.002	10 kHz switches pk-to-pk
$\Delta - 12\,\mathrm{V}$	Voltage ripple ***Nano-Second Amplifier*** [V]	0.005	140 kHz switches pk-to-pk
$\Delta U_{out}(0)$	Voltage ripple ***90V Supply*** [V]	0.04	140 kHz switches pk-to-pk

Table 9: Data Sheet of the ***PIN-Diode*** voltage supplies ***90V Supply*** at the ***Nano-Second Amplifier*** entry

6 Hardware Components

6.1 The *Pulser Box*

Figure 10: The ***Pulser Box***

The ***Pulser Box*** is the main part of the ***Calibration System*** and is situated in the ***Center of the Mirror Dish*** (see fig. 10). It has been designed to provide:

1. Short pulses of 3–4 ns FWHM in green, blue and UV to simulated Cherenkov showers

2. Continuous light of the spectral composition to simulate star light

The ***Pulser Box*** consists of a watertight aluminium housing and inside of two more aluminium boxes containing all the electronics. These two inner boxes contain:

Lower Box*:** ***CAN-BUS steering electronics, a ***DAC*** to produce a voltage steering the strength of the ***Continuous Light LED***s, a stable ***600V Supply*** with low jitter, three 8–bit ***Shift Registers***.

Upper Box*:** The ***Pulser Board with 16 slots containing each between 1 to 5 ***Pulsed LED***s, and the ***Continuous Light LED***s.

Figures 11 and 12 give a view into the two floors of the ***Pulser Box***.

The low voltage needed by the ***Pulser Box*** is provided from the ***LV-Box*** situated just beside. Additionally, an optical ***Trigger*** line is connected to the ***Pulser Box*** carrying the ***Trigger*** to fire the ***Pulsed LED***s The ***Pulser Box*** electronics is steered via ***CAN-BUS***. The CAN-B line exits the ***Control House***, connects directly to the ***Pulser Box*** and goes further to the ***Camera*** for the HV and DC current monitoring there.

There is also a backup pulser in case that the ***Pulser Box*** fails, namely the ***CT1-Pulser*** from the ancient CT1 telescope which has been put on the ***Center of the Mirror Dish*** as well (see fig. 13). It contains UV-LEDs of the same type as the ones used for part of the MAGIC ***Pulsed LED***s.

Note that the distance from the ***Center of the Mirror Dish*** and thus the ***Pulser Box*** to the ***Camera*** can change depending whether the telescope is in zenith or in park position. Figure 14 shows the measurement of the distance of ***CT1-Pulser*** to the camera with respect to different positions of the telescope, performed by Alvin Laille. The ***Pulser Box*** is situated about 1 m further from the camera than the ***CT1-Pulser***-pulser, namely 18.128±0.003 to 18.142±0.003 m, depending whether the telescope is in zenith or park position.

The light pulses from the ***Pulsed LED*** and the continuous light from the ***Continuous Light LED*** exit the ***Pulser Box*** via a diffuser and a subsequent glass window (see figure 10). When run in pulsed mode, the ***Pulser Box*** emits sizeable microwave radiation due to the fast switching of 100 V trigger pulses which radiate away almost 80% of their amplitude. The aluminium boxes are not able to shield completely this radiation, but a planned future copper box with silvered surface will probably do so.

Table 17 in page 87 shows the connectors used to communicate with the outside. All connectors are conform to at least the IP67 standard and are addtionally sealed with silicon. There is one or more spares in the Calibration ***Spares Boxes***. Note that the +12 V and +5 V lines (#4) are connected to ground via resistors of 100 Ω (12 V) and 15 Ω (5 V) directly after the connector (see fig. 15 in page 35). The resistors act as ***Minimum Load*** for the ASTEC power supply (see table 33 in page 122) and heat the box a little bit ($\sim$ 3 W). In total, the box should never consume more than 13 W.

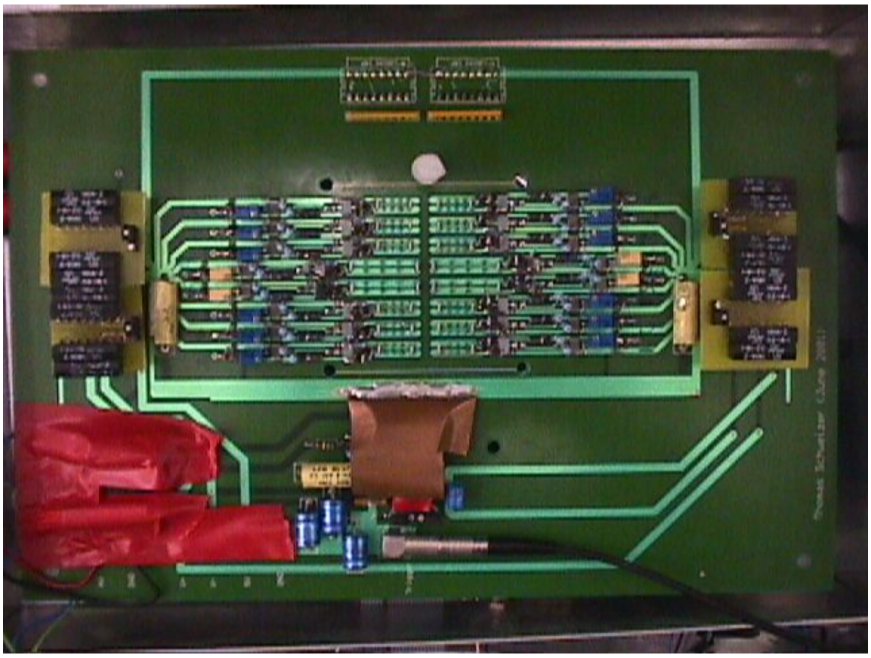


Figure 11: Interior of the ***Pulser Box*** (upper floor)

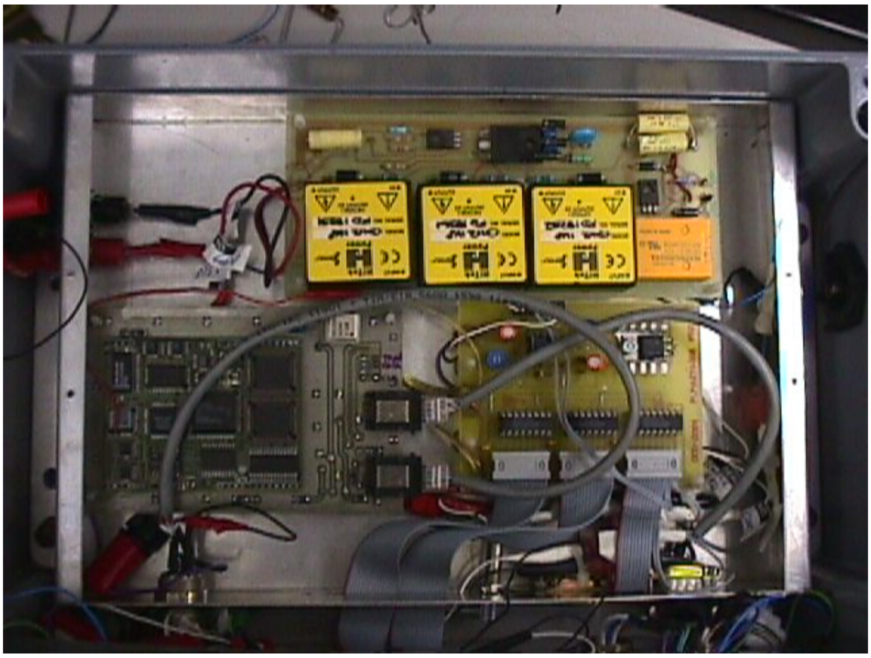


Figure 12: Interior of the ***Pulser Box*** (lower floor)

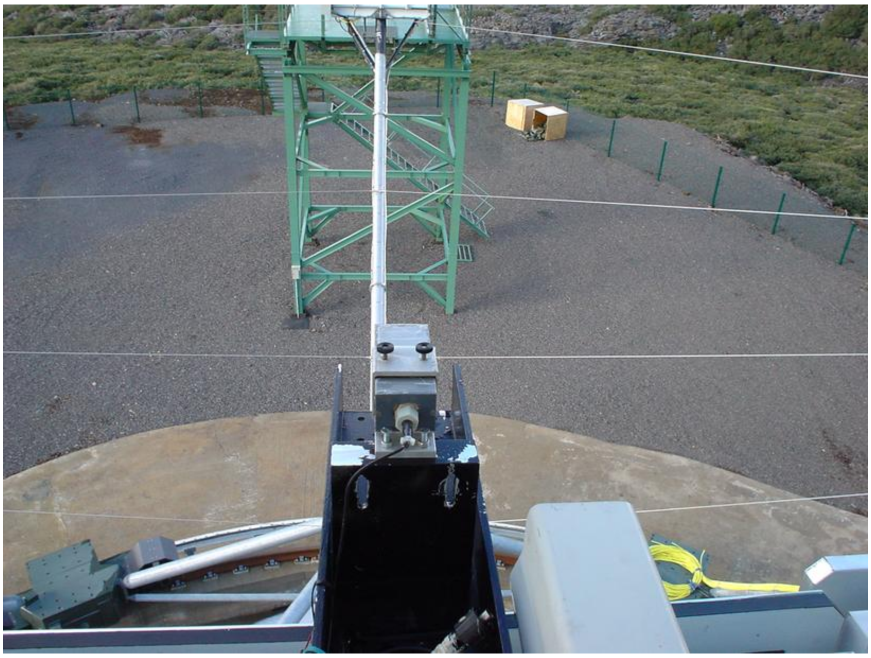


Figure 13: The ***CT1-Pulser***

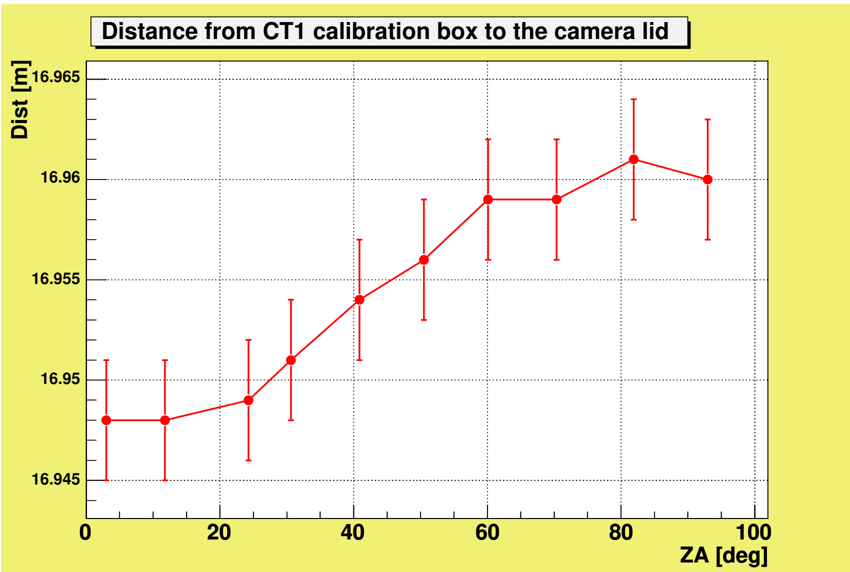


Figure 14: Dependency of the distance of the ***Center of the Mirror Dish*** to the ***Camera***, depending on the telescope zenith angle. Measurement done by Alvin Laille. The numbers show the distance of the ***CT1-Pulser*** (the distance of the ***Pulser Box*** from the ***Camera*** varies from 18.128 to 18.142 m).

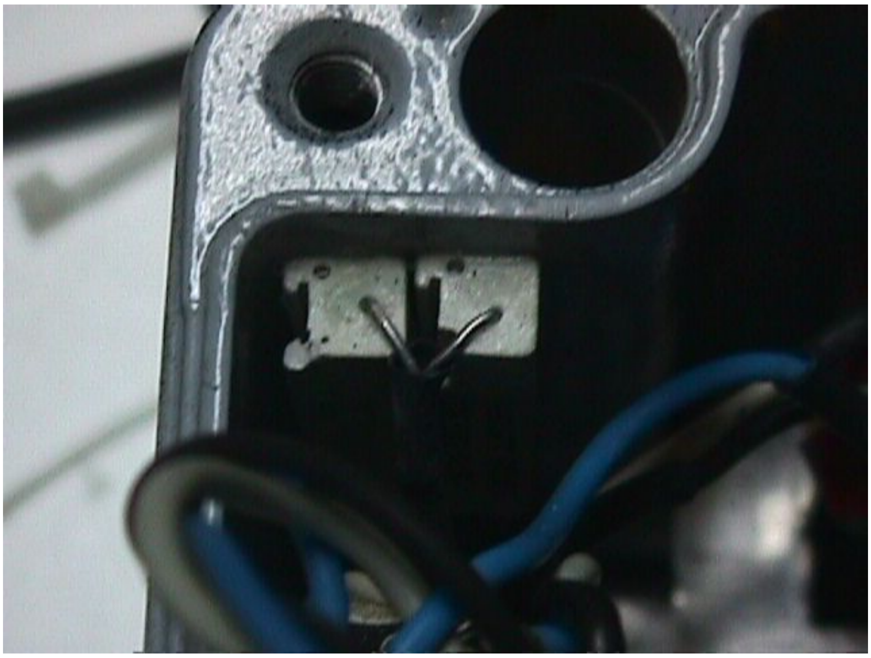


Figure 15: Resistors acting as ***Minimum Load*** for the LPT24 (table: 33 in page 122)

6.1.1 The ***Upper Box***

The ***Upper Box*** is made of aluminium and houses the ***Pulser Board*** and the ***Continuous Light LED***s. Table 27 in page 113 gives a list of the boards that can be found in the ***Upper Box***. The main part are the 16 slots housing the ***Pulsed LED***s (see section 6.1.3) out of which four slots contain green LEDs, four slots UV-LEDs and the remaining 8 slots blue LEDs. By switching different slots simulaneously, different intensities can be achieved.

The ***Continuous Light LED***s are described in section 6.1.4.

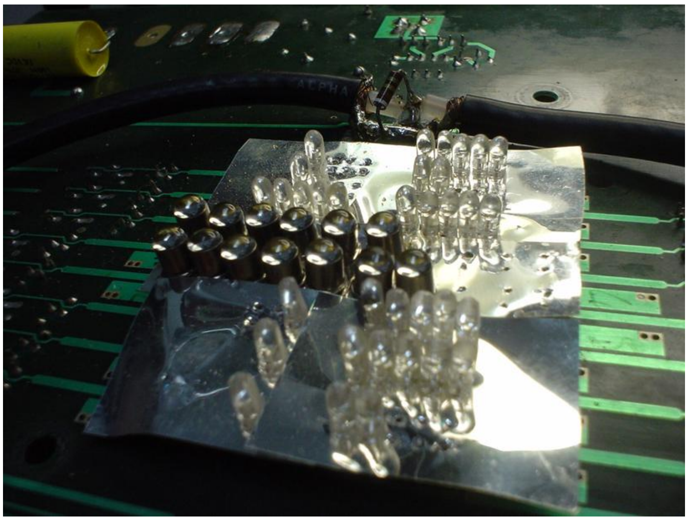


Figure 16: The Pulsed LEDs from beside

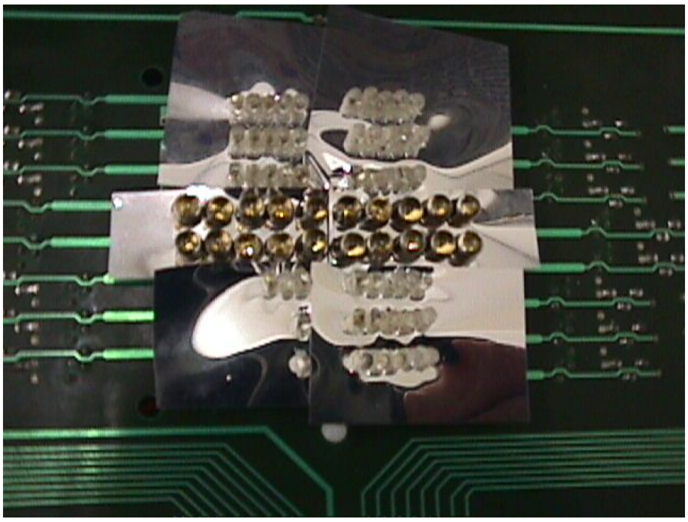


Figure 17: Pulsed LEDs from above

*6.1.2 The **Lower Box***

The ***Lower Box*** is made of aluminium and houses all the steering electronics for the Pulser Board which has the following functionalities:

- The ***600V Supply*** for the ***Pulser Box***
- The ***CAN-BUS*** receiver electronics with an integrated ***DAC***
- The current supply for the ***Continuous Light LED***s
- Three 8-bit ***Shift Registers*** to switch on and off the 16 ***Pulsed LED*** slots, the 3 ***Continuous Light LED***s, the ***600V Supply*** and the ***90V Supply*** for the ***PIN-Diode*** counter voltage

Table 29 in page 114 gives a list of the boards that can be found in the ***Lower Box***.

The ***600V Supply***

Figure 105 in page 127 shows the ***600V Supply***. It contains 3 individual 1kV switching voltage supplies of type GM12-1000P (fig. 106 in page 128) stabilized down to 600 V by three 200 V Zener diodes of type 1N5388B (fig. 107 in page 128) and a following current foldback circuit (see schematics fig. 125 in page 173 and 126 in page 174). Measurements of the current foldback mechanism can be seen in fig. 18. The current foldback takes place at a load power of about 2.2 W and attains a maximal power consumption of about 9.5 W which is just at the limit of what the three GM12-1000P can handle. A short circuit on the load would fold back the output voltage to almost 0 V with a power consumption of about 8 W. The Zener diodes consume about 0.85 W. The voltage starts to drop slowly at a load power of 1 W and faster at 2.2 W. This has to be compared with an average pulser board consumption of about 0.1 mW (if all ***Pulsed LED***s are switched on and pulses are sent with 1 kHz) and a peak consumption (at all load resistencies together) of about 30 W (during about 3 ns).

The output voltage of the ***600V Supply*** has a ripple of only 30 mV ($\sim 5{\cdot}10^{-5}$), but a sizeable time dependance ranging from 607 V at switch on time to 616 V after about one hour (see figure 19). For this reason, the ***600V Supply*** has to be switched on about one hour before taking the first calibration run.

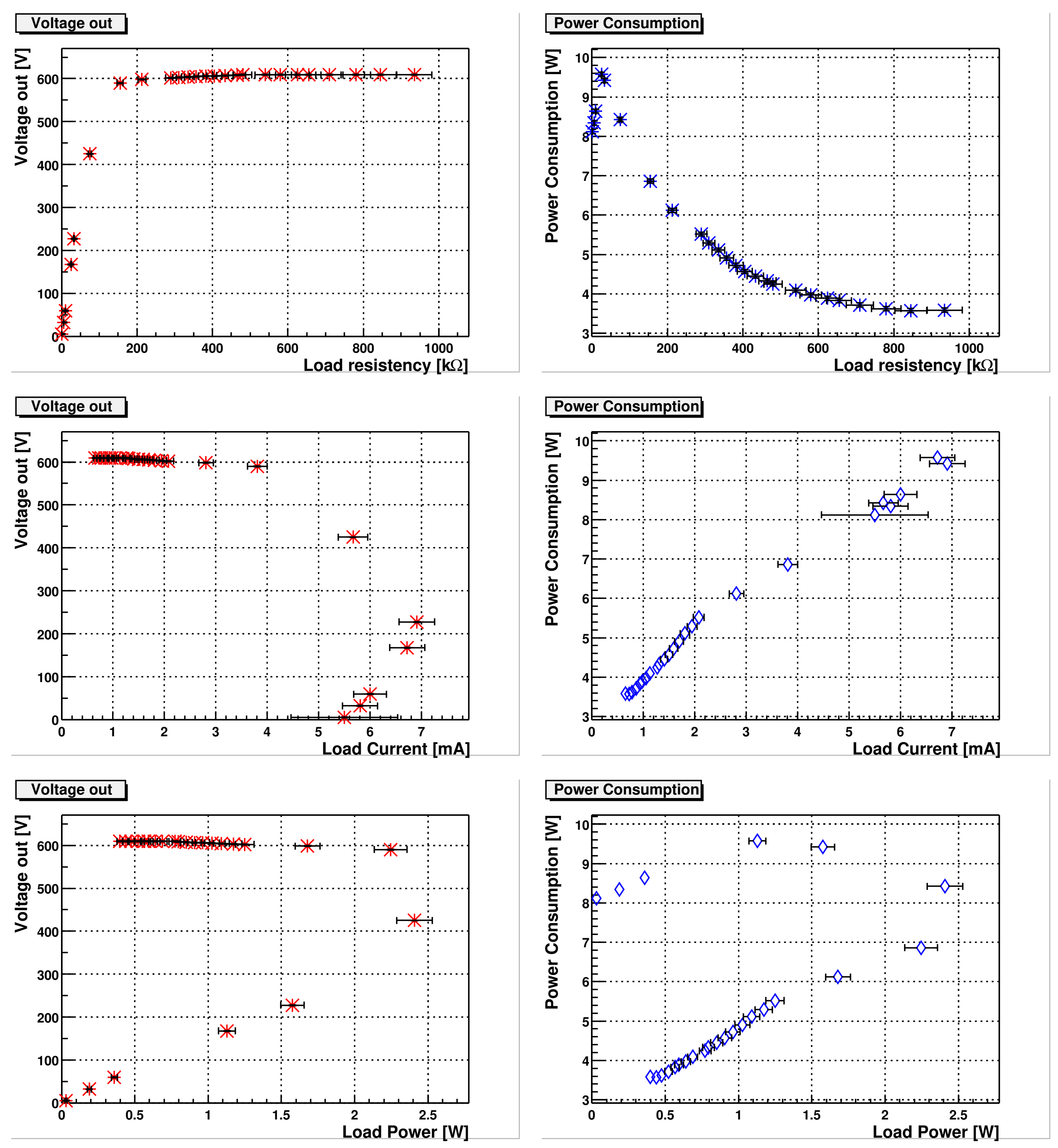


Figure 18: Measurements of the current-foldback mechanism of the ***600V Supply*** board. On the left side, the output voltage is displayed as a function of the load resistency, load current and load power, on the right side the board's power consumption is displayed.

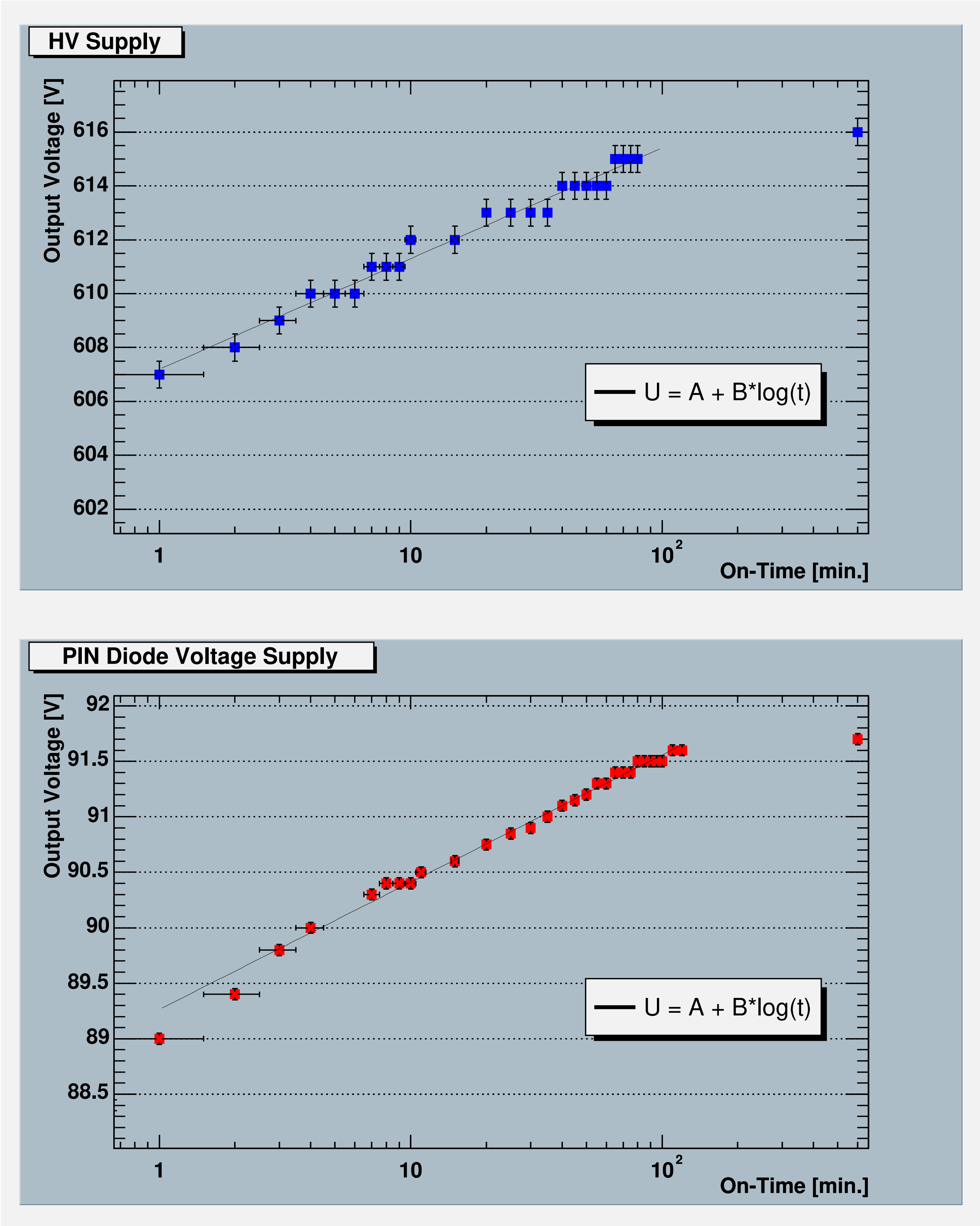


Figure 19: Measurements of the time dependency of the output voltages from the two voltages supplies. One can observe a logarithmic behaviour with some saturation effect beyond 1 hour.

The *CAN-BUS* Receiver Electronics (*CAN-BUS Board*)

The ***CAN-BUS Board*** receiver electronics have been designed for the TILECAL of the ***ATLAS*** experiment by:

`George Blanchot`
`IFAE`
`blanchot@ifae.es`

The main part of the receiver is a standard board called ***ADC2000***, documented at:

`http://wwwpc.ifae.es/Tilecal_Electronics/fabricat.htm`

The ***ADC2000*** (fig. 92 in page 117) houses the ***CAN-BUS*** electronics, a driver for the serial line driving the ***Shift Registers***, a ***DAC*** (fig. 93 in page 117), and an ADC which is not used at the moment. The pin assignments are shown in fig. 20, table 19 in page 89 gives a list of the connectors to and from the ***CAN-BUS Board***. Similiar (but not identical) boards are used for the steering of the ***Camera***.

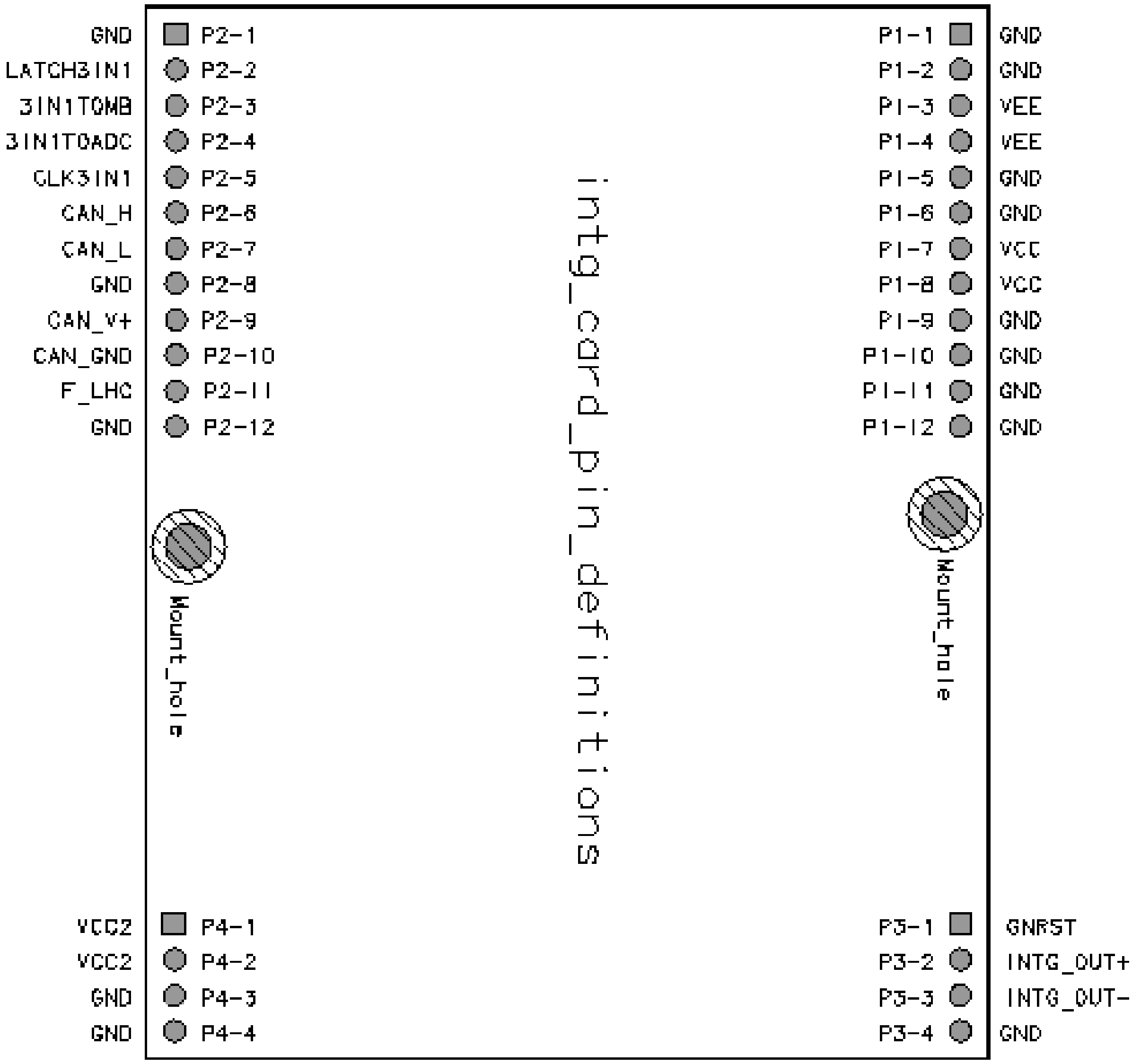


Figure 20: The ***ADC2000*** pin definitions

The ***Shift Registers***

Three ***Shift Registers***s of type 74HC595N are situated on the ***Shift Register Board*** and convert the serial line commands from the ***ADC2000*** to voltage levels to steer the following lines:

Shift Registers lines		
Shift Register Nr.	Lines	steering
1	1–8	***Pulsed LED*** slots 1–8
2	1–8	***Pulsed LED*** slots 9–16
3	1	***600V Supply*** ON/OFF
	2	***Continuous Light Source*** RED ON/OFF
	3	***90V Supply*** ON/OFF
	4	***Continuous Light Source*** AMBER ON/OFF
	5	***Continuous Light Source*** BLUE/GREEN ON/OFF
	6	***Continuous Light Source*** UV ON/OFF

Table 10: Usage of ***Shift Registers*** lines

On the ***Shift Register Board***, there is also a ***Continuous Light Source*** circuit designed to convert the ***DAC*** voltage levels linearly to currents traversing the ***Continuous Light Source***.

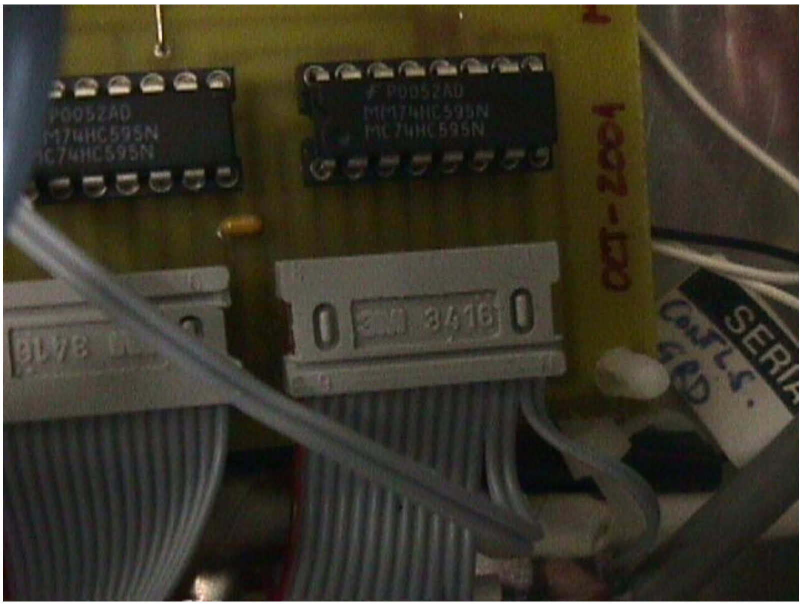


Figure 21: ***Shift Registers*** 74HC595N
Special lines from right to left:
600V Supply ON/OFF, ***Continuous Light Source*** red ON/OFF, ***90V Supply*** ON/OFF, ***Continuous Light Source*** amber ON/OFF, ***Continuous Light Source*** blue/green ON/OFF, ***Continuous Light Source*** UV ON/OFF

The current supply for the ***Continuous Light LED*s**

The four ***Continuous Light LED*s** can be steered at 256 different current levels from 2.5 mA to about 30 mA. These levels can be set by a ***DAC*** as voltage levels which are then converted into current levels by the current supply circuit on the ***Shift Register Board***. The schematics of this circuit is found in figure 129. Figure 22 shows the circuit from above (which is not very beautiful because it had to be converted by hand from a voltage supply to a current supply circuit).

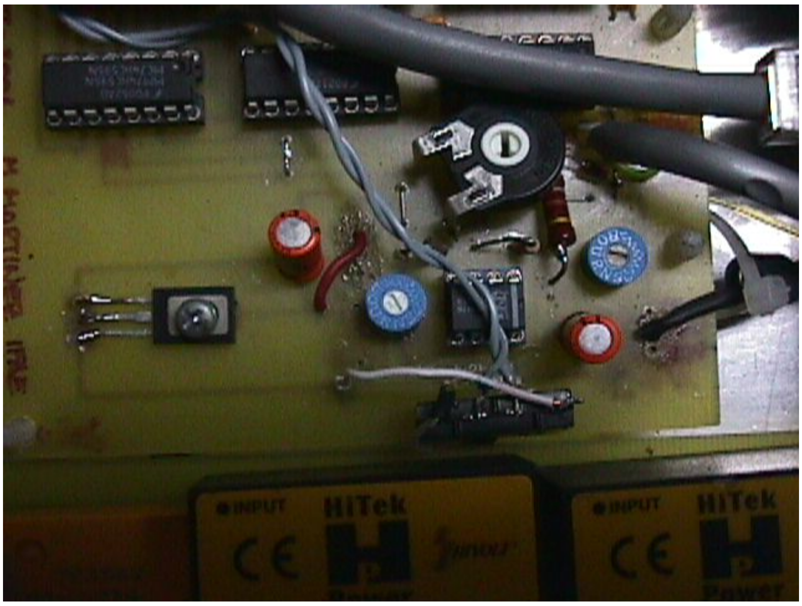


Figure 22: The ***Continuous Light LED*** Current Supply

6.1.3 The ***Pulsed LED****s*

The ***Pulsed LED***s of type NISHIA single quantum well (NSPB-310A and NSPG-310A) are designed to provide ultra-fast, ultra-intense light pulses. They are the central part of the ***Calibration System*** and can be driven with up to 20 A in pulsed mode. These LEDs cannot be purchased any more, unfortunately. In the ***Spares Boxes***, there is a small stock which should be enough for replacements and repairs.

In our case, a peak current of about 6 A traverses the LEDs during 1–2 ns. The LEDs are set into place in slots, where each slot can switched on and off independently, but LEDs situated in one same slot are driven in parallel. A maximum of 5 LEDs has place in one slot. Table 11 and figure 23 show the current usage of every slot. Note that two slots have an additional filter (diffuser) in front, namely slot 16 and slot 9. Slot 10 is not working and cannot be used.

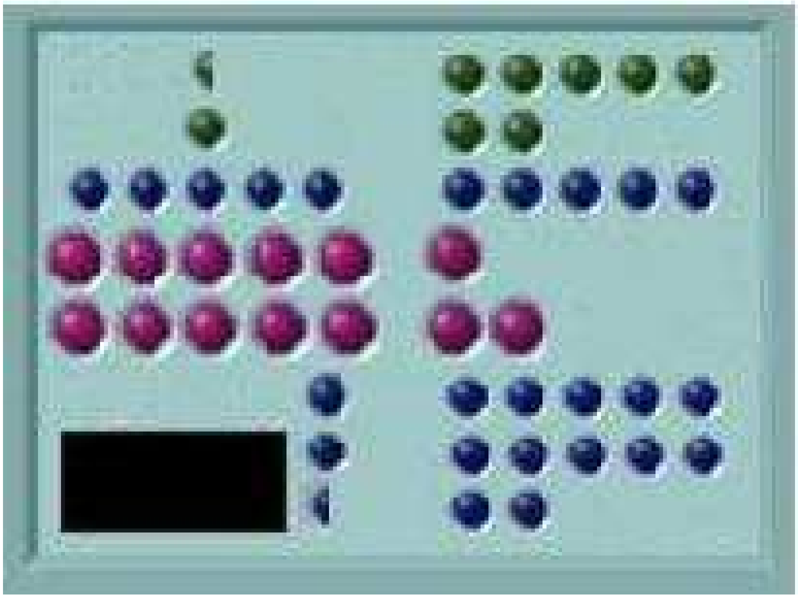


Figure 23: The configuration of the ***Pulsed LED***s

The emitted light is uniform to about 1% in a cone of 2 degrees from the center (see figure 26). Situated at a distance of 18.13 m from the camera, the uniform cone covers thus the entire camera (1.8 deg.). The PIN-Diode lies outside the 2° uniformity cone, but inside the 2% uniformity region at a viewing angle of 2.2 to 4.0 deg., depending on the used slot.

Figure 27 shows the spectra of the three coloured LEDs types and the subsequent pictures give an oscilloscope shot of the electrical pulse (probed with 1MΩ traversing the LEDs. One can see the 2–3 ns FWHM for the green and blue LEDs slots and the 2 ns FWHM for the slots housing UV LEDs. Figure 33 shows the anode pulse of a typical inner pixel with respect to the pulse of one blue LED. One can see about 4.5–5 ns FWHM. This number is smaller than the shaping time of the optical receiver circuit (6.8 ns).

There might be some after-pulsing due to fluorescence in the ***Pulsed LED***s which is probably the reason for the small bump at 10 ns after the peak in figure 33. This after-pulsing is not yet fully understood and investigated.

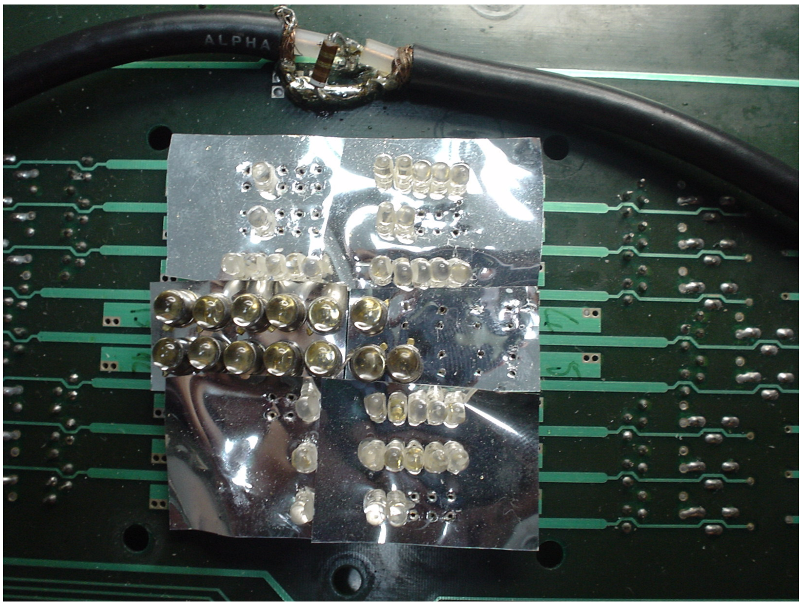


Figure 24: The current configuration of ***Pulsed LED***s: The two upper right rows contain green LEDs, the central bigger ones UV LEDs and the rest blue LEDs. Dismounted and not shown are here the continuous light LEDs (on the bottom left part) and the diffuser plate on top. The top left slot and the bottom left slot have an additional diffuser to decrease the amount of light.

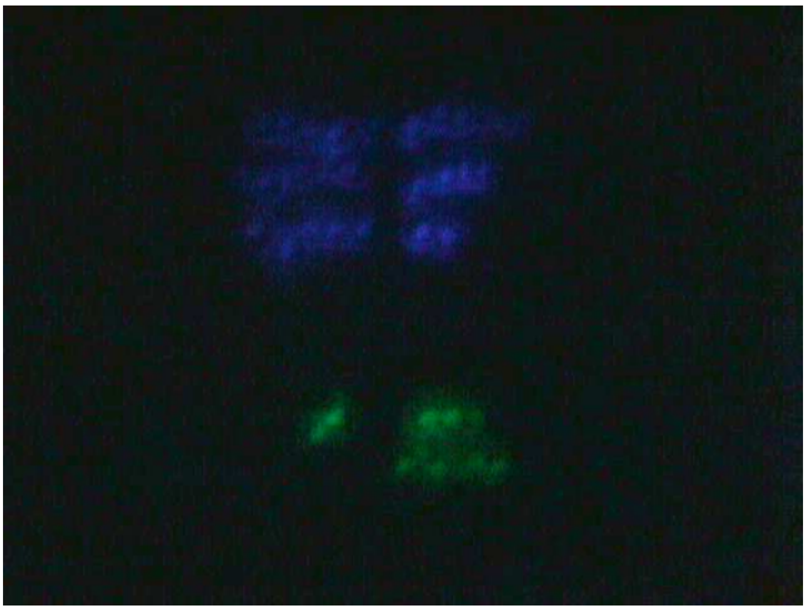


Figure 25: Some ***Pulsed LED***s during night

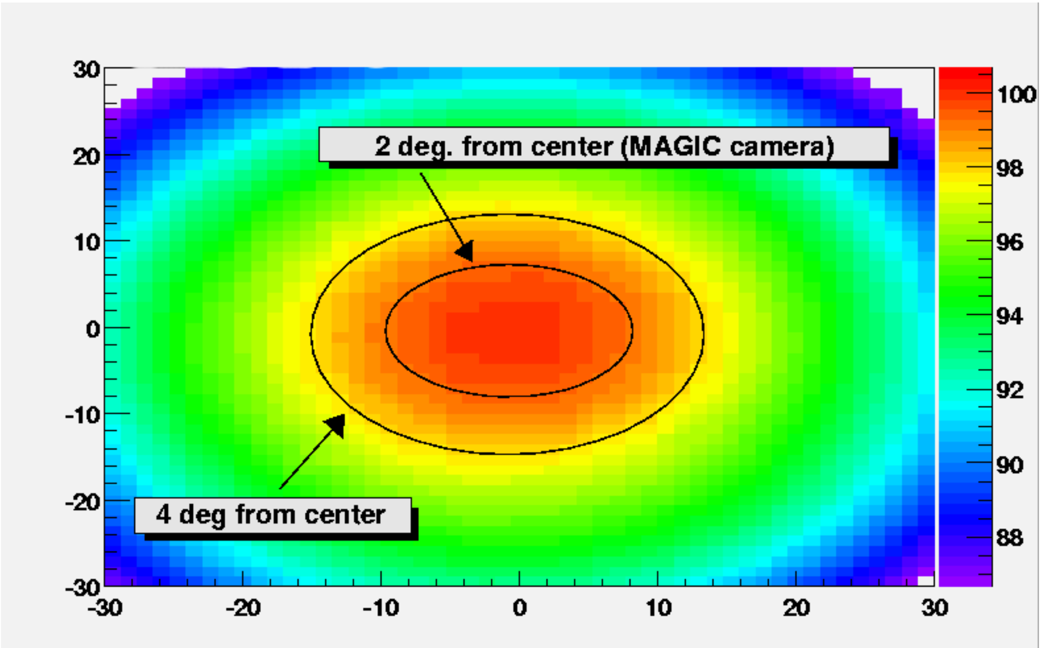


Figure 26: Uniformity of the emitted light of the ***Pulsed LED***s

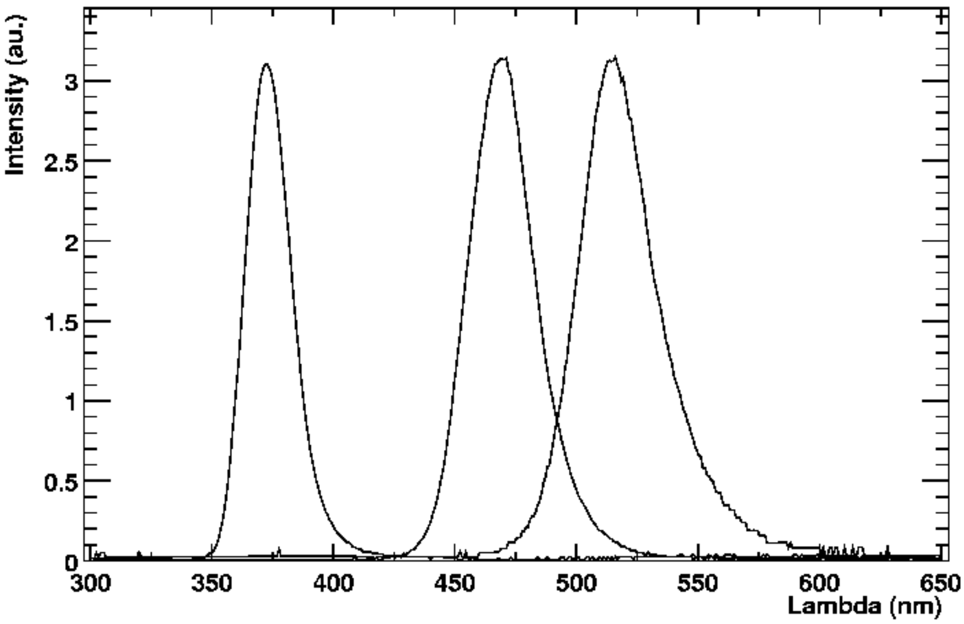


Figure 27: Spectra of the ***Pulsed LED***s

Pulsed LEDs					
Slot Nr.	Nr. LEDs	peak wavelength (nm)	Photons/ inner pixel	Photo-electrons/ inner pixels	Hi-Gain Saturation
1	5	520 (green)	350	65	NO
2	2	520 (green)	180	35	NO
3	5	460 (blue)	650	95	YES
4	1	370 (UV)	12	3	NO
5	2	370 (UV)	25	6	NO
6	5	460 (blue)	650	95	YES
7	5	460 (blue)	650	95	YES
8	2	460 (blue)	400	60	NO
9	1	460 (blue)	80	12	NO
10	1	460 (blue)	0	0	BROKEN
11	1	460 (blue)	300	50	NO
12	5	370 (UV)	100	20	NO
13	5	370 (UV)	100	20	NO
14	5	460 (blue)	650	95	YES
15	1	520 (green)	220	40	NO
16	1	520 (green)	45	8	NO

Table 11: ***Pulsed LED***s used in the ***Pulser Box***. Slot 10 is broken and slots 9 and 16 have an additional filter in front.

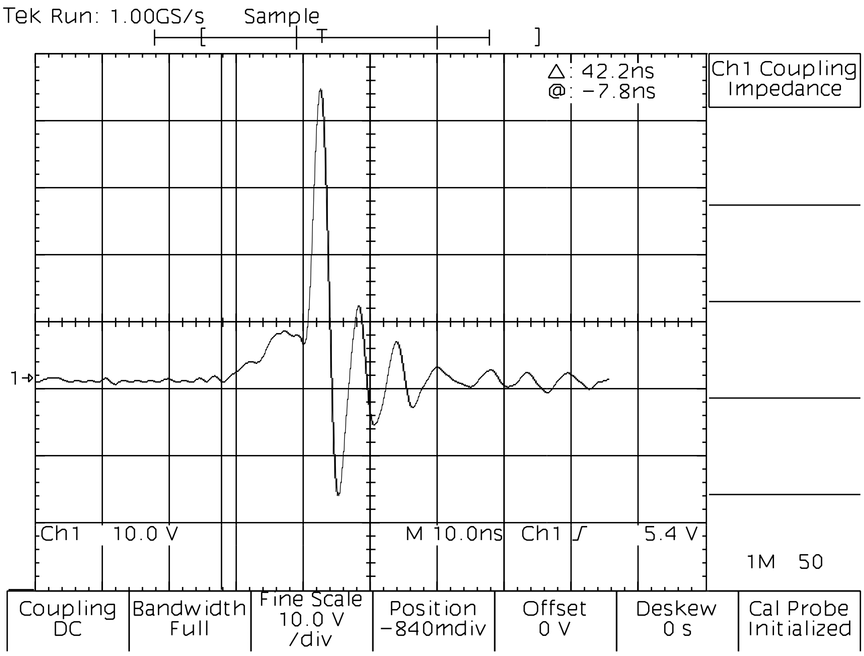


Figure 28: Probe of the electrical pulse traversing a slot with 1 blue ***Pulsed LED***

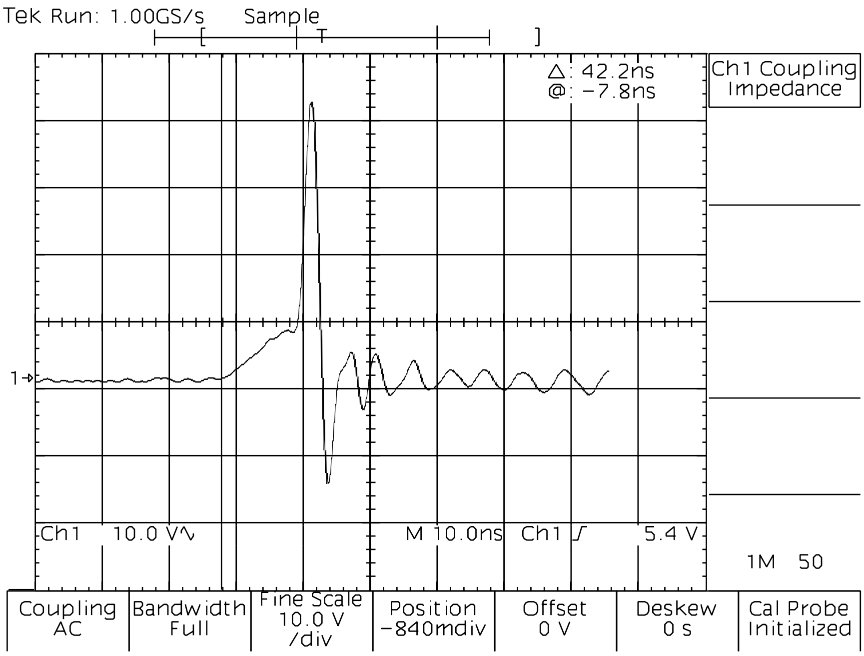


Figure 29: Probe of the electrical pulse traversing a slot with 2 blue ***Pulsed LED***s

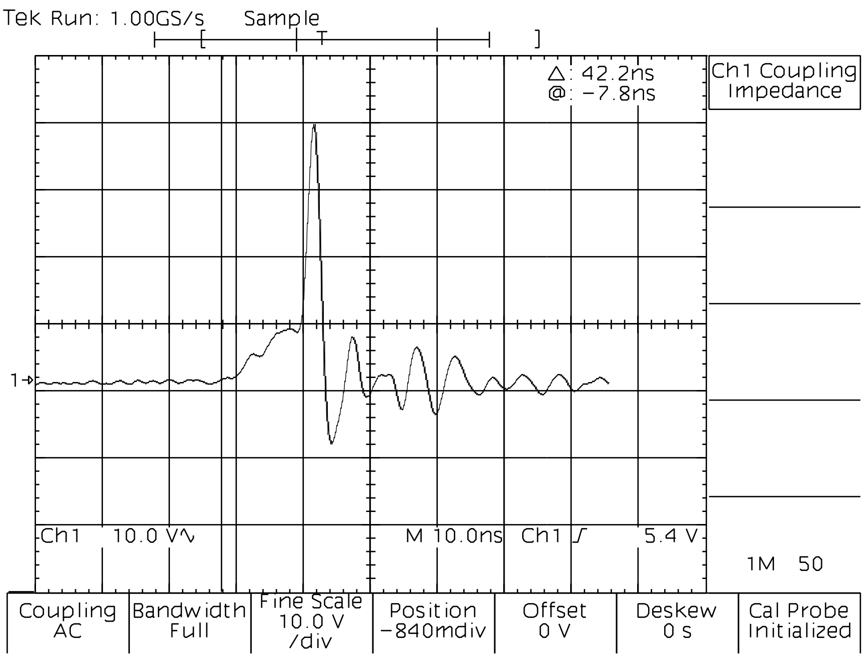


Figure 30: Probe of the electrical pulse traversing a slot with 5 blue ***Pulsed LED***s

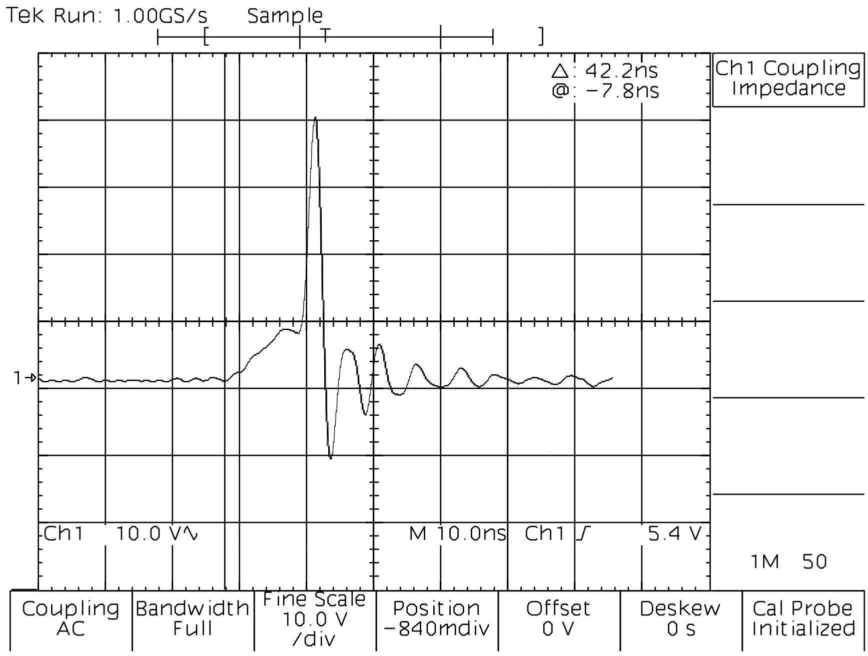


Figure 31: Probe of the electrical pulse traversing a slot with 5 green ***Pulsed LED***s

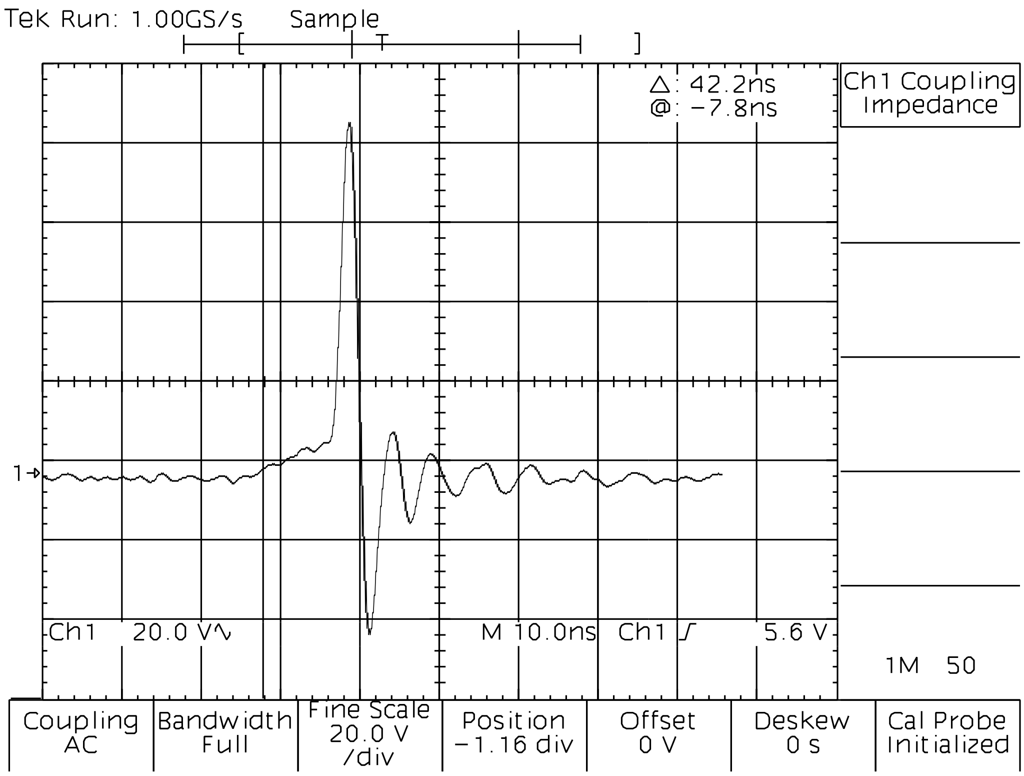


Figure 32: Probe of the electrical pulse traversing one a slot of 5 UV ***Pulsed LED***s

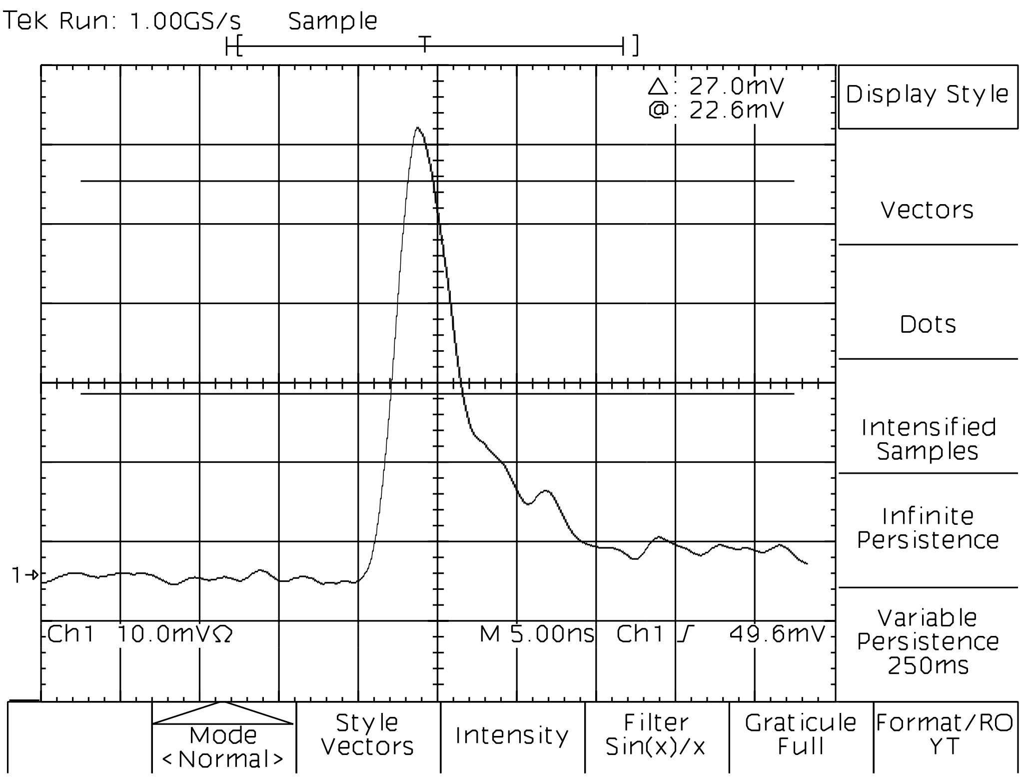


Figure 33: Slightly amplified signal at the anode of an ***Inner Pixel*** before traversing 470Ω.

6.1.4 The ***Continuous Light Source (CL)***

The ***Continuous Light Source*** is designed to simulate star light at different wavelengths and to calibrate the pedestal RMS (here called σ) against PMT anode current I using the following relation [2]:

$$(\sigma^2 - \sigma_0^2) \propto I \tag{1}$$

(σ_0 is the electronic noise). It serves to flat-field the camera currents at different wavelengths.

Table 12 shows the four different slots with ***Continuous Light LED***s available:

Continuous Light LEDs						
Nr.	Name	Nr. LEDs	peak wavelength (nm)	max. intensity (ph/s/sr)	max. intens. ***Inner Pixel*** (ph/ns)	remarks
1	HLMP-CB15	1	472 (blue)	$5.1{\cdot}10^{16}$	$1.2 \cdot 10^{2}$	in series with #2
2	HLMP-CM15	1	526 (green)	$2.4{\cdot}10^{16}$	$0.6 \cdot 10^{2}$	in series with #1
3	HLMP-EL15	2	590 (amber)	$4.4{\cdot}10^{17}$	$2.0 \cdot 10^{3}$	
4	HLMP-EH16	2	615 (red)	$1.5{\cdot}10^{17}$	$3.4 \cdot 10^{2}$	
5	NSHU550E	2	370 (UV)			same as pulsed LEDs

Table 12: ***Continuous Light LED***s used in the ***Upper Box***

Figures 35 show some of the measured properties of the ***Continuous Light LED***s. Please beware that only currents have been measured up to now. The light output was taken from the data sheets and NOT measured explicitely. Figures 36 and 37 show the assumed photon and photo-electron spectra of the combination of green and blue LEDs, respectively. The other ***Continuous Light LED***s have simpler spectra since they consist only of one type of LED, two individual LEDs in series. Section E.4 in the data-sheets appendix shows the specifications of the other ***Continuous Light LED***s.

In principal, different ***Continuous Light LED*** slots can be illuminated in parallel, dividing the current flowing through the individual LEDs. However, the spectra will not be precise since the forward resistancies encountered by the driving current differ from LED type to LED type making it difficult to predict the relative strength of the individual LED slots. The combined spectra would need to be measured in place. However, in a future ***Pulser Box***, different ***Continuous Light LED***s shall be driven independently allowing for a better montitoring of the resulting spectra. For the moment, we advise only to use individual slots and not to combine them.

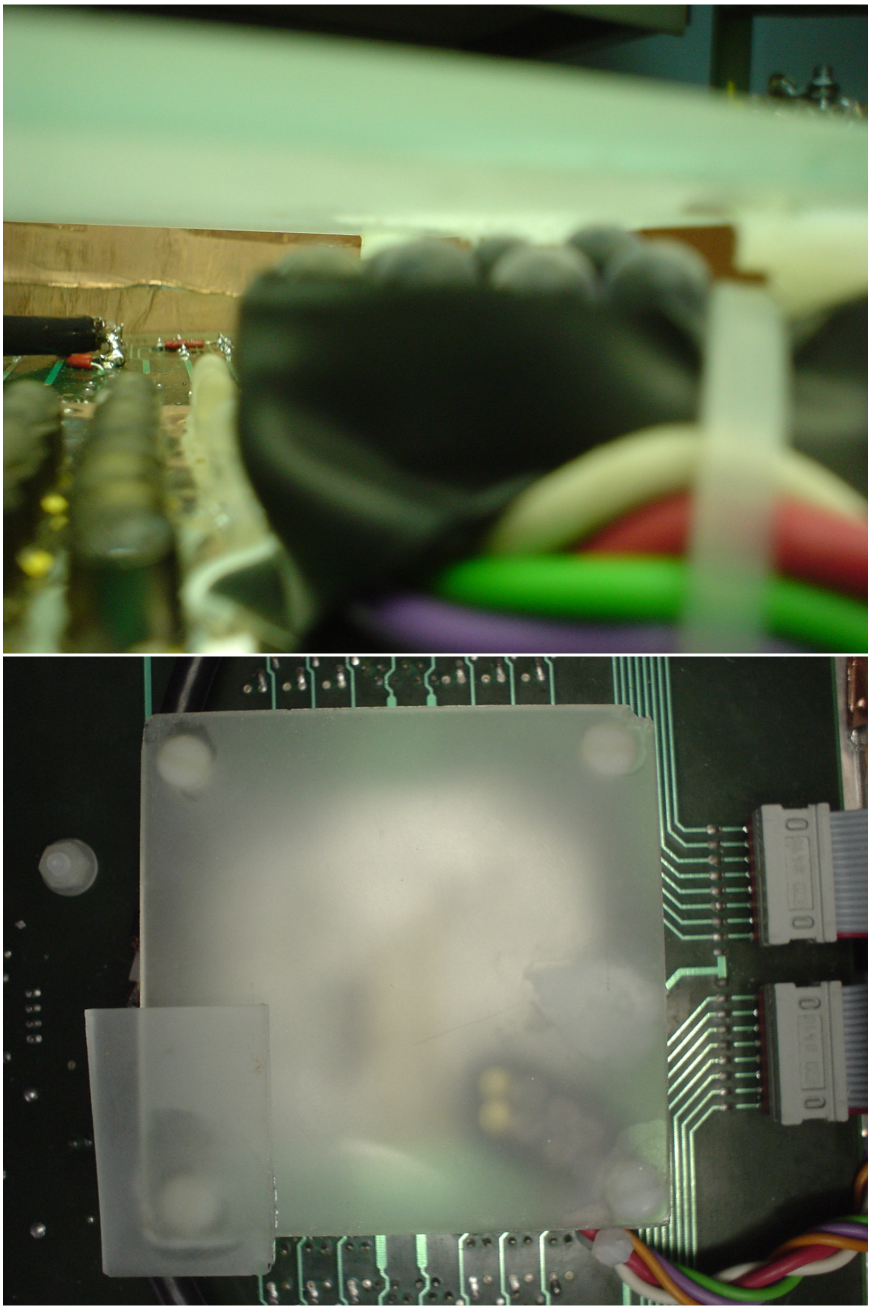


Figure 34: The ***Continuous Light LEDs***

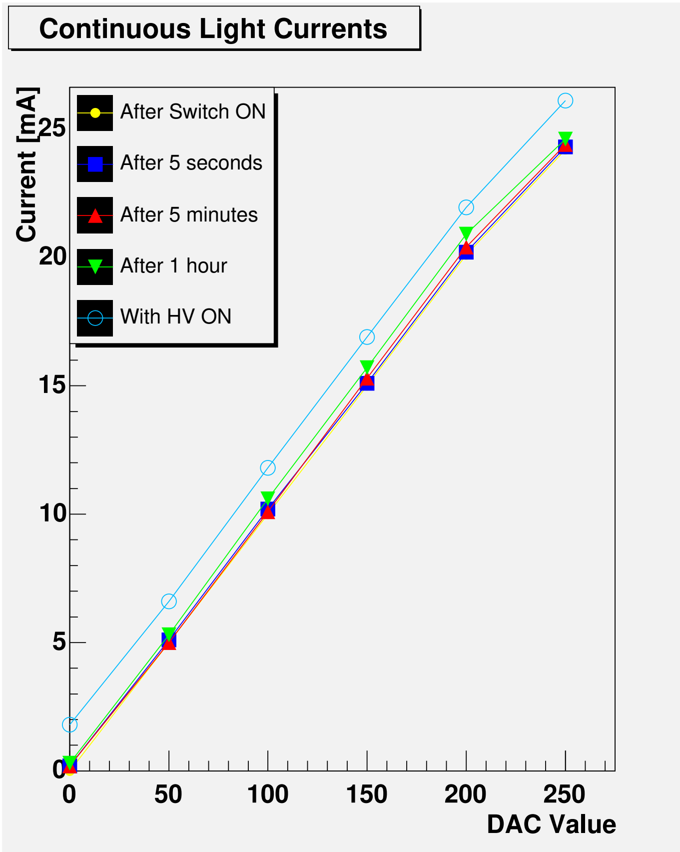


Figure 35: ***Continuous Light Source***: Current behaviour vs. ***DAC*** value. One can see that the current is systematically higher when the ***600V Supply*** is switched on.

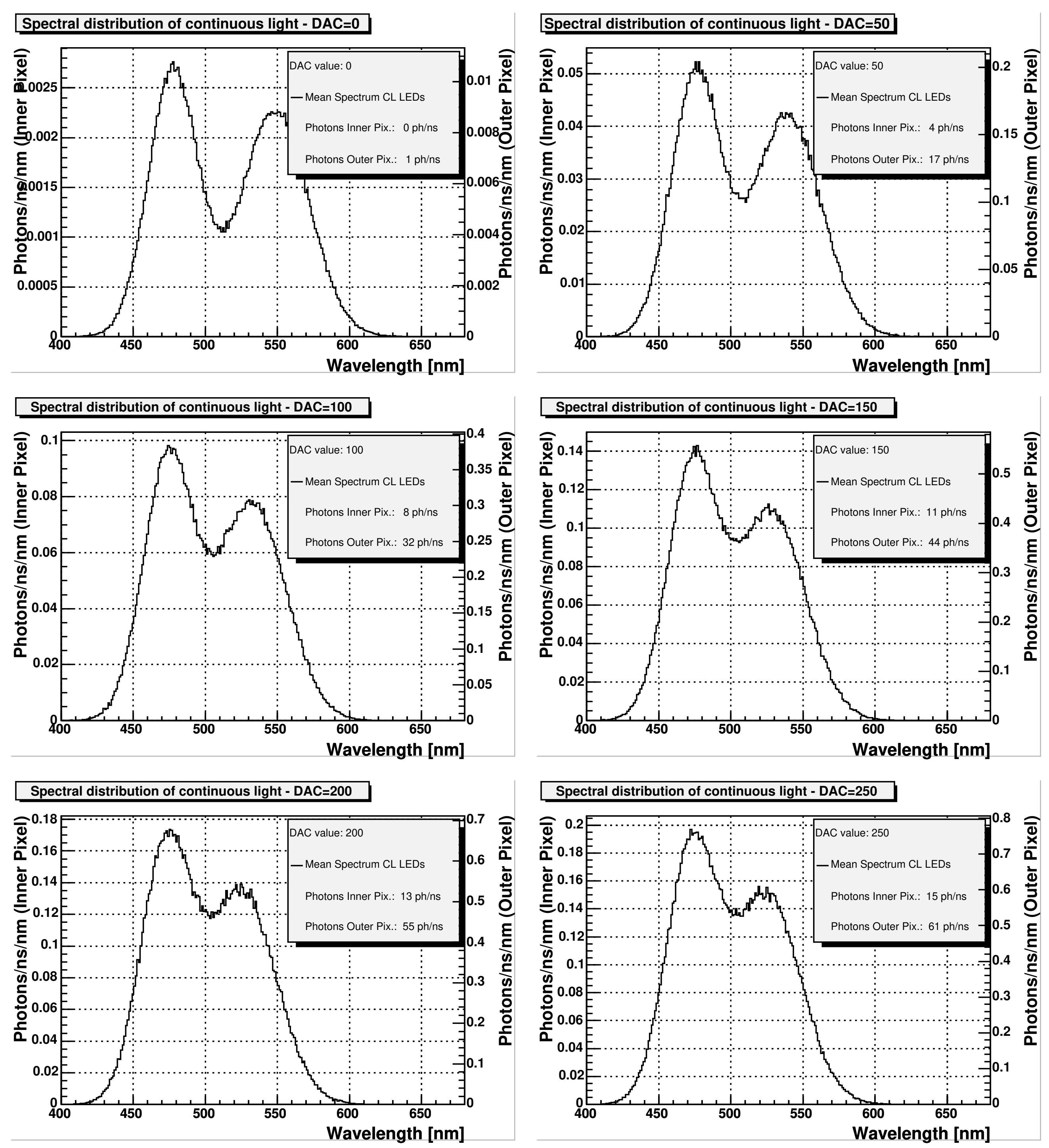


Figure 36: Spectrum of the blue-green ***Continuous Light Source*** in photons/ns. The left axes reference the numbers attributed to the ***Inner Pixel***s, right axes reference the ***Outer Pixel***s. Spectra at ***DAC*** values of 0,50,100,150,200 and 250 are displayed.

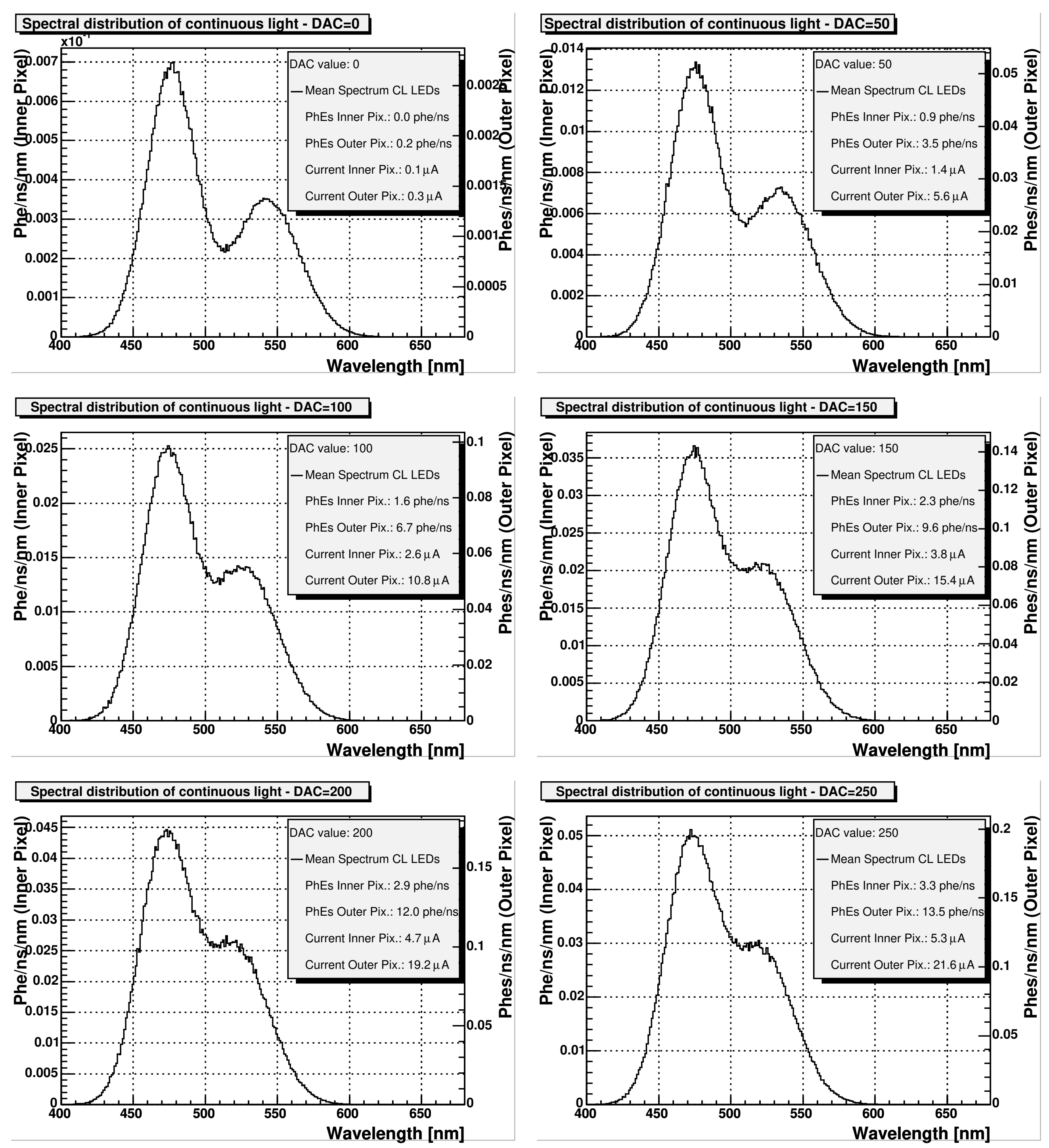


Figure 37: Spectrum of the ***Continuous Light Source*** in photo-electrons/ns arriving at the first dynode of a pixel. The left axes reference the numbers attributed to the ***Inner Pixel***s, right axes reference the ***Outer Pixel***s. Spectra at ***DAC*** values of 0,50,100,150,200 and 250 are displayed.

6.2 The LV-supply

The LV-supply is housed in the small black box on the other side of the black aluminium arm, opposite the ***Pulser Box*** (figure 38 shows the box, not yet set into the correct place). It is powered by a common 230 VAC cable starting from the ***Cooling Box*** box below on the telescope. This power line can be switched on and off remotely (and automatically) from the ***Camera Control***. Inside, the low-voltages are produced to power the electronics in the ***Pulser Box*** and the ***PIN-Diode***. Note that the ***CAN-BUS*** is powered directly from a 15 V line inside the ***CAN-BUS***-cable. The ***LV-Box*** contains a two-floor architecture: Below, the voltages for the ***Pulser Box*** are produced, above those for the ***PIN-Diode*** (see fig. 39 and 40). The whole box is of hard plastic (unfortunately an ordering error!!) and IP68 proof.

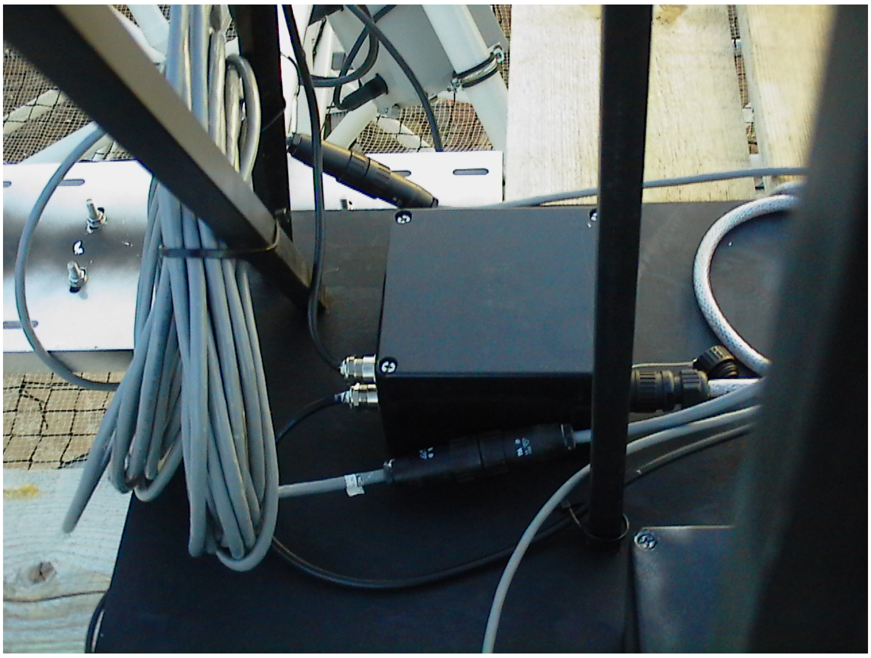


Figure 38: The ***LV-Box***

Table 33 in page 122 gives a list of the power supplies that can be found inside the box. Note that the ASTEC (#1) needs a ***Minimum Load*** which is situated at the entry of the ***Pulser Box*** and is used to heat that box.

BEWARE!! THE ASTEC POWER SUPPLY CAN CARRY DANGEROUS VOLTAGES UP TO 5 MINUTES AFTER DISCONNECTION FROM THE AC POWER .

The separate linear ±12 V supply from SOLA was chosen in order to provide very stable voltages for the ***Nano-Second Amplifier*** of the ***PIN-Diode*** readout. It is filtered at several subsequent stages before reaching the ***Nano-Second Amplifier***. The same holds for the 90 V counter voltage for the ***PIN-Diode*** produced by a small board stabilizing the voltage with zener diodes and a transistor-current foldback circuit (see schematic on fig. 127 in page 174). (There is one spare of this board in the ***Control House***).

Table 20 in page 90 and fig. 74 in page 102 show the used connectors. All connectors have spares in the Calibration ***Spares Boxes*** (fig. 2 in page 14) situated in the ***Control House***. They should

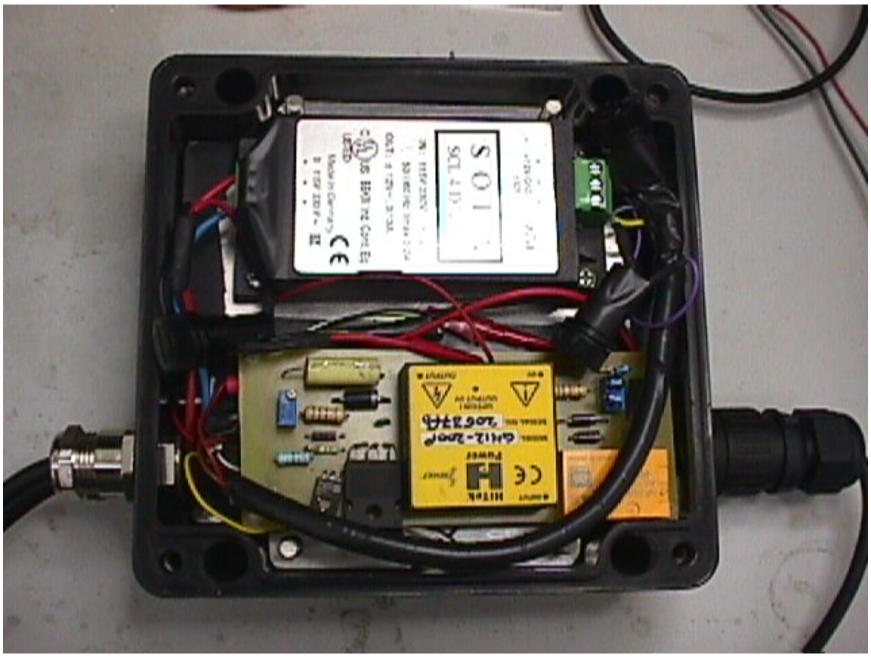


Figure 39: Interior of the ***Lower Box*** (upper floor)

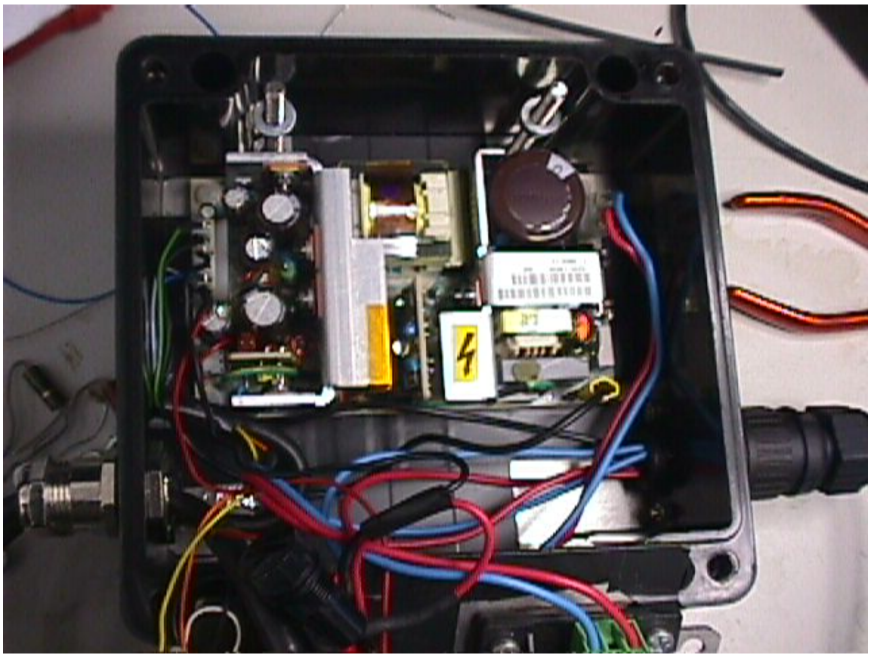


Figure 40: Interior of the ***Lower Box*** (lower floor)

all be watertight (IP67 and IP68), but beware that they are treated with care so that they will not loose this quality. Note that cable #2 in table 20 in page 90 carries not only voltages *t*o the ***Pulser Box*** but also receives *o*ne bit 5 V from it. These are the two lines in yellow and orange carrying the information if the ***90V Supply*** is switched ON or OFF.

6.3 The *Blind Pixel*s

The three ***Blind Pixel***s are selected ***Inner Pixel***s with accurately measured quantum efficiencies (see figures 44, 46, 47 and [7]). Their collection efficiencies are somewhat higher than those of the rest of ***Inner Pixel***s because of the higher voltage difference between photo-cathode and first dynode. They are situated just outside the swiss cheese of the ***Camera***, about 10 cm from the outer ring of pixels, each 120° from the two others. They are alimented from a common base in the place of the outer pixel nr. 560 (see figure 53), the voltages are split in a small distributor box below (see figure 52). The ***Blind Pixel***s are darkened PMTs with filters of absorption 1/100 of type Oriel instruments 50550 (***Blind Pixel*** #1), 1/1000 type Edmund Optics NT47-212 (***Blind Pixel*** #2) or absorption 1/10 obtained with an additional diaphragm (***Blind Pixel*** #3). The filters are approximately uniform over the used wavelengths (see figure 43). Moreover, small diapraphms of exactly 1 cm^2 area let only photons of straight incidence angles pass onto the photo-cathode. The ***Blind Pixel***s have the possiblity of single-photo-electron counting and thus to derive the incident photo-electron flux with great precision. They are un-affected by the light guides and are situated still in the uniform cone illuminated by the ***Pulsed LED***s. In order to improve the single-photo-electron separability, the Zener diodes between first and second dynode have been exchanged such that the difference in voltage is there 440 V instead of the 360 V used for the other PMTs. Moreover, a dedicated copper shielding has been placed around the ***Blind Pixel***s as can be seen in figure 41. The signals from the anodes are amplified about 4 times more than by a common ***Inner Pixel*** (see figure 42). The nominal voltage for the ***Blind Pixel*** is allowed maximum, currently 1300 V.

The ***Blind Pixel***s						
Nr.	PMT ID	Sector	Filter	Company	Readout channel	remarks
1	1911	1	0.01	Oriel 50550	560	
2	1611	3	0.001	Edmunds NT47–212	561	
3	1613	5	0.1	diaphragm	–	currently not connected

Table 13: The ***Blind Pixel***s used in the ***Camera***

Figure 41: One ***Blind Pixel*** in the camera

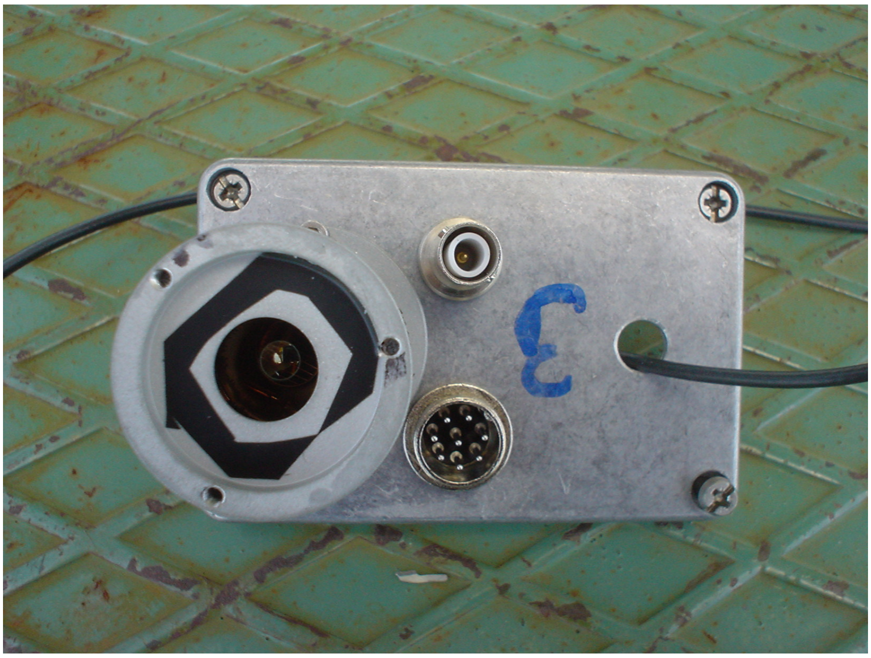
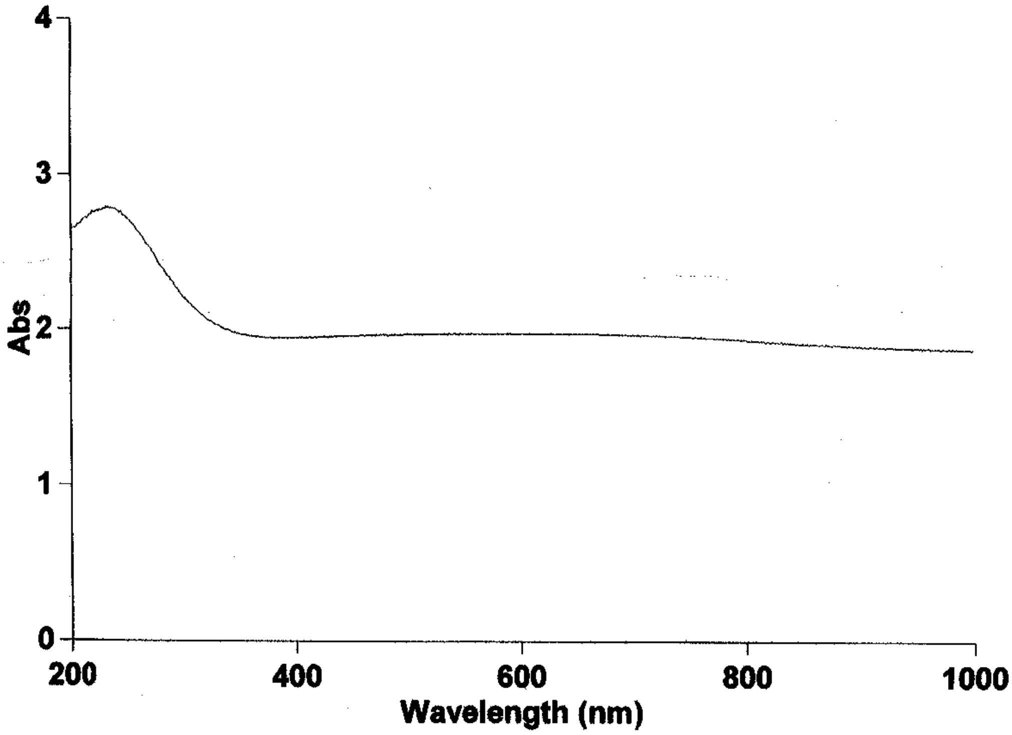


Figure 42: One ***Blind Pixel*** without filter

3/24/99 1:30:44 PM   Page 1 of 1



Report changed 3/24/99 1:30:44 PM

Sample Name: 50550 s\n 23

Collection Time   3/24/99 1:28:39 PM

Peak Table

Peak Type	Peaks
Peak Threshold	2.0000
Range	1000.000nm to 200.000nm

X-Y Pairs Table

Data Interval   50.00

Wavelength (nm)	Abs	Wavelength (nm)	Abs	Wavelength (nm)	Abs
1000.000	1.87271	700.000	1.96556	400.000	1.94343
950.000	1.88286	650.000	1.97218	350.000	1.96552
900.000	1.89221	600.000	1.97291	300.000	2.20508
850.000	1.90917	550.000	1.97147	250.000	2.72298
800.000	1.93023	500.000	1.96904	200.000	2.63776
750.000	1.95088	450.000	1.95697		

Figure 43: The absorption depedency of the light filter Edmunds NT47-212 in the ***Blind Pixel***

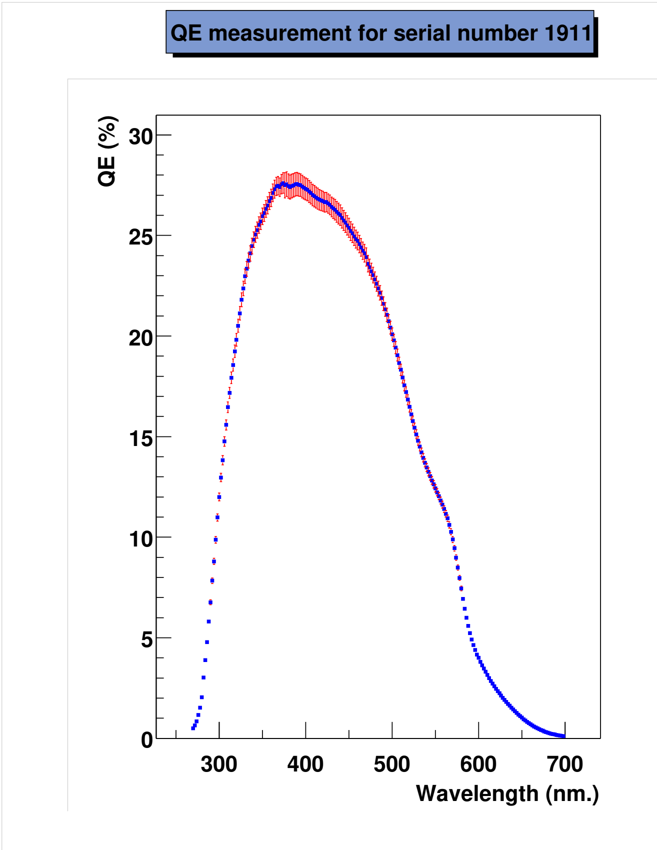


Figure 44: The quantum efficiency of ***Blind Pixel*** #1

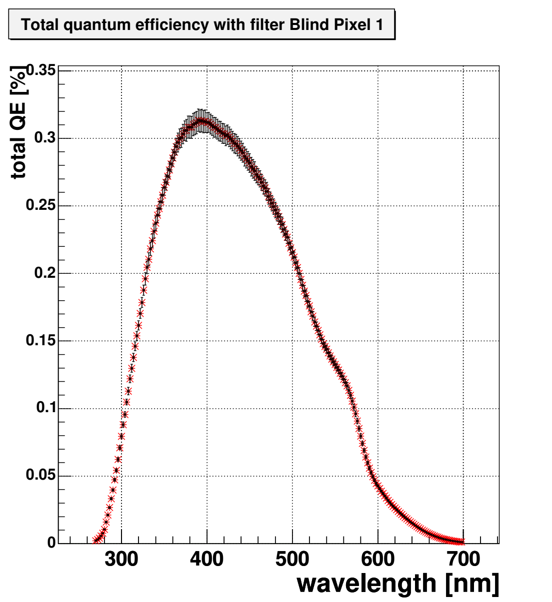


Figure 45: Combined quantum efficiency of ***Blind Pixel*** #1 (with filter included)

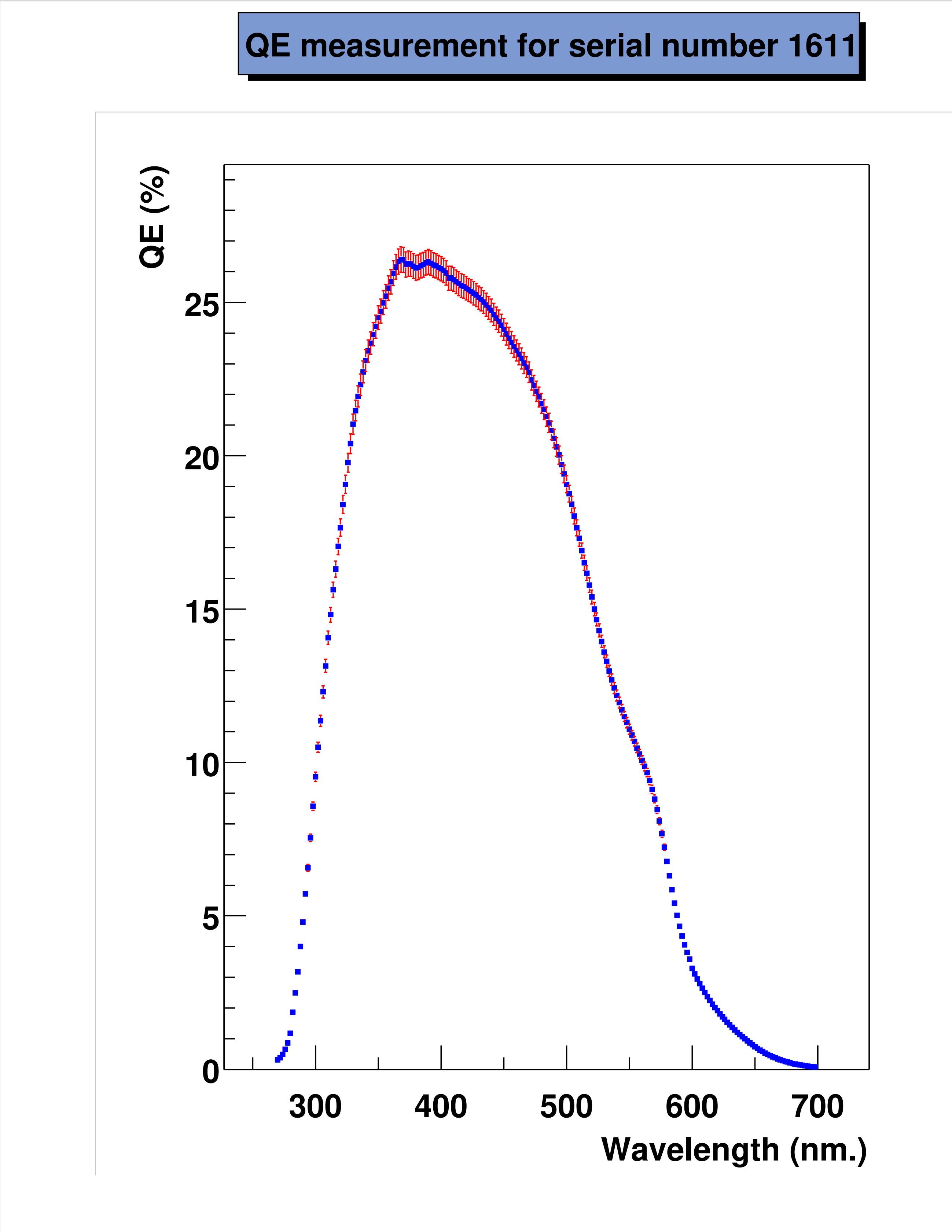


Figure 46: The quantum efficiency of ***Blind Pixel*** #2

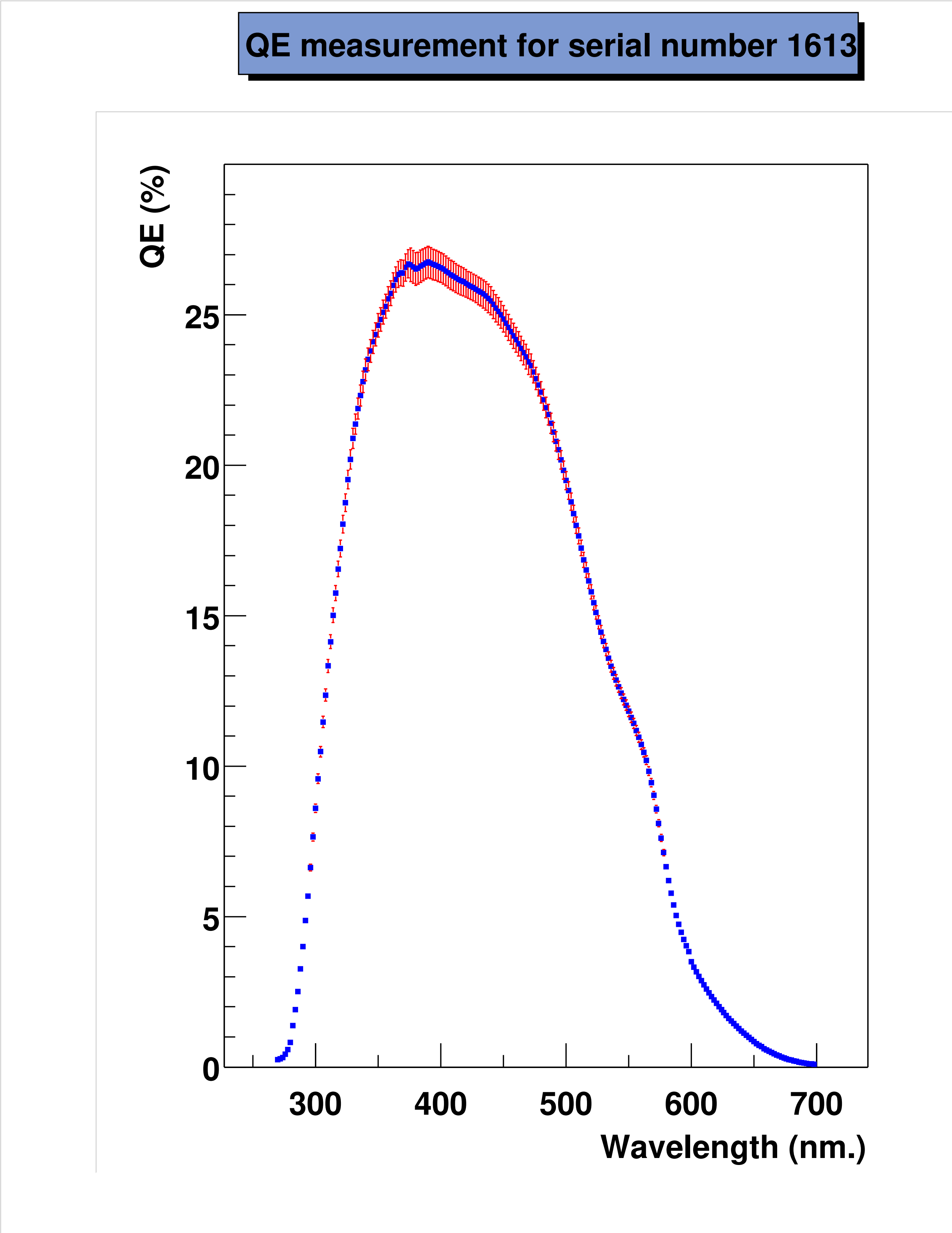


Figure 47: The quantum efficiency of ***Blind Pixel*** #3

Figure 48: The PMT of the ***Blind Pixel***. The black tape has been put in order to prevent formation of sparks to the (grounded) copper protection. The photons strike only on the very top of the PMT because of the diaphragm.

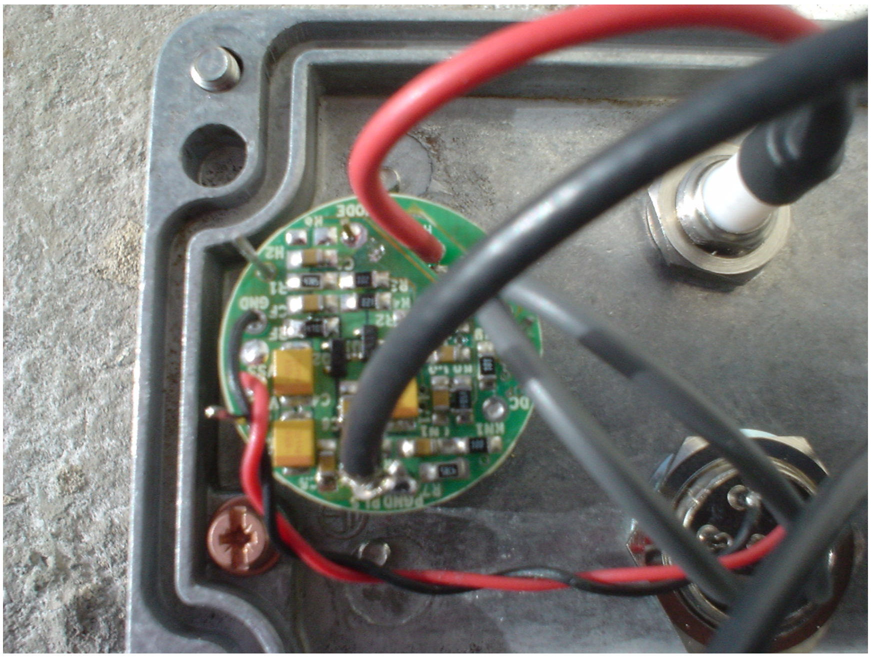


Figure 49: The amplifier of the ***Blind Pixel***

Figure 50: The filter of the ***Blind Pixel*** (open)

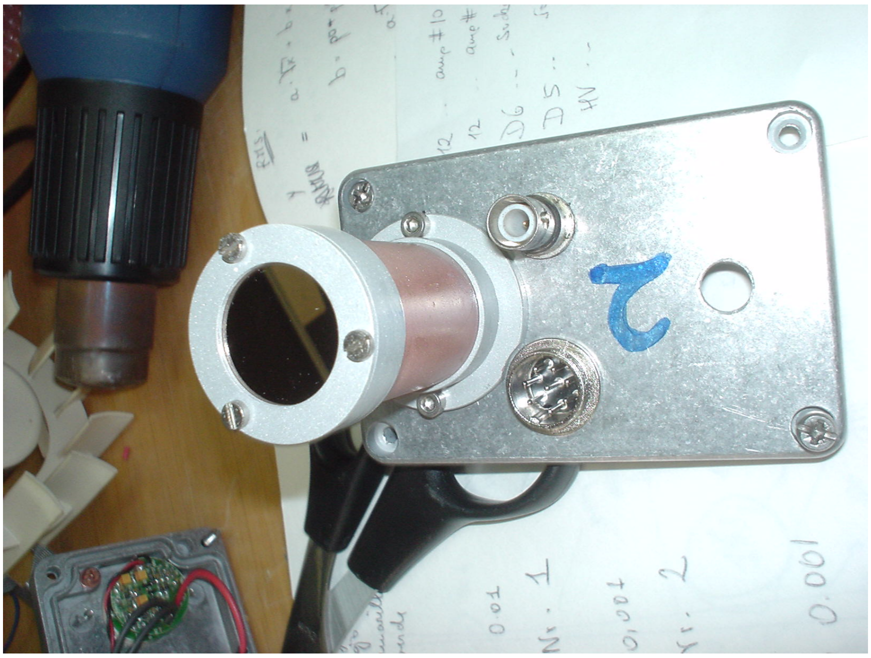


Figure 51: The light filter Oriel Instruments 50550 in the ***Blind Pixel*** (closed)

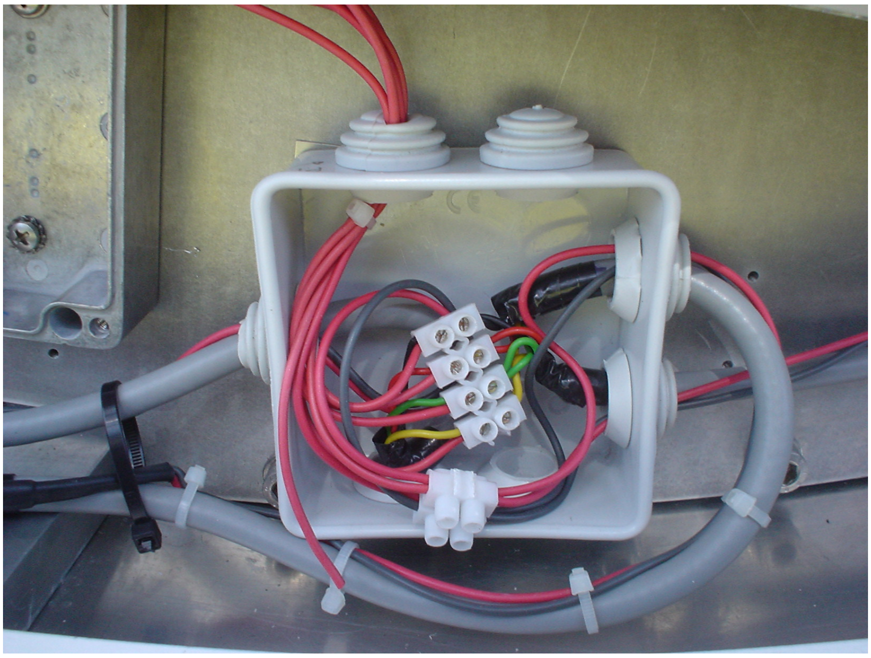


Figure 52: The distributor box for the voltages alimenting the ***Blind Pixel***s

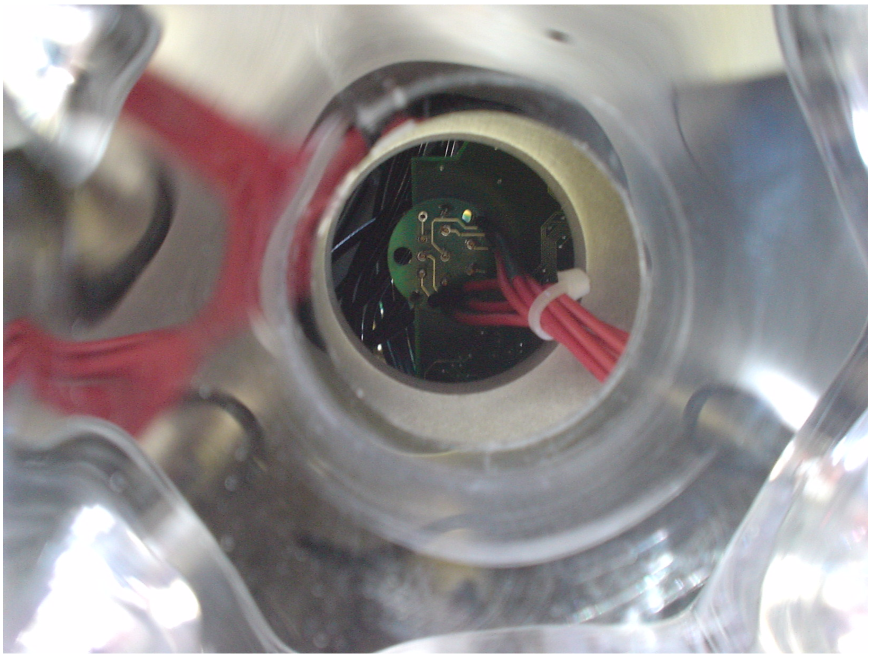


Figure 53: The PMT base at the place of pixel 560 alimenting the ***Blind Pixel***s

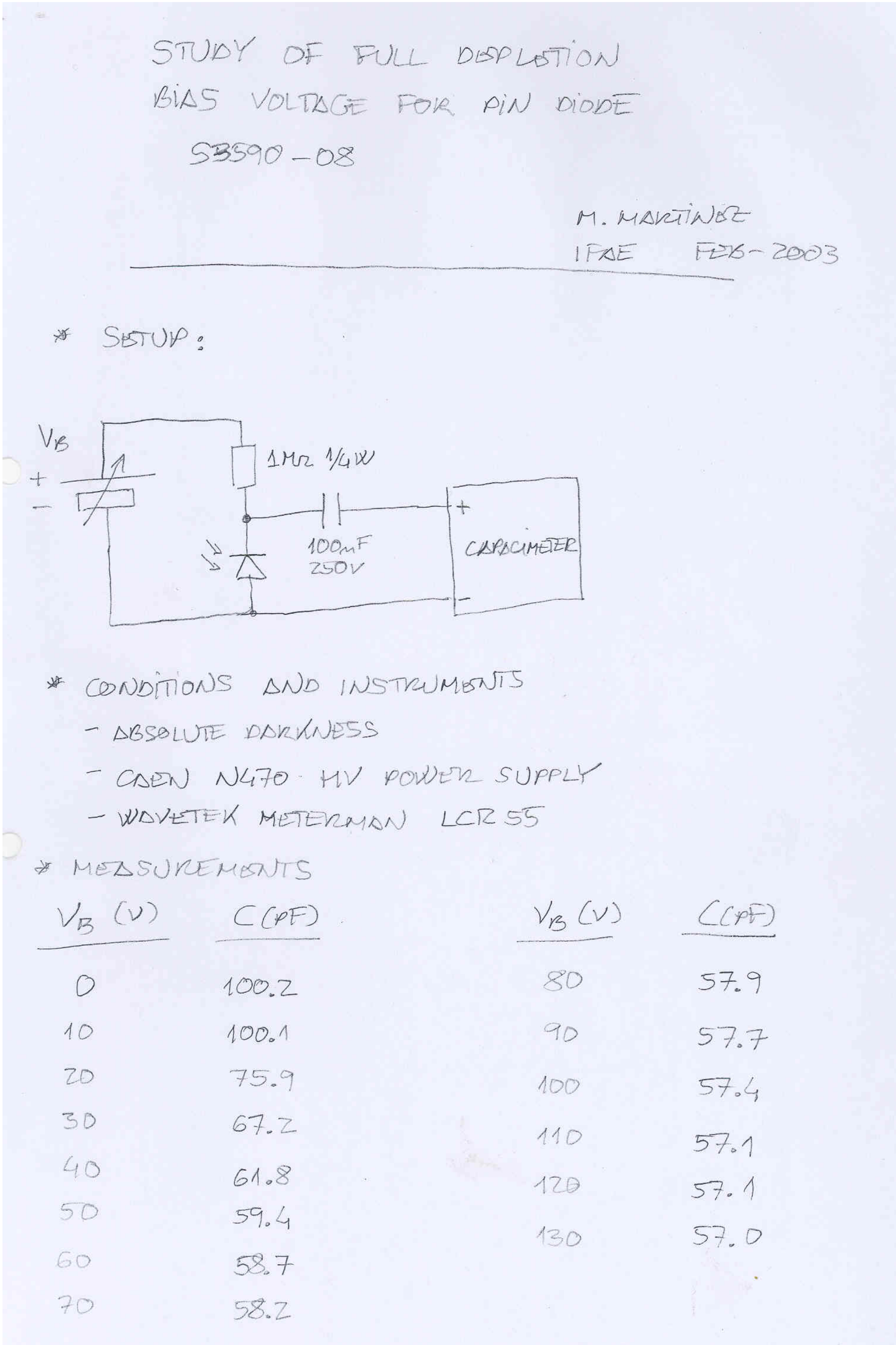
6.4 The ***PIN-Diode***

As a second measurement for the absolute light flux, a Silicium ***PIN-Diode***, type S3590-08 from HAMAMATSU is used in reverse mode. It has a nominal reverse voltage of 70 V and an exact area of 1 cm^2, diminished by a diaphragm to 63.517 mm^2 effective area. In our case, we apply 90 V counter voltage in order to broaden the depletion region as much as possible. Behind the ***PIN-Diode***, a radioactive ^{133}Ba of about 10 μC activity is placed emitting X-rays of exactly 81.0 keV (see the ^{133}Ba spectrum at figure 59). The whole setup is housed in two additional aluminium boxes in order to reduce pick-up noise (see figure 58). The system is housed in a watertight aluminium box situated at the top of the tower, at 1.083 m from the ***Pulser Box*** (see fig. 56). The distance of the ***PIN-Diode*** to the light diffuser in the ***Pulser Box*** is 1.102$\pm$0.004 m.

The ***PIN-Diode*** signal after the ***Nano-Second Amplifier*** is converted into an analogue optical signal by an ***Optical Transmitter Board*** (see schematic figure 137). The optical signal itself travels to the ***Control House*** in an optical fiber and is converted back to an analogue electrical signal via a fast PIN Diode of type HFBR-2406 in a modified ***Optical Receiver Board*** (see schematic figure 141 and picture figure 60). The ***PIN-Diode*** signal gets further delayed by about 60 ns in order to match the arrival times of the ***Camera*** signals to the same ***Pulsed LED***s light pulses.

The ***PIN-Diode*** is able to trigger itself using the (modified) digital part of the ***Optical Receiver Board*** (see figure 61). The resulting (delayed) trigger line is led to the ***Trigger Board*** in the ***Trigger Box*** where the ***MAX7000S*** forms a dedicated trigger signal if the bit PIN is set by software from the ***Camera Control***. It will then send a trigger signal to the ***L2*** which reads out the whole camera including the ***PIN-Diode*** (if the corresponding trigger table is loaded).

Table 22 in page 91 shows the connectors used in the ***PIN-Diode*** box.



STUDY OF FULL DEPLETION
BIAS VOLTAGE FOR PIN DIODE
S3590-08

M. MARTINEZ
IFAE FEB-2003

* SETUP:

* CONDITIONS AND INSTRUMENTS
- ABSOLUTE DARKNESS
- CAEN N470 HV POWER SUPPLY
- WAVETEK METERMAN LCR 55

* MEASUREMENTS

V_B (V)	C (pF)	V_B (V)	C (pF)
0	100.2	80	57.9
10	100.1	90	57.7
20	75.9	100	57.4
30	67.2	110	57.1
40	61.8	120	57.1
50	59.4	130	57.0
60	58.7		
70	58.2		

Figure 54: Study of the Depletion of the ***PIN-Diode***

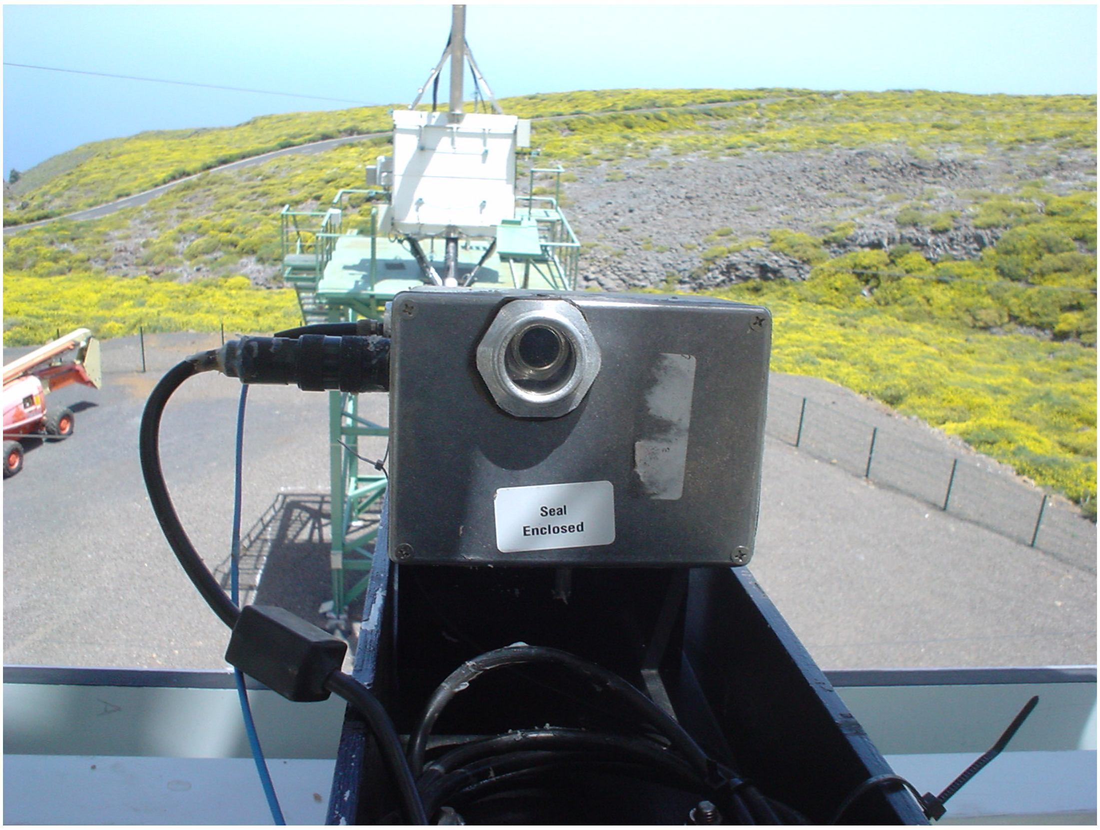


Figure 55: The ***PIN-Diode Box*** on the telescope.

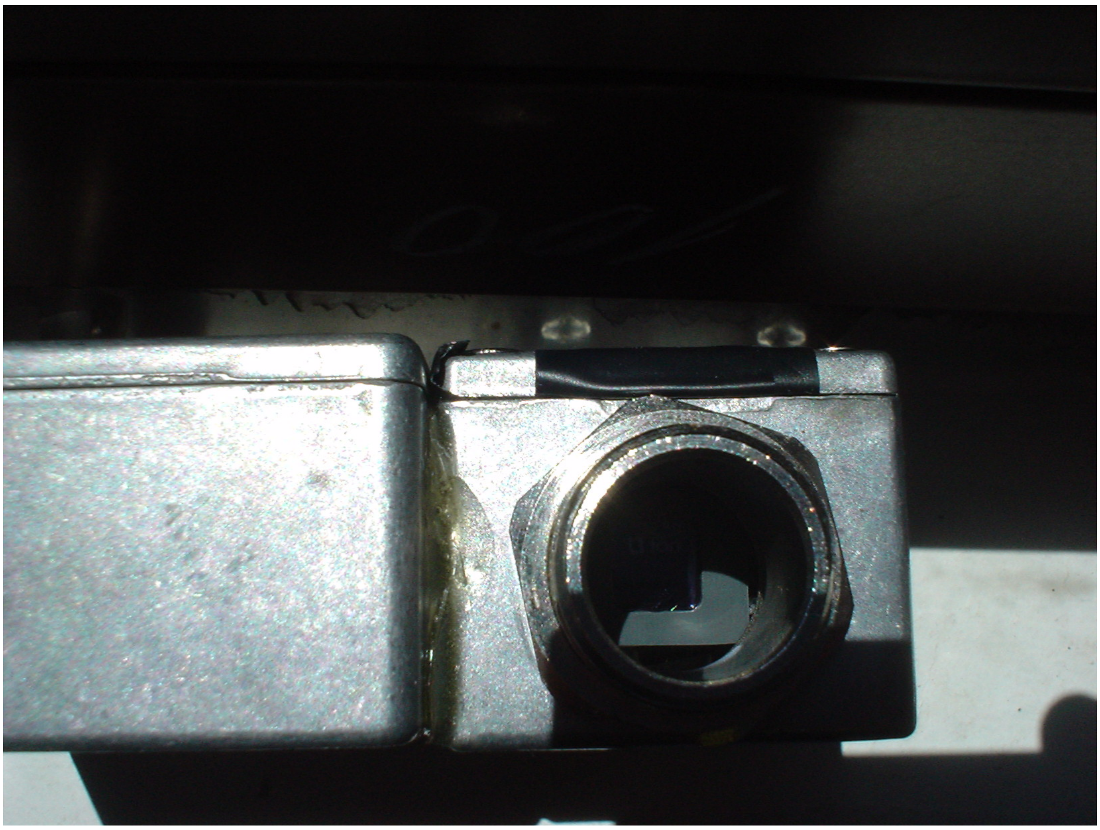


Figure 56: The ***PIN-Diode*** in the lower right hole of the Al-boxes.

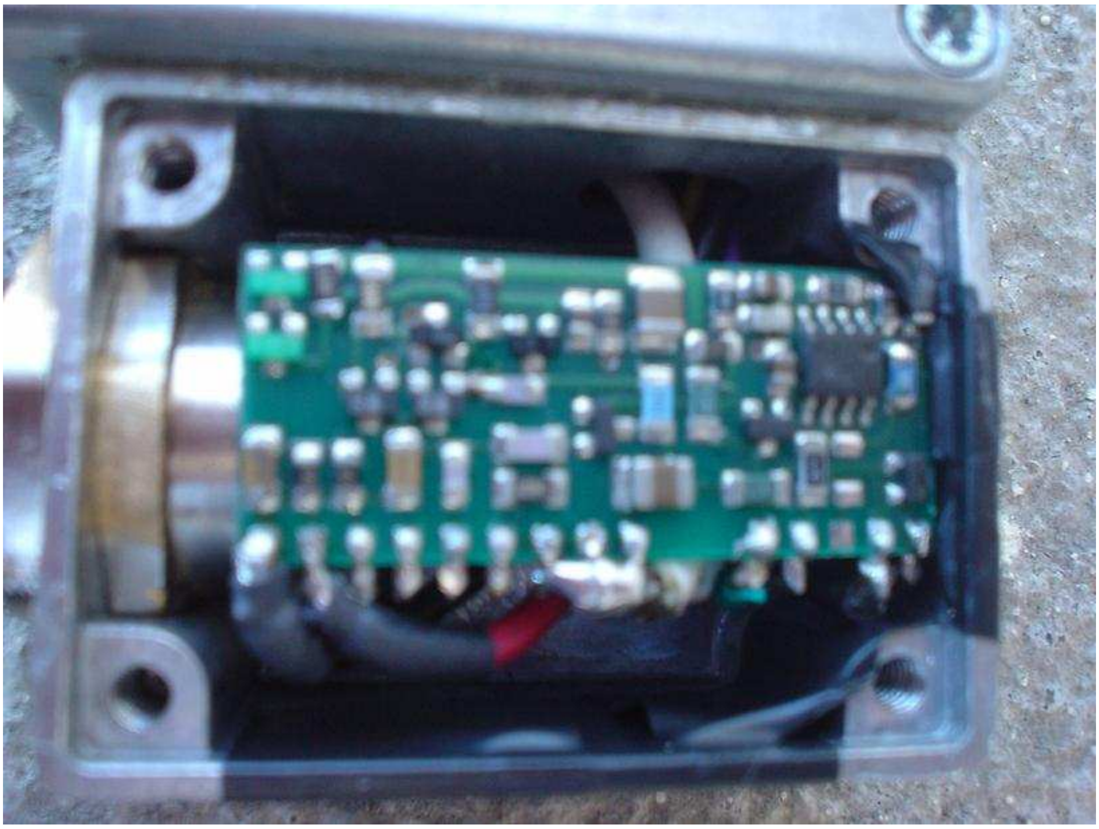


Figure 57: ***Nano-Second Amplifier*** inside the ***PIN-Diode Box***

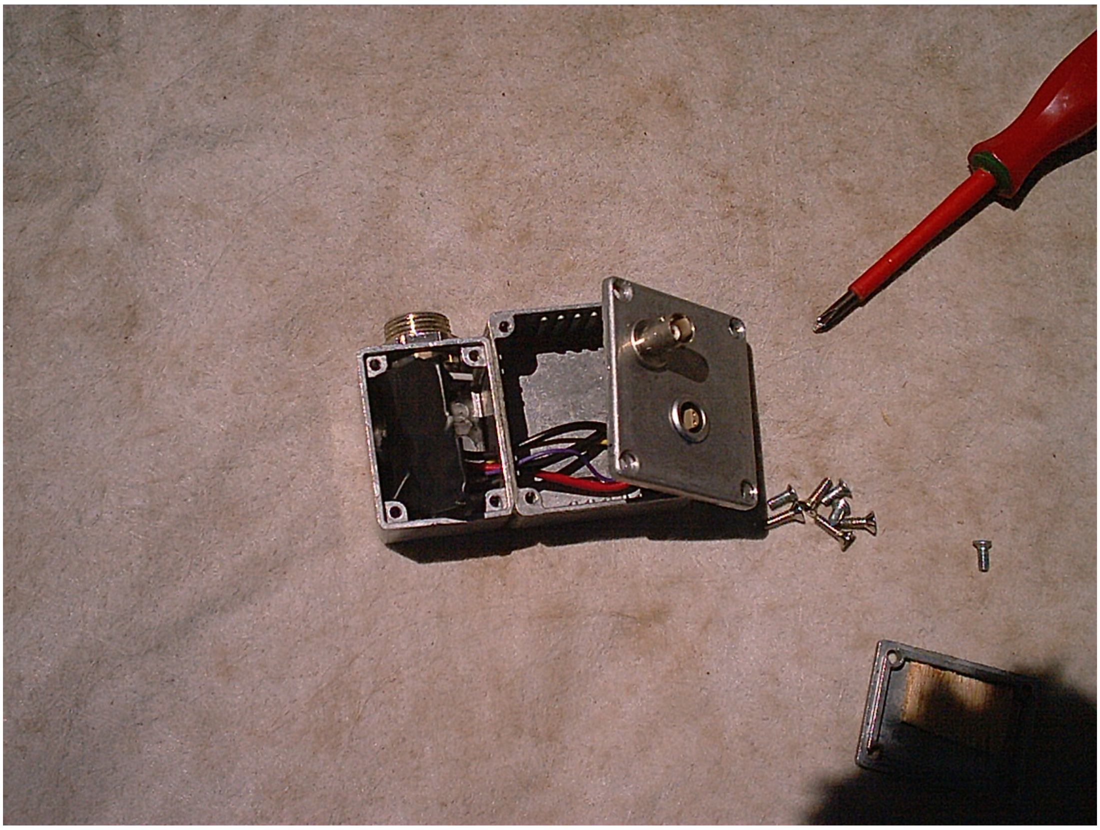


Figure 58: The two aluminium boxes protecting the ***PIN-Diode*** electronics.

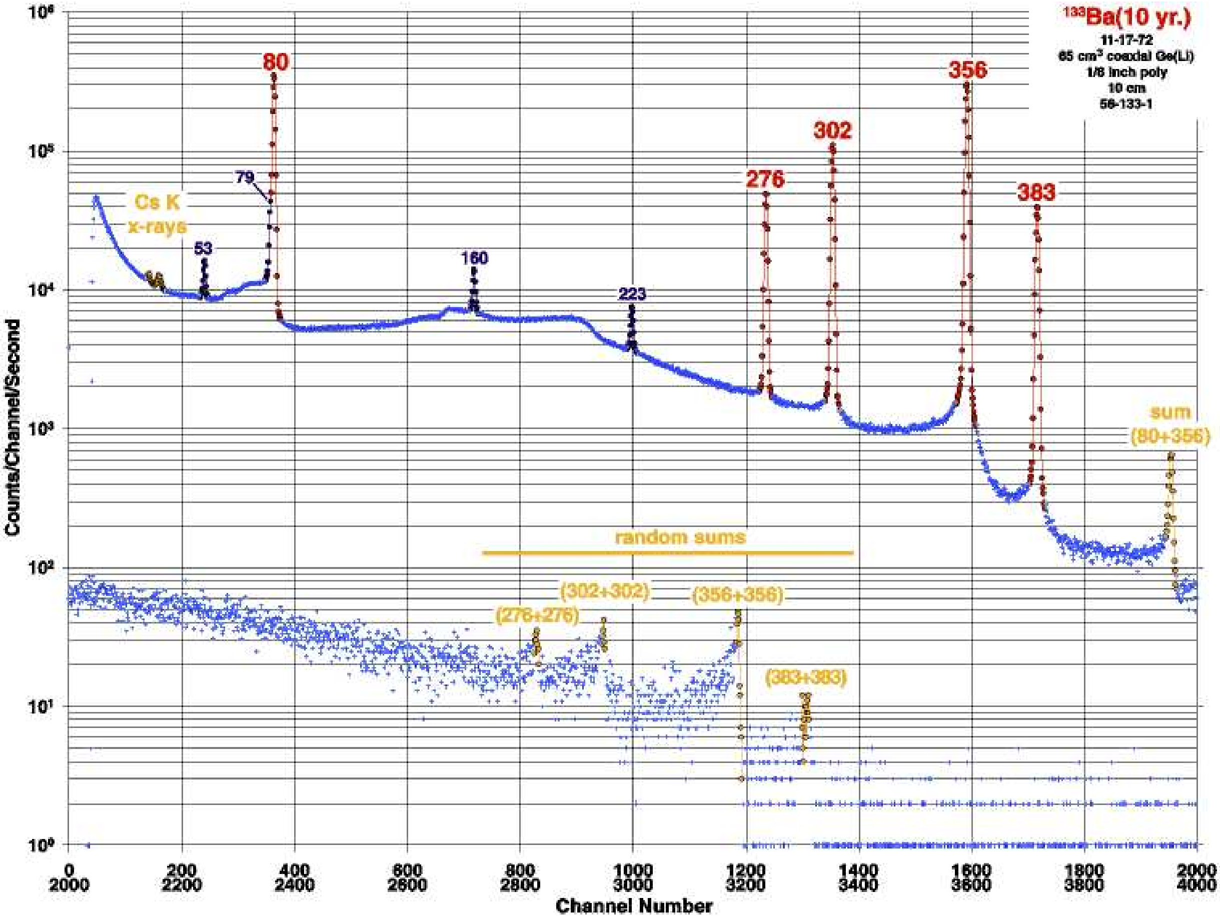


Figure 59: Spectrum of the ^{133}Ba behind the ***PIN-Diode***

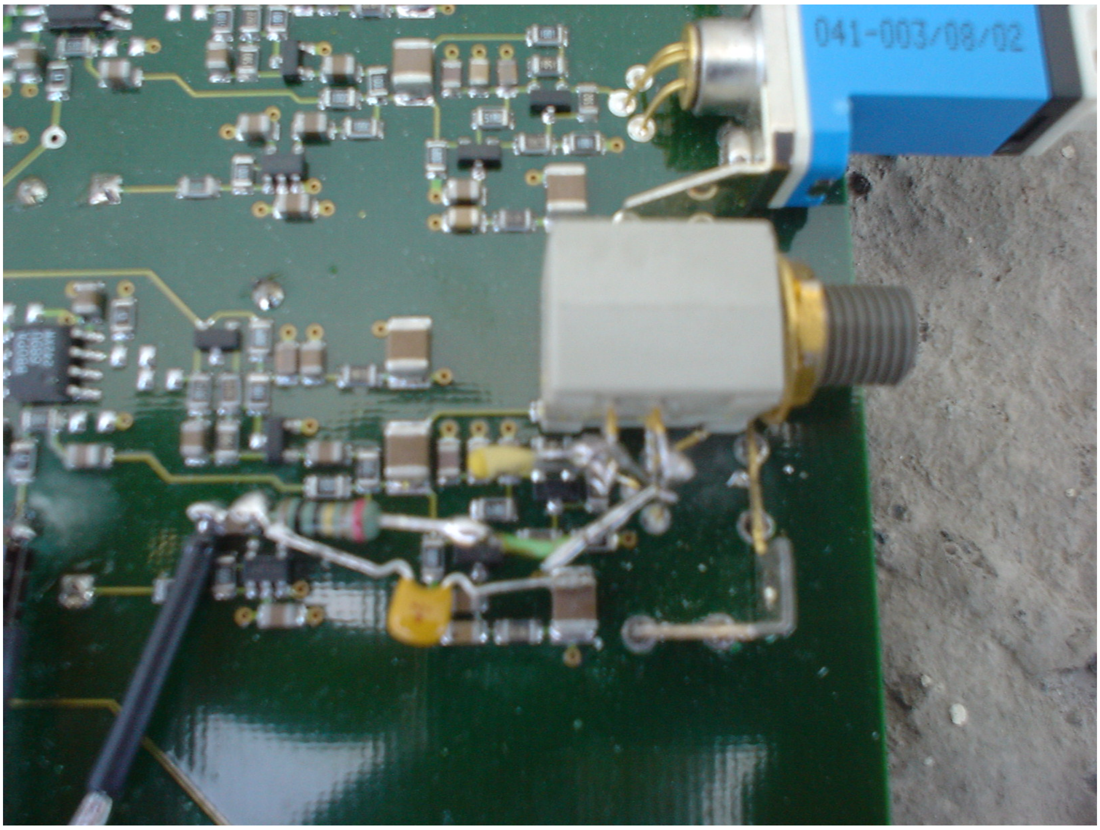


Figure 60: Optical receiver Diode HFBR-2406 in the modified ***Optical Receiver Board***

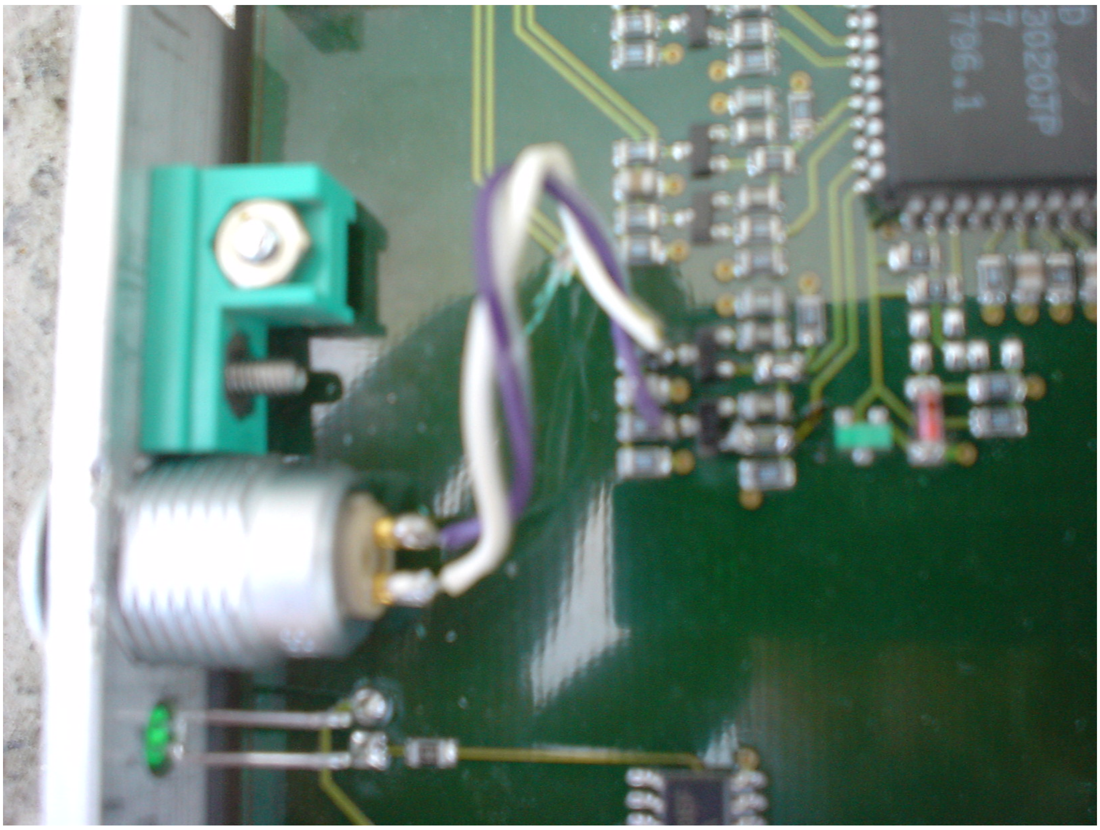


Figure 61: The ***PIN-Diode*** trigger taken out of the ***Optical Receiver Board***.

6.5 The *Trigger* System

To avoid cosmics triggers in a calibration run, the L1 majority trigger is disabled during a normal calibration procedure. Instead, the ***Calibration System*** has a dedicated external trigger which tells the ***L2*** trigger to read out the events exactly when the pulses from the ***Camera*** arrive.

An I/O PCI-board with six individual 10MHz timers inside pc6 creates a series of software-adjustable pulses which travel to the calibration trigger system in the electronics room. There, an ALTERA chip ***MAX7000S*** builds four different pulses from the incoming signals, namely:

- A pulse sent to the calibration box in the telescope triggering the ***Pulsed LED***s to fire.
- Three optional pulses sent to the general MAGIC ***L2*** hardware trigger. These are:
  - One pulse used to trigger calibration events.
  - One pulse used to trigger pedestal events.
  - One pulse used to trigger ***PIN-Diode*** calibration events.

These four triggers are formed in an I/O–card of type Meilhouse Electronics ***ME1400***, situated in ***pc6*** (see fig 95 in page 118) together with a small ***Trigger Board*** performing the necessary logics in an ALTERA chip ***MAX7000S*** (EPM7032SLC44-6) (see fig. 62 in page 76, 96 in page 119 and 133 in page 183).

The ***Trigger*** signal to the ***Pulser Box*** gets then translated into optical in a small ***Optical Transmitter Board*** (see fig. 98 in page 120 and 137 in page 187) and travels to the ***Pulser Box*** in an optical fiber (marked with "TRIGGER"). In the ***Pulser Box***, they are converted back in a small ***Optical Receiver Board*** (see fig. 139).

The three optional triggers get delayed and converted to the LVDS standard and are further sent to the general MAGIC ***L2*** trigger.

The whole system starting from the ***MAX7000S*** is disconnected from the PC by a set of optocouplers.

The ***ME1400***–I/O card has been programmed by:

```
Javier Lopez
IFAE
Tel.: 0034-93-5812834
email: jlopez@ifae.es
```

A listing of the drivers is given in section D.2.

The ***ME1400*** contains six individual 10MHz timers with each two entries ($Clk, Gate$) and one output line (Out). Counting and delays are done via software, connections between the different timers are soldered at the backside of the connector (see fig. 82 in page 106 and 62).

The output lines of the four timers ($Out0, Out2, Out4, Out5$) are sent to the calibration ***Trigger Box*** via Twisted Pair lines (see fig. 96). Out of these four lines, the ALTERA chip produces one $TRIGGER$ signal (converted into optical and sent to the calibration box) and two identical, but delayed lines $CALOUT$ and $PEDOUT$ (converted into LVDS levels and sent to the ***L2***) depending on the state of the two bits CAL and PED. A third trigger line $PINOUT$ is formed from a ***PIN-Diode*** signal (most probably from the ^{133}Ba source) coming from the digital part of the ***PIN-Diode Optical Receiver Board*** line (in ECL mode). Its two voltages are compared to each other in a

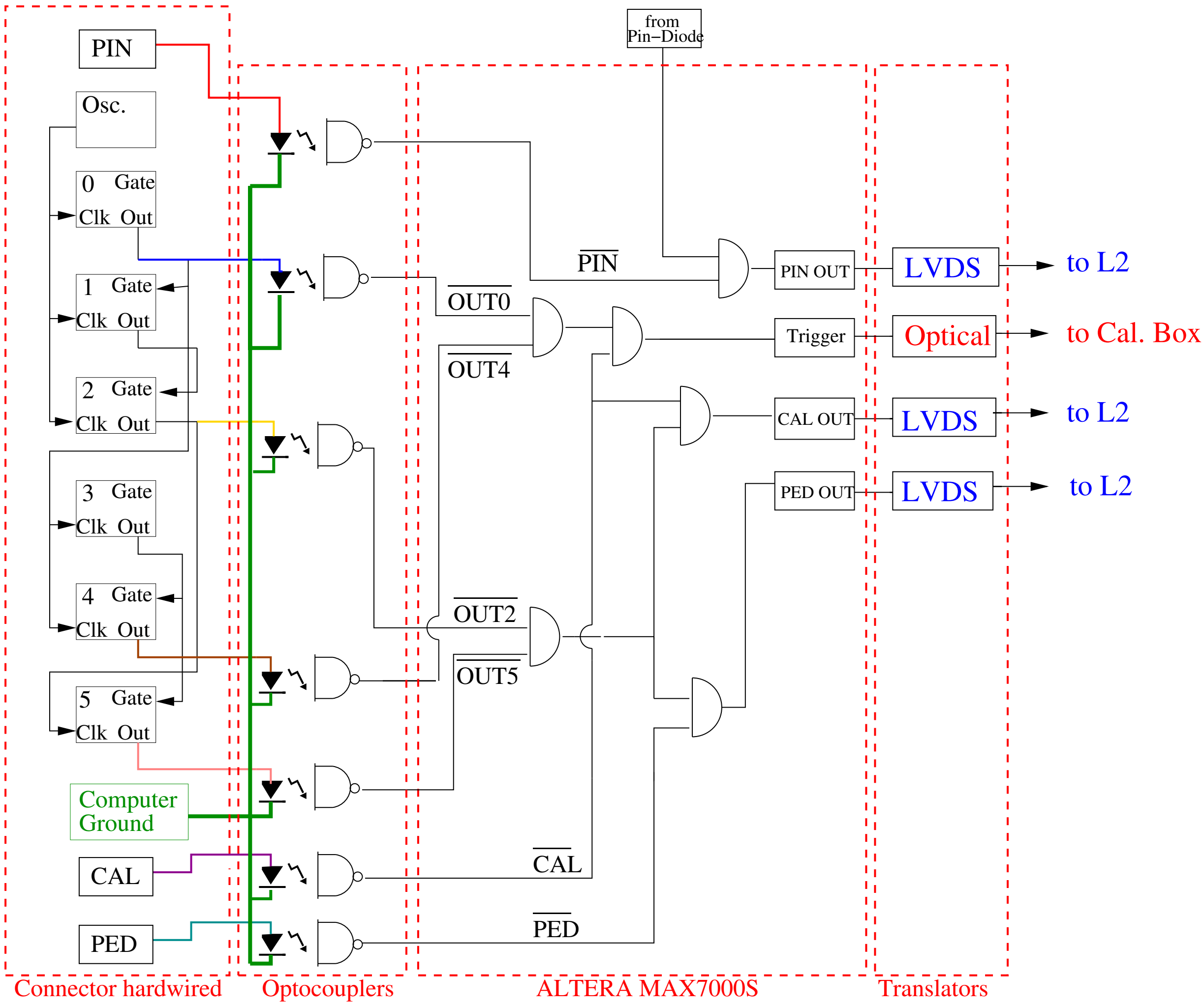


Figure 62: Applied logics after the ***ME1400***

Figure 63: The front panel of the ***Trigger Board*** with the test lines and the ***Indicator LEDs***s.

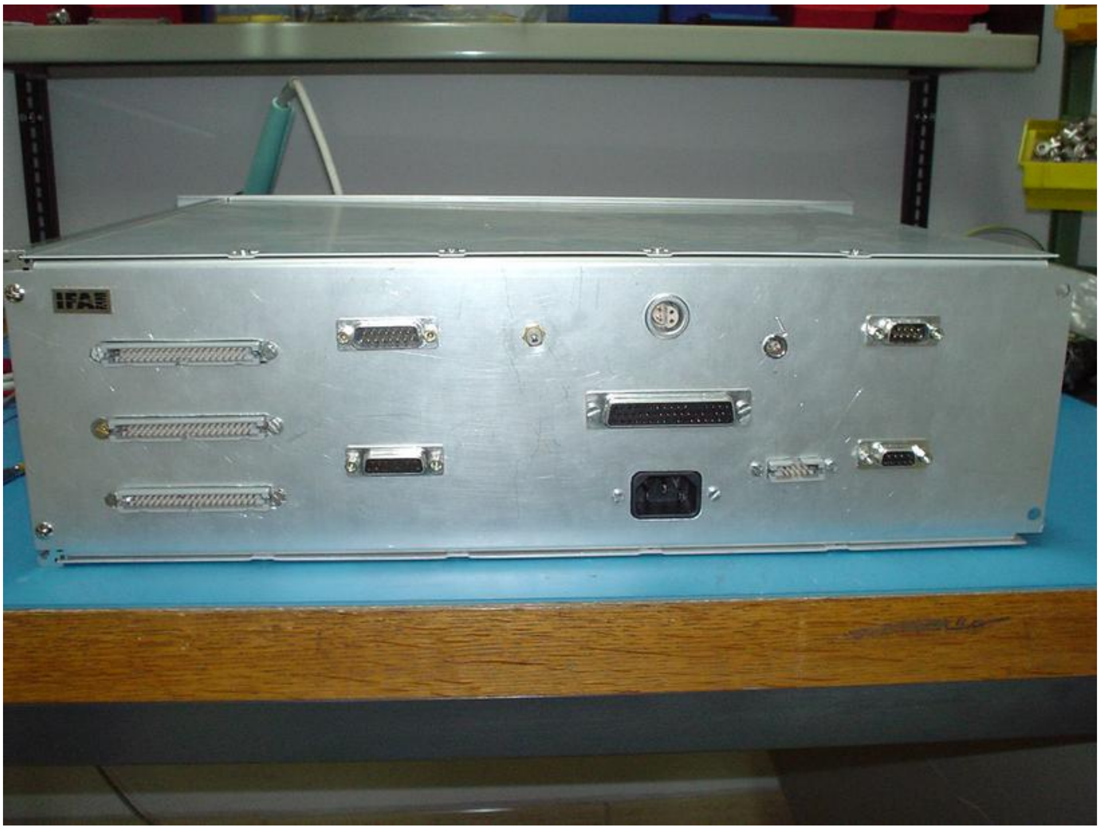


Figure 64: The back panel of the ***Trigger Board*** with the input connectors lines

comparator (AD8561) and further led into the ***MAX7000S*** (line ”from Pin-Diode”). Depending on the state of the bit PIN, an LVDS-converted trigger is sent to the ***L2***, time synchronized such that the ***PIN-Diode*** signal is readout by the DAQ at the correct time.

In appendix D, the used AHDL code can be found. Table 7 in page 97 shows the designation of ***ME1400*** output pins to the entries of the ALTERA chip or the DM lines, correspondingly. Table 24 in page 95 gives the connectors and pin-assignments of the ***Trigger Box***.

```
Device: EPM7032SLC44-6

Device Options:
    Turbo Bit                                   = ON
    Security Bit                                = OFF
    Enable JTAG Support                         = ON
    User Code                                   = ffff

              P  R  R                    P  R
              C  E  E                    C  E
              I  S  S                    I  S
              _  E  E                    _  E
              O  R  R                    O  R
              U  V  V  V  G  G  G  G  G  U  V
              T  E  E  C  N  N  N  N  N  T  E
              O  D  D  C  D  D  D  D  D  1  D
            -----------------------------------_
          /   6  5  4  3  2  1 44 43 42 41 40   |
    #TDI |  7                                39 | RESERVED
RESERVED |  8                                38 | #TDO
RESERVED |  9                                37 | PCI_OUT2
     GND | 10                                36 | RESERVED
     CAL | 11                                35 | VCC
     PED | 12          EPM7032SLC44-6        34 | PCI_OUT5
    #TMS | 13                                33 | RESERVED
 TRIGGER | 14                                32 | #TCK
     VCC | 15                                31 | RESERVED
 CAL_OUT | 16                                30 | GND
 PED_OUT | 17                                29 | PCI_OUT4
         |_  18 19 20 21 22 23 24 25 26 27 28  _|
           ------------------------------------
              P  P  R  P  G  V  R  R  P  R  R
              I  I  E  I  N  C  E  E  C  E  E
              N  N  S  N  D  C  S  S  I  S  S
              _  _  E           E  E  _  E  E
              O  S  R           R  R  O  R  R
              U  I  V           V  V  U  V  V
              T  G  E           E  E  T  E  E
                    D           D  D  3  D  D


N.C. = No Connect. This pin has no internal connection to the device.
VCC = Dedicated power pin, which MUST be connected to VCC.
GND = Dedicated ground pin or unused dedicated input,
      which MUST be connected to GND.
RESERVED = Unused I/O pin, which MUST be left unconnected.
```

6.5.1 The optical ***Trigger*** to the calibration box

Because the MAGIC motor drive lines can induce up to 100 V pickup in any eletrical cable running parallel to it, we chose to transmit the ***Trigger*** pulses optically. The ALTERA chip provides (negative) TTL pulses with a fall time of about 6 ns. These pulses are then translated into optical ones in the ***Optical Transmitter Board***. After 155 m of (blue) optical fiber, an ***Optical Receiver Board*** translates the signal back to an inverted TTL-pulse which is then compared to a reference voltage of about –1 V by a comparator AD8561. The output of this comparator drives the FMMT415 which produces the HV-trigger. This setup was tested to be reasonably stable.

There is a test output for the TTL line of the ***Trigger*** signal before it goes into the ***Optical Transmitter Board*** (marked with TTL, see fig 63). Note that the outlets: ECL and GND are outdated and not used any more.

6.5.2 The LVDS trigger to the ***L2***

The Level-2 trigger (***L2***) requires $LVDS$ pulses of about 50 ns length which are provided by the $CALOUT$, $PEDOUT$ and $PINOUT$ lines translated into $LVDS$ with a DS90LVDS47ATM. The output $LVDS$ levels are then transmitted directly to the ***L2***.

There are test outputs for the TTL line of the ***L2*** signals before they go into the $LVDS$-converter (marked with CAL, PED and PIN, see fig 63). Additionally, a mono-flop converts the short signals into pulses of about 10 s and drives them through the ***Indicator LEDs*** (see figure 100). The colour code of the ***Indicator LEDs*** are given in table 14.

Indicator LEDs			
Nr.	Colour	Trigger	remarks
1	red	CAL	Calibration events
2	green	PED	Pedestal events
3	yellow	PIN	PIN-Diode calibration events

Table 14: Significance of the ***Indicator LEDs*** in the ***Trigger Box***

6.5.3 Adjusting the timing of the ***L2*** triggers

An important feature is the correct time adjustment between the arrival of these trigger signals and the arrival of the corresponding signals from the ***Optical Receiver Board***s. A delay in steps of 100 ns can be chosen by software directly from the ***ME1400*** timers. The rest had to be adjusted via cable lengths and delays introduced in the ALTERA chip.

The whole way of sending trigger pulses to the calibration LEDs, emitted light pulses travelling towards the camera, light pulse detection and signals travelling through the optical fibers back to the control house takes about 2 microseconds. This time needs to be introduced as a dedicated delay in the pulse used to trigger the calibration events at the general MAGIC L2 hardware trigger.

As the calibration events should peak in the same FADC time slice as the cosmics events, the precision of this adjustment should be about the width of one time slice which is 3.3 ns. The pulse sent to the calibration box in the telescope jitters with less than 1 ns, the one sent to the L2 trigger with even less, so a general limit to the precision of the adjustment of about 1-1.5 ns has to be considered.

The delay of the ***L2*** triggers can be adjusted in three steps:

Figure 65: The ***ByteBlaster*** in connected to ***pc39***

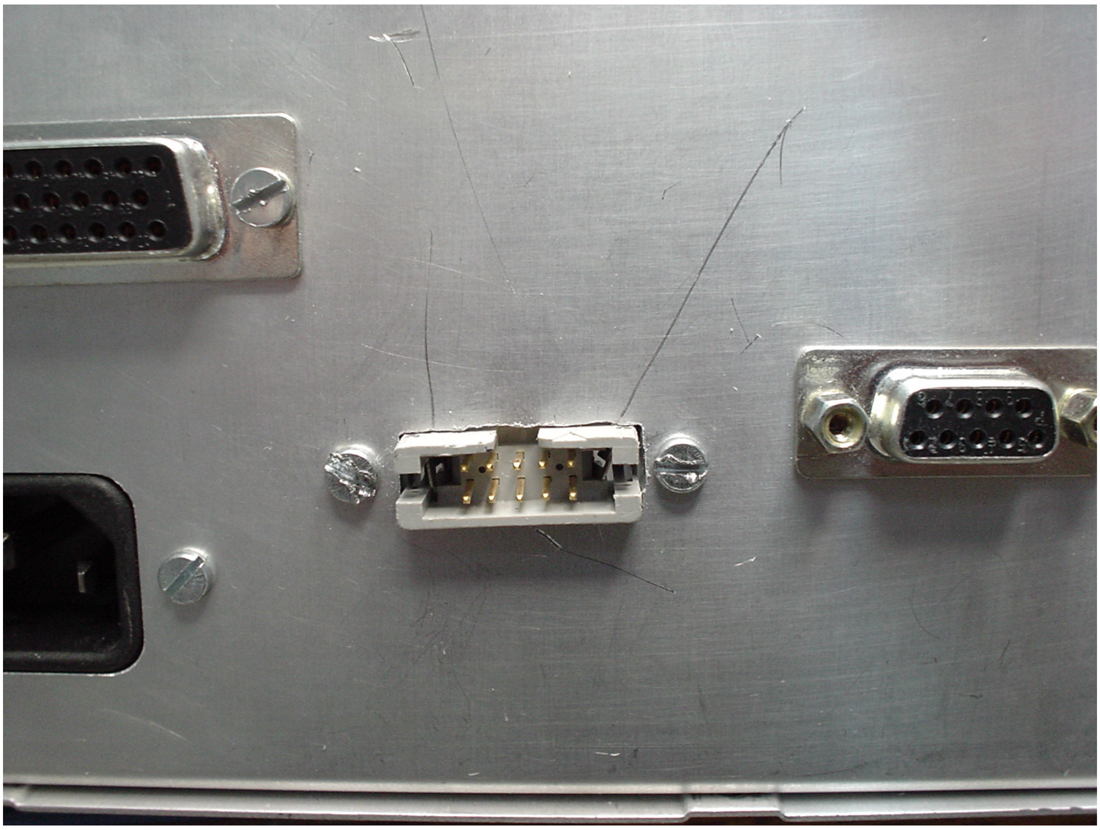


Figure 66: The ***ByteBlaster*** connection in the ***Trigger Board***

1. A rough adjustment in steps of 100 ns can be done directly in the configuration of La Guagua:
    - Log into pc6 as user *control*
    - cd /home/control/CaCo/config/
    - open the file *CaCo.conf* and go to [*Calibration*]
    - edit the line: $delay(ns) =$
    - note that only multiples of 100 ns are allowed (because of the 10MHz clock of the I/O card)
2. A more precise adjustment in steps of about 4 ns can be done inside the ALTERA chip:
    - Go to the calibration and IFAE cupboard in the electronics room
    - Find a small box labelled *ByteBlaster* and take out the whole cable with connector
    - Take the loose part of the cable and connect it at the rear of the Calibration Trigger Box. Make sure that the red line (pin 1) is connected to at the right side of the connector.
    - Do not yet connect the ByteBlaster connector!
    - Switch on the Calibration Trigger Box (red lamp in front).
    - Take a voltage tester and check that the red banana plug has 5V with respect to the black banana plug.
    - You are not allowed to proceed further if this voltage is not correct or inverted!
    - Go to the Windows pc in the control room
    - Connect the ByteBlaster connector to the serial port of the windows pc (pc39)
    - Click on *Start* -> *Programme* -> $MAX + plusII$ 10.2 $BASELINE$ -> $MAX + plusII$ 10.2 $BASELINE$
    - The MAX+plus II program should launch now
    - Click *File* -> *Project* -> *Name*
    - A menu should appear with three possible choices all starting with *magic_optp*
    - Click on *magic_optp.gdf* and then *OK*
    - Click $Ctrl - O$
    - A menu should appear with many possible choise all starting with *magic_optp*
    - Click on *magic_optp.gdf* and then *OK*
    - Now the graphic editor should appear. Here, you have to make your changes
    - Now, it depends whether you want to shift the FADC signal to higher or to lower FADC slices:
        - Shift the signal to lower FADC slices (delay the pulse to the general MAGIC L2 trigger):
            * Go to CAL_OUT in the lower right part of the scheme and try to move the line connecting CAL_OUT with the $AND2$ symbol (leaving a space between both parts)

    * Go to one of the $LCELL$ symbols in the scheme, push on the right mouse button and click on *copy*. This symbol stands for a delay of about 4 ns.
    * Go to the space between the $AND2$ symbol and the connecting line, click on the right mouse button and click on *paste*.
    * Try to connect the lines again.
  - Shift the signal to higher FADC slices (delay the pulse to the calibration box):
    * Go to $TRIGGER$ in the lower right part of the scheme and try to move the line connecting $TRIGGER$ with the NOT symbol (leaving a space between both parts)
    * Go to one of the $LCELL$ symbols in the scheme, push on the right mouse button and click on *copy*. This symbol stands for a delay of about 4 ns.
    * Go to the space between the NOT symbol and the connecting line, click on the right mouse button and click on *paste*.
    * Try to connect the lines again.
- Click $Ctrl - s$ in order to save the changes
- Click on $MAX + plusII$ -> $Compiler$
- The compiler window should appear
- Click on $Start$
- Three WARNINGS should appear which you ignore
- Click on OK
- Click on $MAX + plusII$ -> $Programmer$
- The programmer window should appear
- Now, you should make sure that the calibration trigger box in the electronics room is switched on. (push the red button until it shines in red)
- Click on $Program$
- A new window should appear saying $Programming\ complete$
- If it says: $No\ device\ found$, try to push a bit on the ByteBlaster connector. There might be a bad contact.
- Click on OK
- You are done now.

3. An even more precise adjustment has to be done with cables:

   - You can only delay the signal going to the general MAGIC ***L2*** trigger (moving signals to lower FADC slice numbers).
   - Go behind the calibration trigger box in the electronics room
   - Find a piece of cable between two yellow shrink tubes
   - Cut betwee the two shrink tubes and solder additional pieces of twisted pair cables.
   - You are done now.

4. Take a calibration run and test the modifications!

Figure 67: The twisted pair cable to the ***L2*** trigger

6.5.4 The digital input of the DAQ (DM-boards)

48 digital lines can be programmed in the ***ME1400*** PCI. 44 of these lines enter an electronic card transforming them into LVDS levels (the remaining four are used for the trigger bits CAL, PED and PIN and one bit, $D0$, is connected with the camera crate in order to switch ON and OFF remotely the CANBUS). See a picture of ***ME1400*** card, fig. 99 in page 121, and the connector, fig. 87 in page 111.

At the moment, only 31 out of the 48 lines are used further to enter the DAQ via the two ***Digital Module***s (DM) and to code the pulsed light calibration pattern (DM #1), the continuous light strength (DM #2, bits 1–8) and the continuous light colour (DM #2, bits 9–12). Further, the trigger bits CAL, PED and PIN are stored in DM #2, bits 13–15.

The DAQ reads these numbers and stores them in the variable CalPattern in the event header.

DM 1:		
line Nr.	***ME1400*** pin	significance
1	A4	***Pulsed LED***s Slot 1
2	A5	***Pulsed LED***s Slot 2
3	A0	***Pulsed LED***s Slot 3
4	A1	***Pulsed LED***s Slot 4
5	A2	***Pulsed LED***s Slot 5
6	A3	***Pulsed LED***s Slot 6
7	A6	***Pulsed LED***s Slot 7
8	A7	***Pulsed LED***s Slot 8
9	B0	***Pulsed LED***s Slot 9
10	B1	***Pulsed LED***s Slot 10
11	B2	***Pulsed LED***s Slot 11
12	B3	***Pulsed LED***s Slot 12
13	B5	***Pulsed LED***s Slot 13
14	B4	***Pulsed LED***s Slot 14
15	B7	***Pulsed LED***s Slot 15
16	B6	***Pulsed LED***s Slot 16

Table 15: The type of calibration coded in DM1

DM 2:		
line Nr.	***ME1400*** pin	significance
1	E7	***Continuous Light LED*** strength bit 1
2	E6	***Continuous Light LED*** strength bit 2
3	E5	***Continuous Light LED*** strength bit 3
4	E4	***Continuous Light LED*** strength bit 4
5	E3	***Continuous Light LED*** strength bit 5
6	E2	***Continuous Light LED*** strength bit 6
7	E1	***Continuous Light LED*** strength bit 7
8	E0	***Continuous Light LED*** strength bit 8
9	D7	***Continuous Light LED*** colour bit 1
10	D6	***Continuous Light LED*** colour bit 2
11	D5	***Continuous Light LED*** colour bit 3
12	D4	***Continuous Light LED*** colour bit 4
13	D3	Trigger bit CAL
14	D2	Trigger bit PED
15	D1	Trigger bit PIN
16	unconn.	

Table 16: The calibration pattern coded in DM2

7 Listing of Connectors

Connectors from the ***Pulser Box*** outside					
Nr	type	lines	pin usage		description
1	50011LNF (presser/ stopper)	8	whole cable 10 mm		***CAN-BUS*** IN Connection to ***Control House*** IP68
			orange:	CANL	
			orange/white:	CANH	
			blue/white:	+12 V	
			blue:	GND	
2	50011LNF (presser/ stopper)	8	whole cable 10 mm		***CAN-BUS*** OUT Connection to ***Camera*** IP68 (see fig. 68)
			orange:	CANL	
			orange/white:	CANH	
			blue/white:	+12 V	
			blue:	GND	
3	Socket: CA6GD Plug: CA6LS	7	whole cable		***Trigger*** IP68 (see fig. 69)
			GND:	GND-shield	
			1: blue:	Q (ECL)	
			2: white:	$\overline{Q}$ (ECL)	
			3: brown:	GND	
4	Binder Socket: Series 423 09-0123-00-06 Plug: Series 723 09-0122-25-06	6	1: black	common GND	connection to ***LV-Box*** IP67 (see fig. 70)
			2: grey/violet	+12 V	
			3: yellow/black	bit 90 V ON/OFF	
			4: blue	+5 V	
			5: white	-5 V	
			6: orange/white	bit 90 V GND	

Table 17: Connectors from the ***Pulser Box*** outside (see also fig. 68 in page 98 through 73 in page 101) All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2 in page 14)

Connectors inside the ***Pulser Box***					
Nr	type	lines	pin usage		description
1	terminal block	4	orange blue orange/white blue/white	CANL GND CANH VCC	Connection to ***CAN-BUS Board*** (see fig. 68)
2	Binder Series 423 09-0473-00-08	8	3: blue 4: grey/red 6: black 7: white	+5 V +12 V common GND –5 V	Connection to • ***Shift Registers*** • ***CAN-BUS Board*** • ***600V Supply*** (see fig. 71)
3	Plug : MC 2223701 MC 221042 Socket: Hirschmann 972356-100	4	red black white blue black	+600 V HV GND –5 V +5 V LV GND	• Connection from ***600V Supply*** to ***Pulser Board*** • Connection from #4 in table 17 (see fig. 72)
4	LEMO	1	***Trigger***		Connection from ***Opt. to TTL Converter*** to ***Pulser Box***
5	Flatband	2 × 16	Pulser Bit Pattern		Connection from ***Shift Registers*** to ***Pulser Board*** (see fig. 73)
6	Single Lines	2	Continuous Light Current red amber green violet white	 (0–2.2) V (0–2.2) V (0–2.2) V (0–2.2) V –5 V	Connection from ***CL*** Board to ***Continuous Light LED***s (see fig. 73 and 34)
7	single lines	2	white: black:	bit 90 V–ON/OFF bit 90 V–GND	Connection from ***Shift Registers*** ***LV-Box*** (see fig. 73)

Table 18: Connectors inside the ***Pulser Box*** (see also fig. 68 in page 98 through 73 in page 101). All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2)

Connectors inside the ***CAN-BUS Board***					
Nr	type	lines	pin usage		description
1	DB9	4	2: 3: 7: 9:	CANL CAN GND CANH CAN VCC	Connection from terminal block outside (table 18 #1 All voltages from ***Control House***
2	Mounting Terminal Block	4	1: blue 2: white 3: black 4: grey	+5 V –5 V common GND +12 V	All voltages from ***LV-Box***
3	Serial (soldered)	4	1 2 3 4	CLK DATA LOAD common GND	Connection to ***Shift Registers***
4	Single	1		***DAC*** voltage out	Connection to ***Shift Register Board***
5	Twisted Pair	2		LV-supply for ***Shift Register Board***	Connection to ***Shift Register Board***

Table 19: Connectors of the ***CAN-BUS Board***. All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2)

Connectors used for the ***LV-Box***					
Nr	type	lines	pin usage		description
1	50011LNF (presser/ stopper)	8	whole cable 10 mm		connection to ***PIN-Diode*** IP68
			grey/violet:	+12 V	
			yellow:	–12 V	
			red:	+90 V	
			brown:	GND (90 V)	
			black:	common GND	
2	50011LNF (presser/ stopper)	8	whole cable 10 mm		connection to ***Pulser Box*** IP68 (see fig. 75)
			grey/violet:	+12 V	
			blue:	+5 V	
			green:	–5 V	
			yellow:	bit 90 V ON/OFF	
			orange:	bit 90 V GND	
			black:	common GND	
3	Socket: CA3GD Plug: CA3LS	4	1: red	230 V	connection to ***Cooling Box*** (at ground) IP67 (see fig. 74)
			2: none	free	
			3: blue	230 V	
			4: black	GND	

Table 20: Connectors in the ***LV-Box*** (see also fig. 74 in page 102 through 80 in page 105)

Connectors in the ***Blind Pixel***s				
Nr	**type**	**lines**	**pin usage**	**description**
1	Pixel Socket	5	SIGNAL: to Amp. HV1: to Base HV HV2: to Base D5 HV3: to Base D6 GND: to Base GND, HV GND to opt. transm. GND	Signal and Dynode Voltages from ***Blind Pixel*** three GNDs connected
2	Pixel Base	8	DC: unconn. -12V: unconn. +12V: to amp. HV GND: to Al-box LV-GND: to amp. HV: to socket HV1 D5: to socket HV2 D6: to socket HV3	Conn. with HV motherboard
3	Connector	8	1 (black): GND 2 (red): +12 V 4 (yellow): D5 (-375 V) 5 (green): D6 (-175 V)	conn. to LV-GND (“AGND”) of base
4	HV-conn.	1	1: HV to PMT Al-Box: HV-GND	
5	LEMO	1	SIGNAL: to opt. transmitter GND: to opt. transm. GND	Al-housing of trans. (“PGND”)

Table 21: Connectors inside the ***Blind Pixel***-boxes.

Connectors in the ***PIN-Diode Box***				
Nr	**type**	**lines**	**pin usage**	**description**
1	Socket: QX2612/10 Plug: QX2611/10	1	LEMO	Signal from ***PIN-Diode***
2	Binder Socket: Series 723 09-0123-00-06 Plug: Series 723 09-0122-25-06	6	1: yellow: -12 V 2: grey/violet: +12 V 3: red: 90 V 4: brown: GND (90 V) 6: black: common GND	connection to ***LV-Box*** IP67

Table 22: Connectors from the ***PIN-Diode Box*** outside. All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2)

Connectors in the ***pc6***					
Nr	type	lines	pin usage		description
1	78-pin	78	see fig. 132		output for
		9 lines	14	PC7	***Trigger Box***
		to #2	33	PC6	and
		27 lines	53	PF7	***DM-Board***
		to ***DM-Board***	16	*Out*0	
			19	*Out*2	
			76	*Out*4	
			58	*Out*5	(see fig. 82)

Table 23: Connectors from ***pc6*** outside. All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2)

Connectors in the ***Trigger Box***					
Nr	type	lines	pin usage		description
1	50-pin	50 47 lines to ***DM-Board***	1	DM1 #5	connection from ***ME1400*** (Table 23) to the opto-couplers of the ***DM-Board*** (see fig. 84)
			2	DM1 #10	
			3	DM1 #4	
			4	DM1 #15	
			5	NC	
			6	DM2 #1	
			7	DM3 #13	
			8	DM2 #4	
			9	DM3 #11	
			10	DM2 #7	
			11	GND	
			12	DM2 #9	
			13	DM3 #2	
			14	DM2 #12	
			15	DM3 #5	
			16	DM2 #15	
			17	NC	
			18	DM1 #9	
			19	DM1 #3	
			20	DM1 #14	
			21	DM1 #2	
			22	NC	
			23	DM3 #1	
			24	DM2 #3	
			25	DM3 #11	
			26	DM2 #6	
			27	DM3 #9	
			28	GND	
			29	DM3 #7	
			30	DM2 #11	
			31	DM3 #6	
			32	DM2 #14	
			33	DM3 #3	
			34	DM1 #12	
			35	DM1 #6	
			36	DM1 #13	
			37	DM1 #1	
			38	DM1 #16	
			39	DM3 #15	

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Connectors in the ***Trigger Box***

Nr	type	lines	pin usage		description
			40	DM2 #2	
			41	DM3 #14	
			42	DM2 #5	
			43	DM3 #10	
			44	DM2 #8	
			45	DM3 #8	
			46	DM2 #10	
			47	DM3 #1	
			48	DM2 #13	
			49	DM3 #4	
			50	DM2 #16	
2	DB9	9	1: green	$Out1$	connec-
			2: yellow	$Out2$	tion from
			3: white	GND	***ME1400***
			4: brown	$Out4$	to opto-
			5: orange	$Out5$	couplers
			6: blue	$Out0$	in the
			7: violet	CAL	trigger
			8: grey	PED	board
			9: red	PIN	(see fig. 83)
3	SMA	1		optical	trigger to ***Pulser Box***
4	LEMO ERA. 1S	2	1: blue	from	***PIN-Diode***
			2: white	***Optical Receiver Board***	trigger
5	DB9 with flatband connection	9	1:	GND	connection to ***L2***
			2:	$CALOUT$ +	
			3:	$CALOUT$ -	
			4:	$PEDOUT$ +	
			5:	$PEDOUT$ -	
			6:	$PINOUT$ +	
			7:	$PINOUT$ -	
			8:	GND	
			9:	GND	(see fig. 85)
6	10-pin	10	1:	TCK	connection from ***ByteBlaster*** to ***Trigger Board*** (see fig. 86)
			2:	GND	
			3:	TDO	
			4:	VCC	
			5:	TMS	
			6:	NC	
			7:	NC	
			8:	NC	

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Connectors in the ***Trigger Box***				
Nr	type	lines	pin usage	description
			9: TDI 10: GND	

Table 24: Connectors from the ***Trigger Box*** outside.

Connectors in the ***DM-Board***				
Nr	type	lines	pin usage	description
1	NFP-80A	80 (54 used)	see tab. 7 (48 digital lines, 6 grounds)	see fig. 132 and 87
2		4	1: red +5 V 2: black GND 3: white +5 V	VCC for optocoupler VCC LVDS drivers (reduced to 3.8 V)
3	40-pin	40	1-4: GND 5-36: 16 LVDS-lines 36-40: GND	3x, connection to DMs

Table 25: Connectors from the ***Digital Module*** outside. All connectors have at least one spare in the Calibration ***Spares Boxes*** (fig. 2)

ME1400 output lines and further connections			
Nr (***ME1400***)	name (***ME1400***)	name (ALTERA)	hardwired connections
1	VCC (+5 V)	–	
2	PA1	DM1 – 4	
3	PA3	DM1 – 6	
4	PA5	DM1 – 2	
5	PA7	DM1 – 8	
6	PB0	DM1 – 9	
7	PB2	DM1 – 11	
8	PB4	DM1 – 14	
9	PB6	DM1 – 16	
10	GND	–	
11	PC1	–	
12	PC3	–	
13	PC5	–	
14	PC7	CAL – Pin 11	
15	Clk 0	–	conn. with 39
16	Out 0	PCI_OUT0 – Pin 6	conn. with 17,54,75
17	Gate 1	–	conn. with 16
18	Clk 2	–	conn. with 39
19	Out 2	PCI_OUT2 – Pin 37	conn. with 57
20	GND	–	
21	PA0	DM1 – 3	
22	PA2	DM1 – 5	
23	PA4	DM1 – 1	
24	PA6	DM1 – 7	
25	GND	–	
26	PB1	DM1 – 10	
27	PB3	DM1 – 12	
28	PB5	DM1 – 13	
29	PB7	DM1 – 15	
30	PC0	–	
31	PC2	–	
32	PC4	–	
33	PC6	PED – Pin 12	
34	GND	–	
35	Gate 0	–	not used
36	Clk 1	–	conn. with 39
37	Out 1	PCI_OUT1 – Pin 41	conn. with 38
38	Gate 2	–	conn. with 37
39	OSC/IR IN	–	conn. with 15,18,36

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ME1400 output lines and further connections			
40	VCC (+5 V)	–	
41	PD1	DM2 – 15	
42	PD3	DM2 – 13	
43	PD5	DM2 – 11	
44	PD7	DM2 – 9	
45	PE0	DM2 – 8	
46	PE2	DM2 – 6	
47	PE4	DM2 – 4	
48	PE6	DM2 – 2	
49	GND	–	
50	PF1	–	
51	PF3	–	
52	PF5	–	
53	PF7	PIN – Pin 21	
54	Clk 3	–	conn. with 16
55	Out 3	–	conn. with 56,77
56	Gate 4	–	conn. with 55
57	Clk 5	–	conn. with 19
58	Out 5	PCI_OUT5 – Pin 34	
59	GND	–	
60	PD0	CANBUS ON/OFF	conn. with CANBUS
61	PD2	DM2 – 14	
62	PD4	DM2 – 12	
63	PD6	DM2 – 10	
64	GND		
65	PE1	DM2 – 7	
66	PE3	DM2 – 5	
67	PE5	DM2 – 3	
68	PE7	DM2 – 1	
69	PF0		
70	PF2		
71	PF4	–	
72	PF6	–	
73	GND	–	
74	Gate 3	–	not used
75	Clk 4	–	conn. with 16
76	Out 4	PCI_OUT4 – Pin 29	
77	Gate 5	–	conn. with 55
78	VCC (+5 V)	–	

Table 26: ***ME1400*** output lines and further pin usages

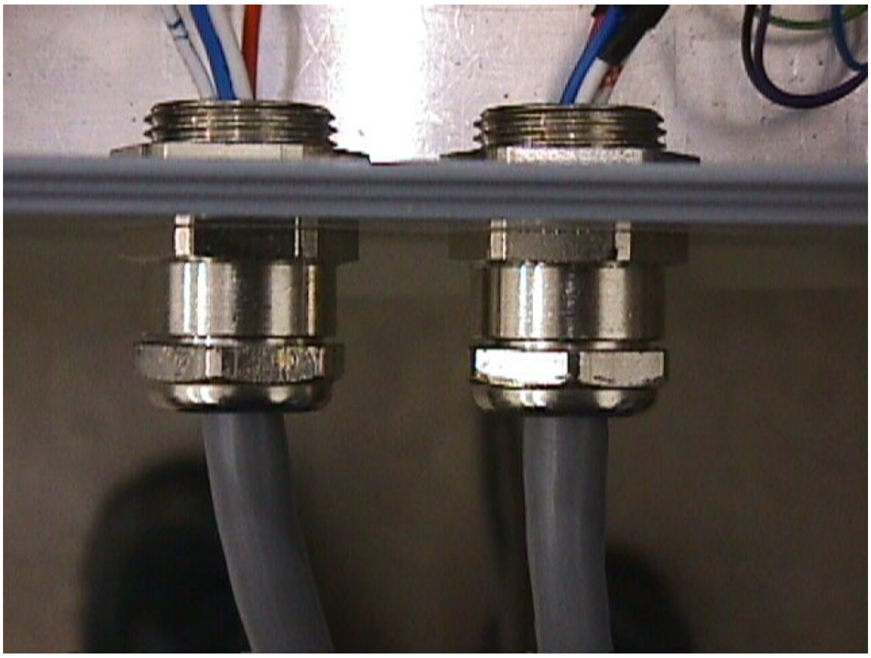

Figure 68: ***CAN-BUS*** connector on the ***Pulser Box***:
CANL, CANH, VCC, GND, SHIELD

Figure 69: Optical fiber connector used for the ***Trigger*** to the ***Pulser Box***

Figure 70: LV connector on the ***Pulser Box***: Binder Series 723
Pin 1: common GND, Pin 2: +12 V, Pin 3: bit 90 V–ON/OFF, Pin 4: +5 V, Pin 5: –5 V,
Pin 6: 90 V–GND

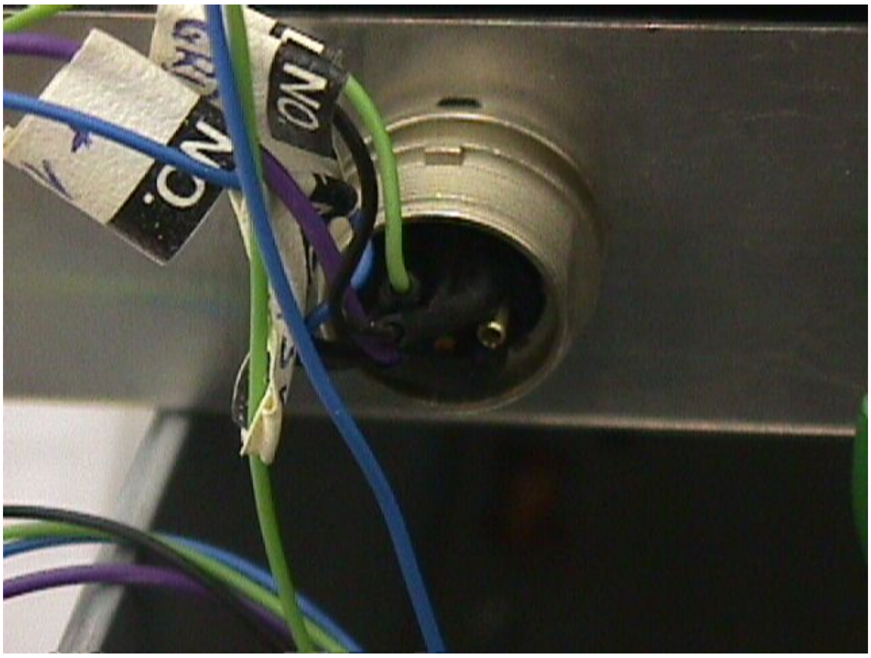

Figure 71: LV connector inside the ***Pulser Box***:
(WARNING: COLOR IN PICTURE HAS CHANGED MEANWHILE! REFER TO TABLE 18)
Pin 3: +5 V, Pin 4: +12 V, Pin 6: common GND, Pin 7: –5 V,

Figure 72: HV connection between ***Lower Box*** and ***Upper Box***:
(WARNING: COLOR IN PICTURE HAS CHANGED MEANWHILE! REFER TO TABLE 18)
red: +1000 V, black: common GND, white (upper left): –5 V, blue (upper right): +5 V, black (not visible on this photo): LV GND

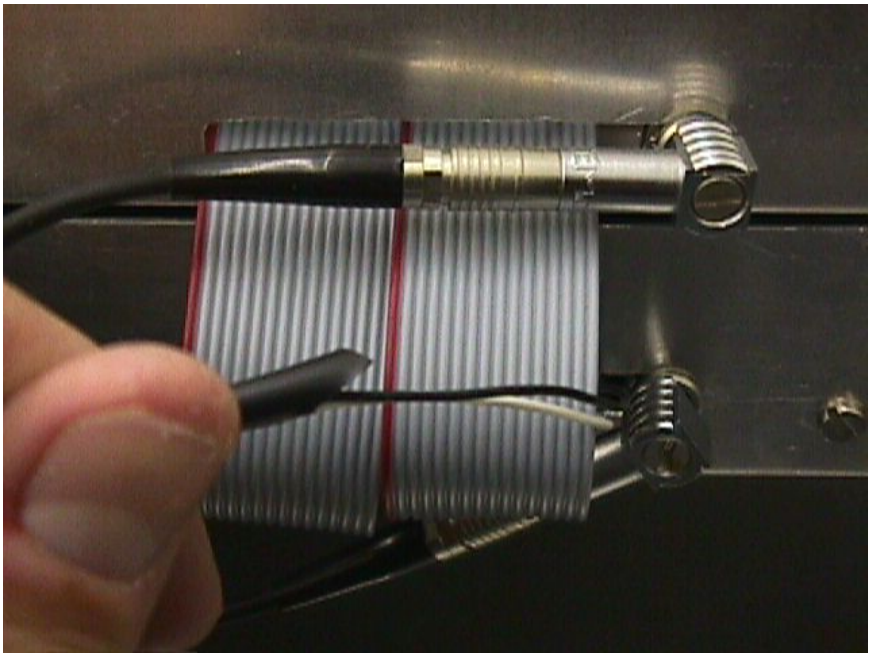

Figure 73: Connections between ***Lower Box*** and ***Upper Box***:
Flatband: pulser bit pattern from ***Shift Registers***,
Twisted Pair Red/White (here as LEMO): current for ***Continuous Light LED***s,
white: bit 90 V–ON/OFF, black: bit 90 V–GND

Figure 74: VAC connector on the ***LV-Box***: Socket CA3GD and Plug CA3LS
Pin 1: 230 V, Pin 2: free, Pin 3: 230 V, Pin 4: GND

Figure 75: Presser-Stopper connectors on the ***LV-Box***

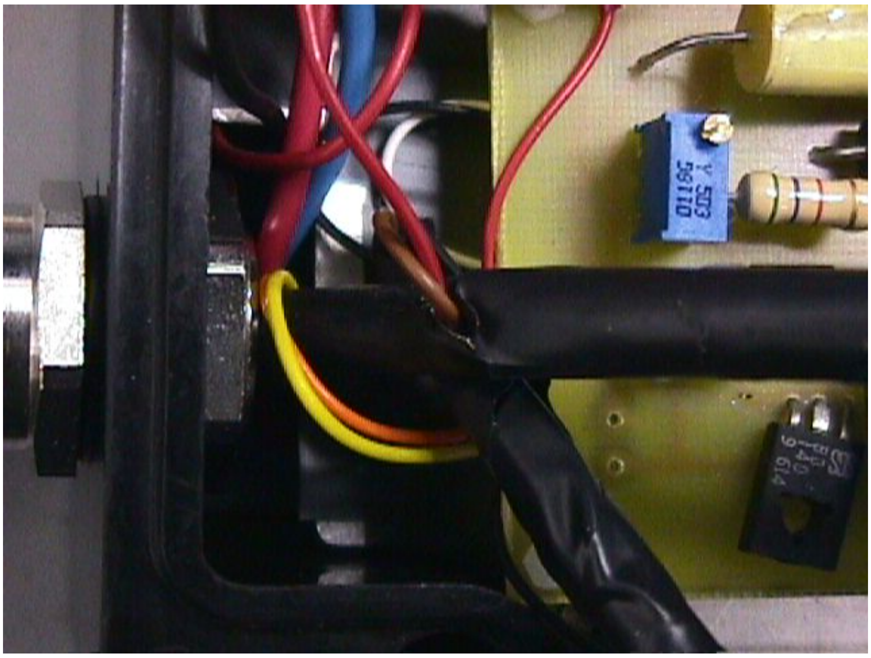

Figure 76: 90 V entrance to ***PIN-Diode Box***:
Cables: To ***PIN-Diode Box***: +90 V, GND
Bit from shift register (***Pulser Box***): 90 V–ON/OFF, 90 V–GND

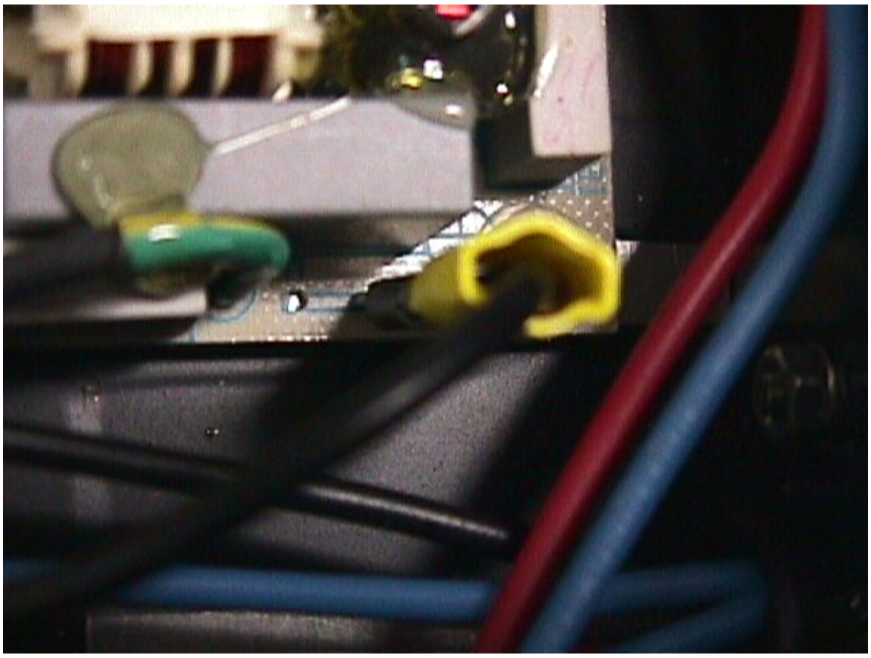

Figure 77: GND connection of the LV-generator ASTEC LPT24

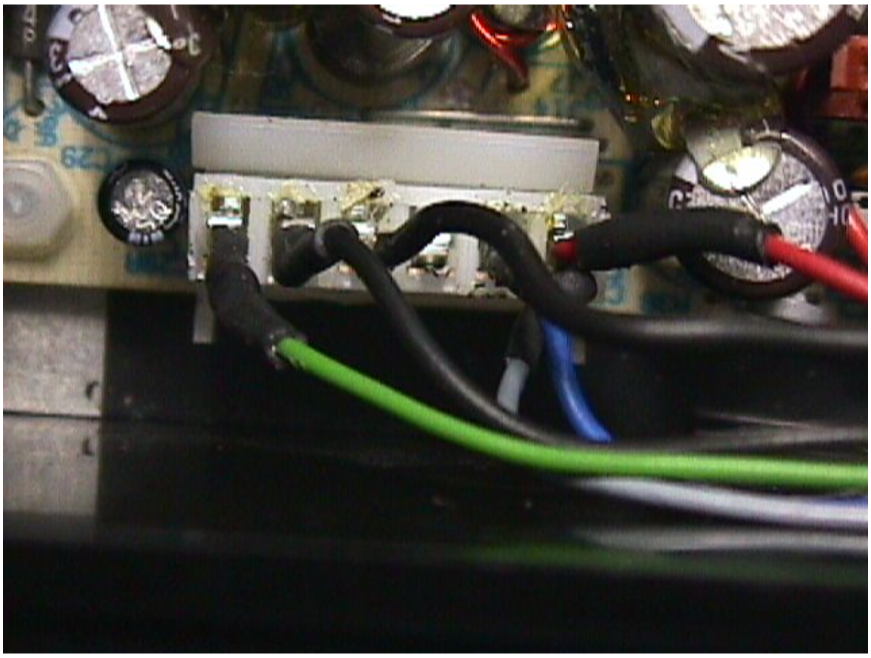

Figure 78: LV output of the ASTEC LPT24 (from right to left):
Pin 1: +12 V, Pin 2: +5 V, Pin 3: +5 V, Pin 4: GND, Pin 5: GND, Pin 6: -5 V

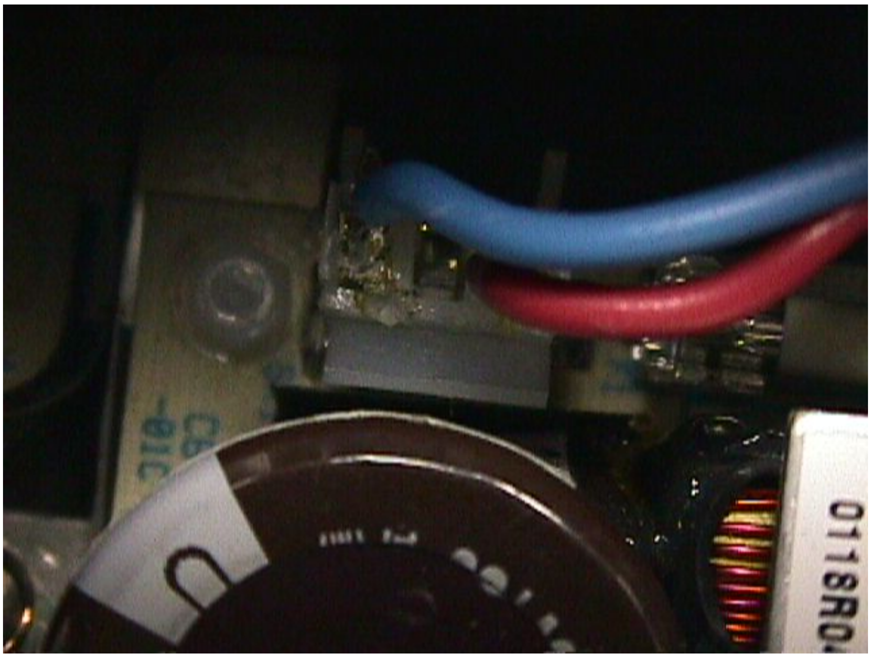

Figure 79: ASTEC LPT24 VAC input:
Pin 1: 230 V, Pin 2: free, Pin 3: 230 V

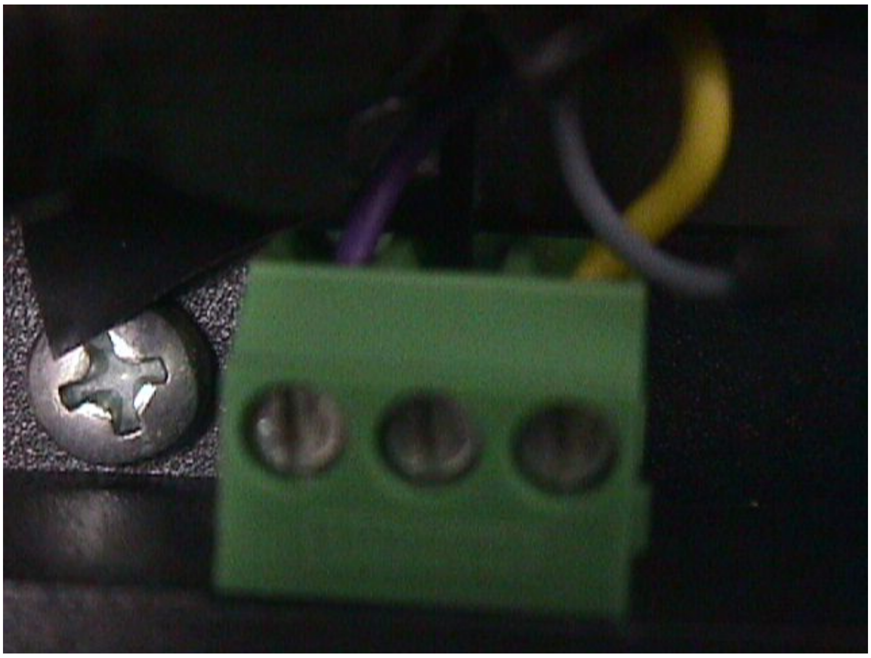

Figure 80: LV output of the SOLA SCL4D12–DN (from left to right):
(WARNING: COLOR IN PICTURE HAS CHANGED MEANWHILE! REFER TO TABLE 33)
Pin 1: +12 V, Pin 2: GND, Pin 3: -12 V

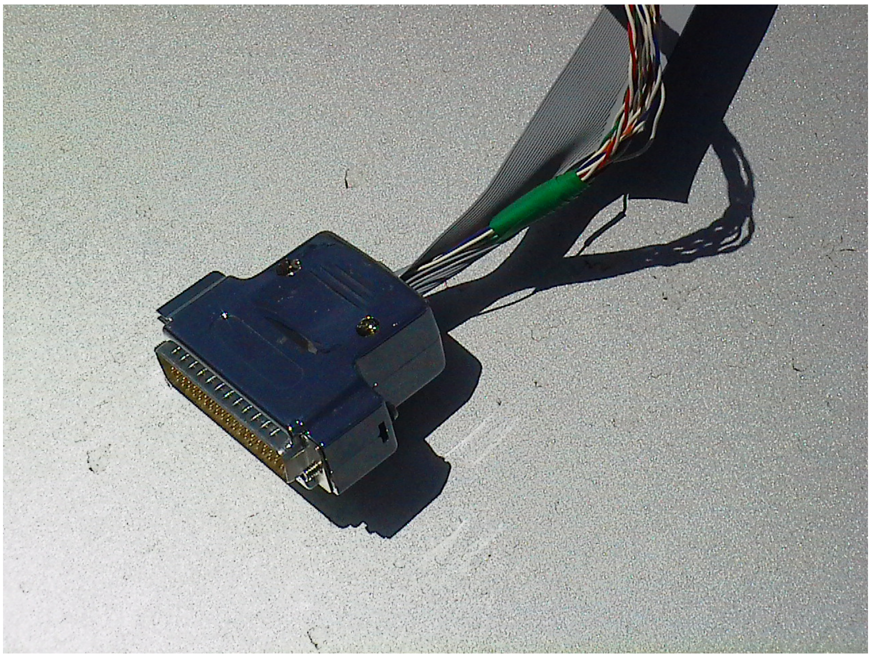

Figure 81: Connector from the ***ME1400***

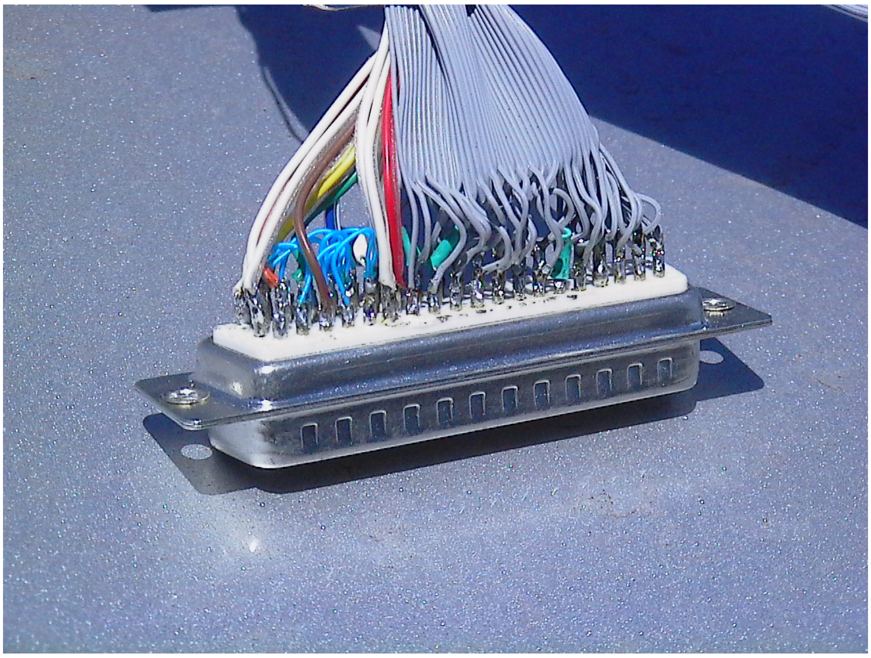

Figure 82: Connector from the ***ME1400*** with parts of the logics hardwired by soldered connections

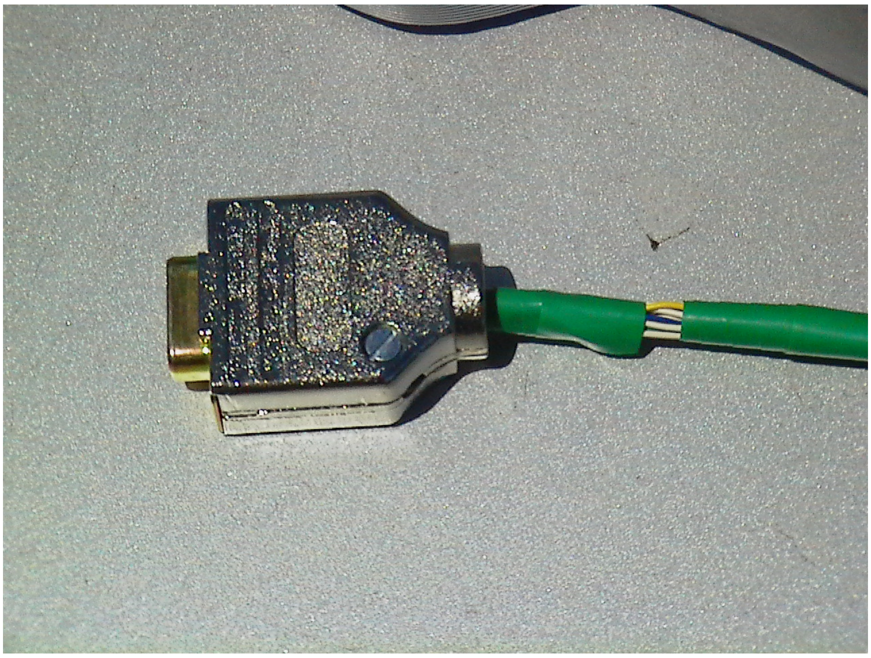

Figure 83: DB9 Connector from the ***ME1400*** to the ***Trigger Box***

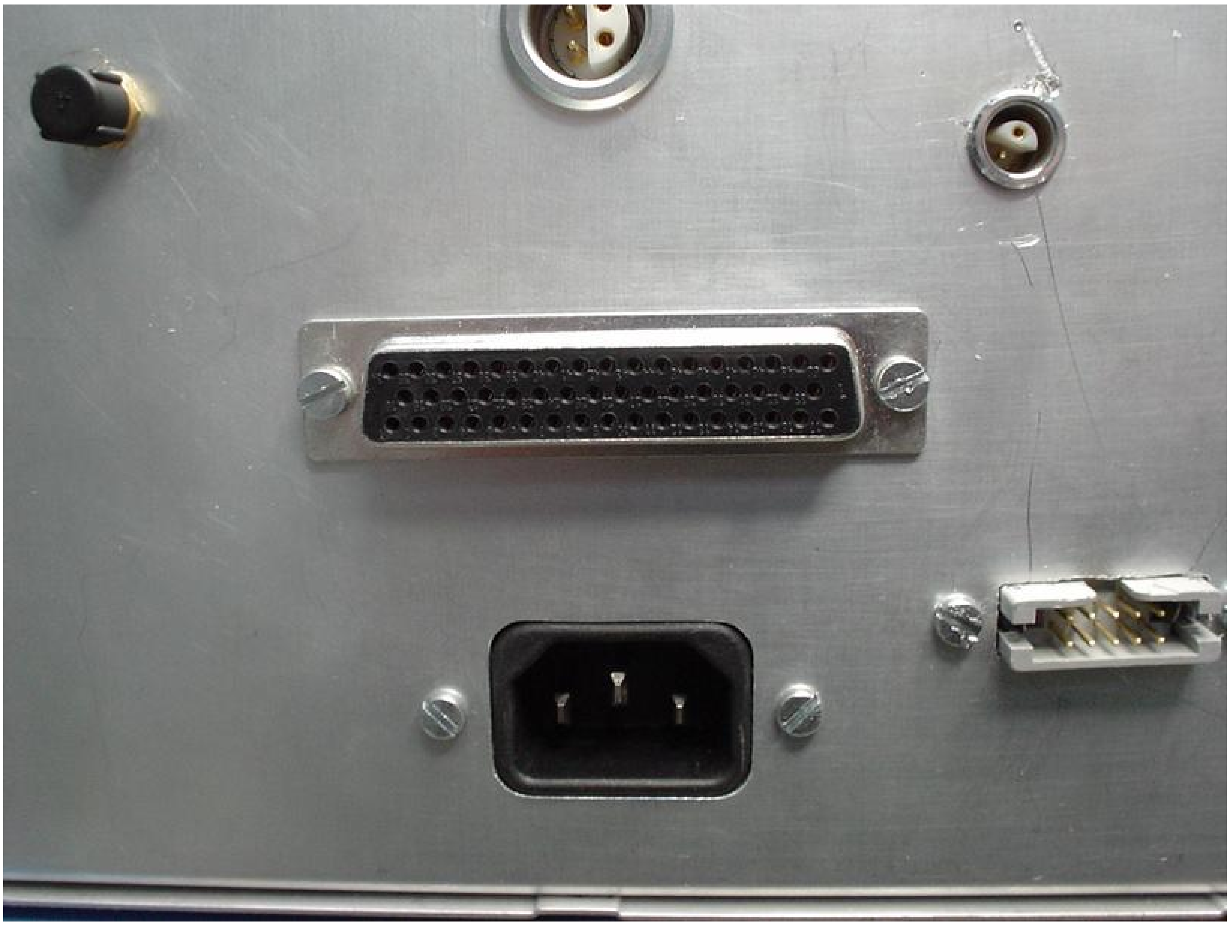

Figure 84: The Digital Modules lines connecting pc6 with the ***Trigger Box***.

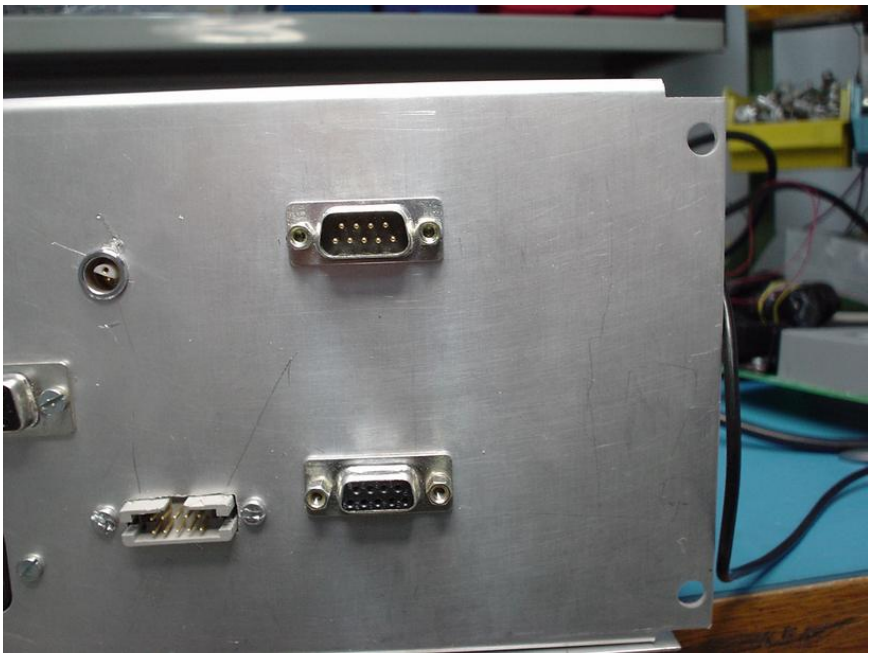

Figure 85: DB9 Connector to the ***L2*** (top) and the ***pc6*** (bottom)

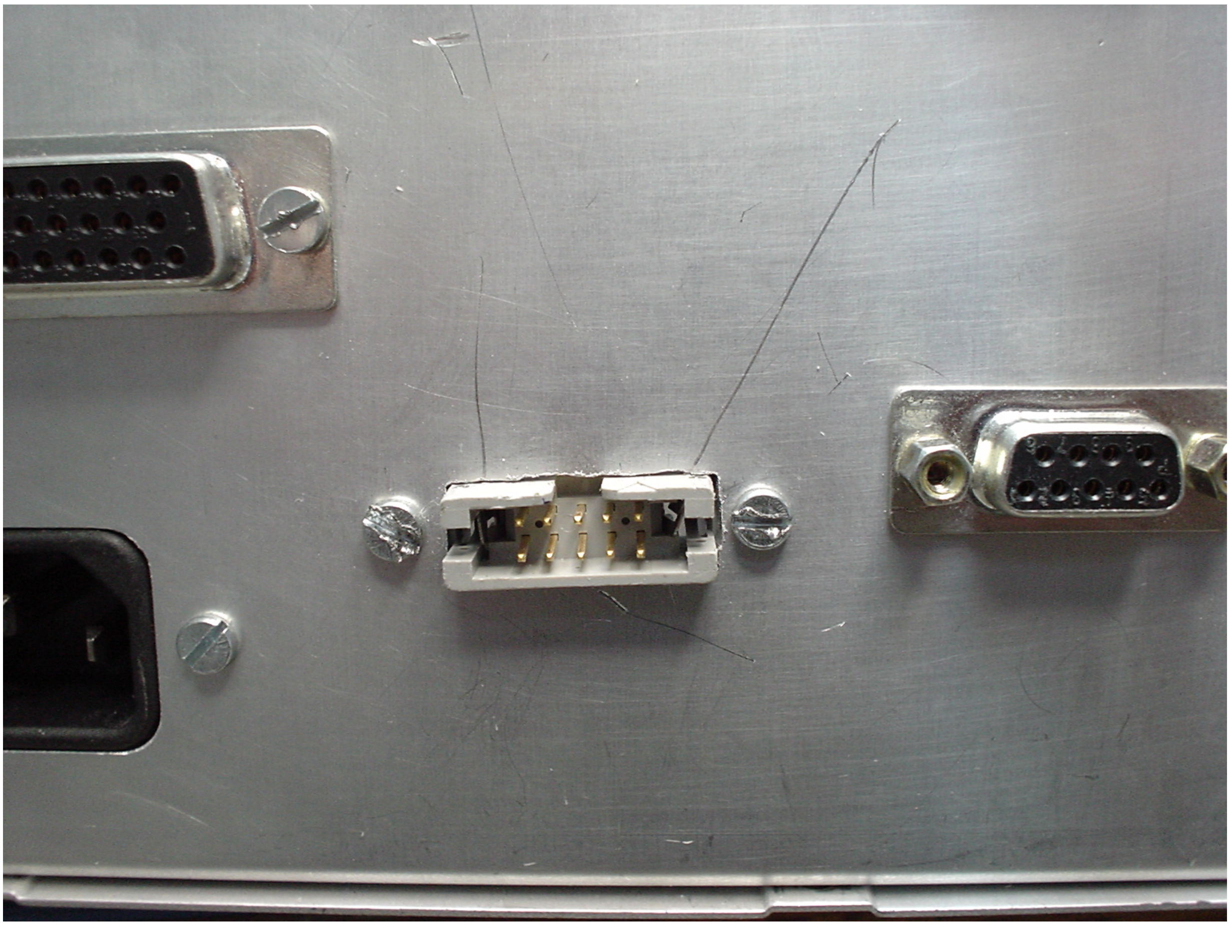

Figure 86: The ***ByteBlaster*** connector connecting ***pc39*** with the ***Trigger Box***.

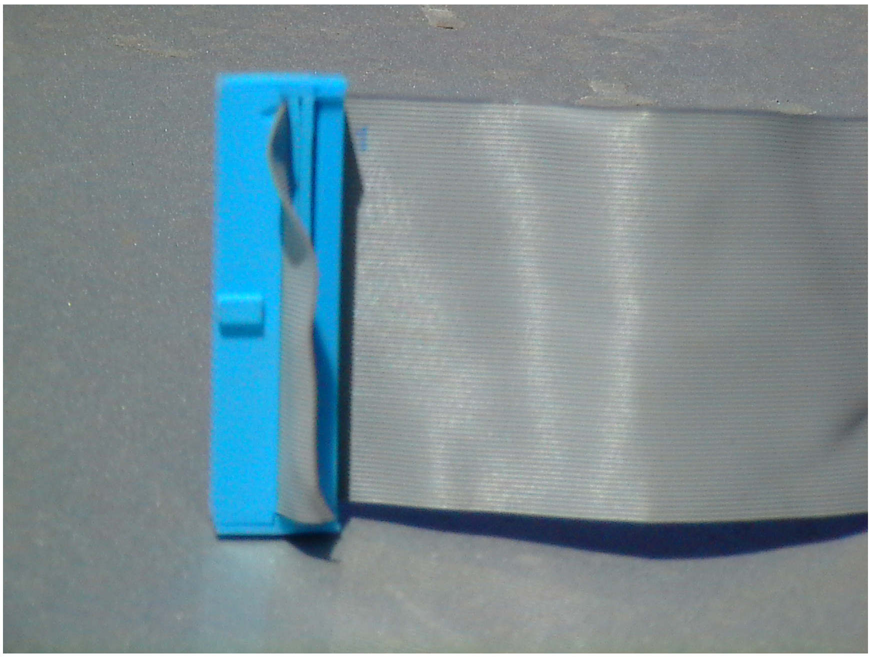

Figure 87: 78-Pin connector from the ***ME1400*** to the ***DM-Board***

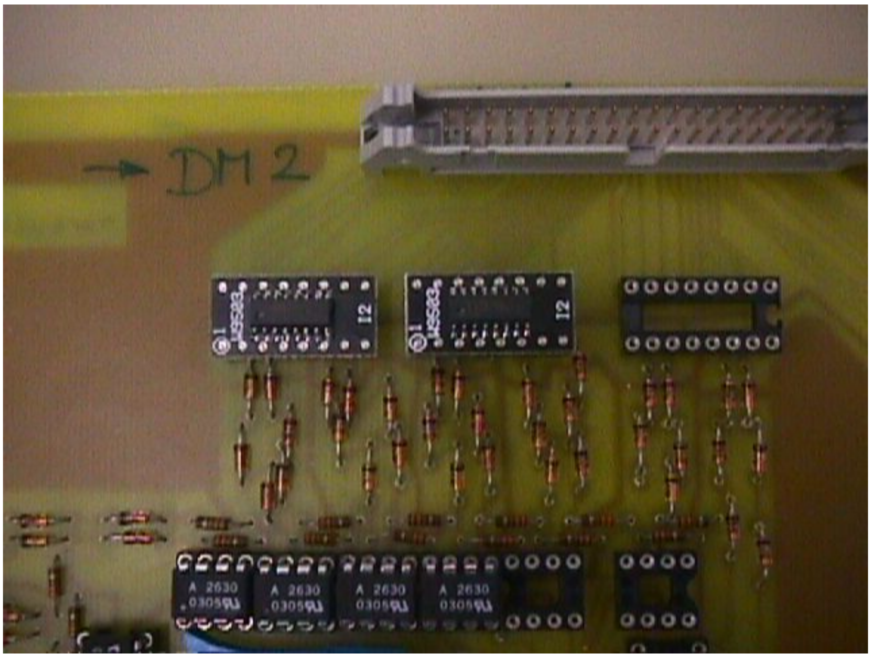

Figure 88: Connection to the ***Digital Module*** #1

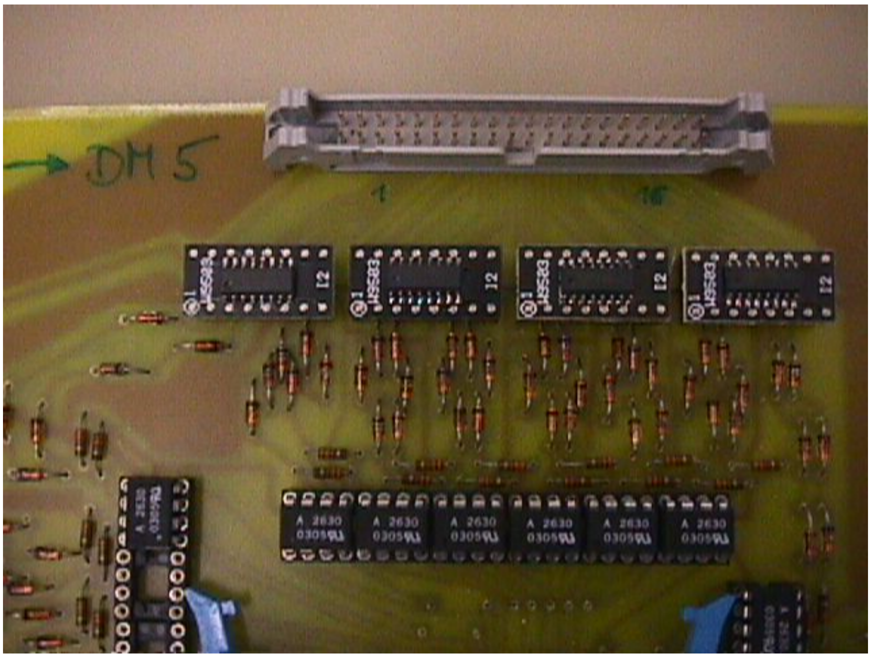

Figure 89: Connection to the ***Digital Module*** #2

8 Listing of Electronic Boards

Boards inside the ***Upper Box***					
Nr	name	description	input	output	contact
1	Pulser Board (see fig. 11)	produces the LED pulses	600 V. GND +5 V, -5 V 16 bits ***Trigger***	Light pulses ***CL***	Thomas Schwezizer tschweiz@ifae.es Markus Gaug markus@ifae.es
2	Relay Boards (see fig 90) and 91)	4 boards, each holds 4 REED relays steering the indiv. 16 slots (replaced earlier MOSFETS)	4 bits (5V,GND) 4 ***Trigger*** signal	***Trigger***, depending on state of bits	Thomas Schwezizer tschweiz@ifae.es Markus Gaug markus@ifae.es

Table 27: Boards used in the ***Upper Box***

Boards inside the ***Pulser Box*** (outside the inner boxes)					
Nr	name	description	input	output	contact
1	Optical Receiver Board	converts the light levels into TTL pulses	SMA opt. conn. +5 V, -5 V +12 V, GND	TTL GND	Markus Gaug markus@ifae.es Manel Martinez martinez@ifae.es

Table 28: Boards inside the ***Pulser Box*** (outside the inner boxes)

Boards inside the ***Lower Box***					
Nr	name	description	input	output	contact
1	***CAN-BUS*** board (see fig. 92 and 93)	• Reads the CAN line • Provides signal for ***Shift Registers*** • DAQ: signal for ***Continuous Light LED***	• +12 V, 5 V, GND • CANH,CANL VCC,GND	*bullet* 4 lines serial • 1 ***DAC*** voltage	Georges Blanchot blanchot@ifae.es Javier Lopez jlopez@ifae.es
2	Shift Register Board (see fig. 94 and 21)	• Provides bit pattern for ***Pulser Board***. • Transforms DAQ voltage into ***CL*** current • Switches ON/OFF: ○ ***600V Supply*** ○ ***90V Supply*** ○ ***CL***	• +5V GND • 4 lines serial • 1 var. voltage (0–2.5) V	2 × 8 bits 1 bit HV 1 bit ***CL*** 1 bit 90 V ***CL*** current	Manel Martinez martinez@ifae.es Markus Gaug markus@ifae.es
3	600 V supply (see fig. 105, 106 and 107)	• Provides 600 V for ***Pulser Board***	• +12 V +5 V GND • 1 bit ON/OFF	+600 V GND	Markus Gaug markus@ifae.es

Table 29: Boards used for the steering electronics of the ***Pulser Board***.

Boards inside the ***Trigger Board***					
Nr	name	description	input	output	contact
1	***Trigger Board***	forms trigger signals	+5 V, -5 V, GND 8 lines from pc6 2 trigger lines from ***Optical Receiver Board***	TTL to ***Optical Transm. Board*** 3 LVDS to ***L2*** 3 TTL to test 3 TTL to test	Markus Gaug markus@ifae.es
2	***Optical Transmitter Board***	converts TTL trigger into optical	+5 V, -5 V, GND 1 TTL line from 1	optical	Alex Gonzalez gonzales@ifae.es (see fig 98)
3	***DM-Board***	converts digital modules lines	+5 V, -5 V, GND 47 lines from pc6	31 lines to ***Digital Modules***	Markus Gaug markus@ifae.es
4	***Indicator LEDs Boards***	drives the ***Indicator LEDs***	+5 V, GND 3 lines TTL *CAL,PED,PIN*		Markus Gaug markus@ifae.es (see fig 100)

Table 30: Boards inside the ***Trigger Board***

Spare Boards						
Nr	Art.Nr.	situated in:	input	output	description	contact
1	***ME1400***	***pc6***	–	6 timers 48 bits	calibration trigger (see fig 95)	Javi Lopez jlopez@ifae.es
2	trigger board	trigger box	4 trigger lines 3 bits 1 ***PIN-Diode*** signal	1 ECL line 3 LVDS lines 1 TTL test 1 ECL test 1 LVDS trigger	calibration trigger	Markus Gaug markus@ifae.es
3	translator board	pulser box table 27	1 ECL line GND	3 TTL lines	calibration trigger	Markus Gaug markus@ifae.es

Table 31: Spare Boards in the ***Control House***.

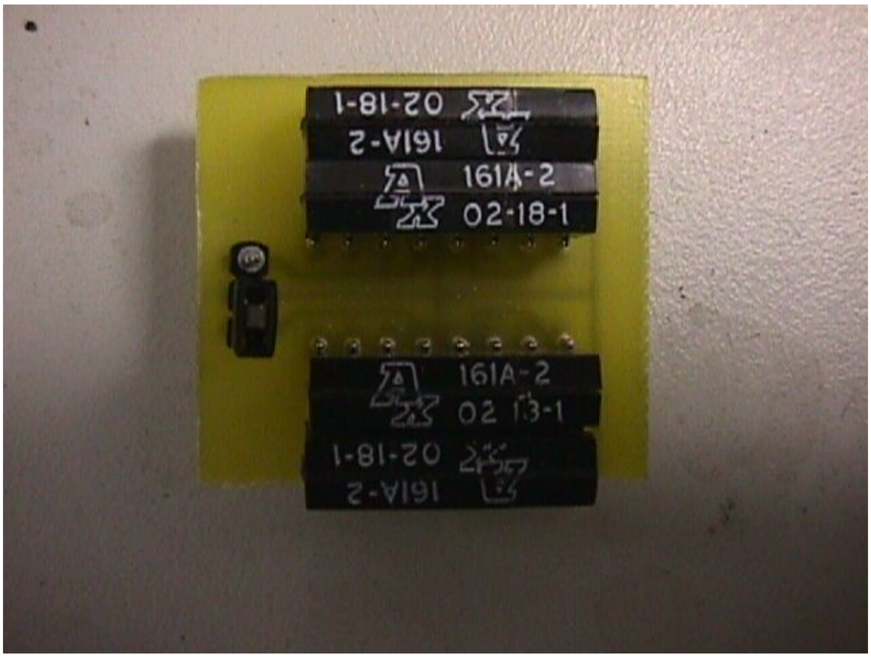

Figure 90: The ***Relays Board*** holding 4 REED relays (front)

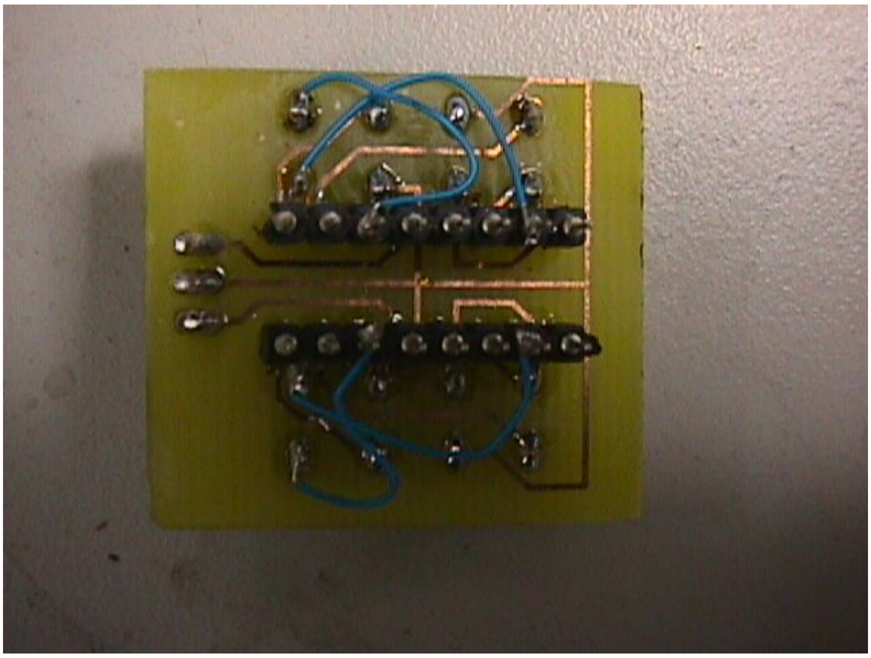

Figure 91: The ***Relays Board*** (back)

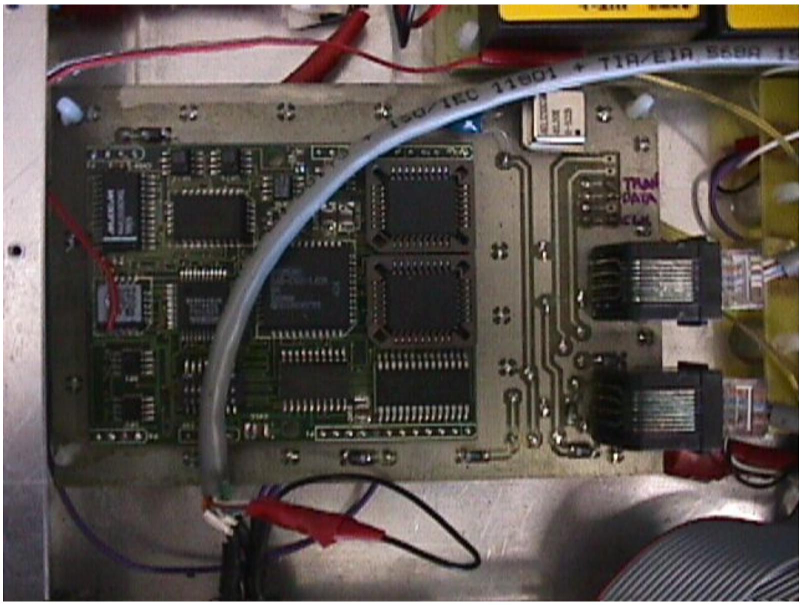

Figure 92: ***CAN-BUS Board*** situated in the ***Lower Box***

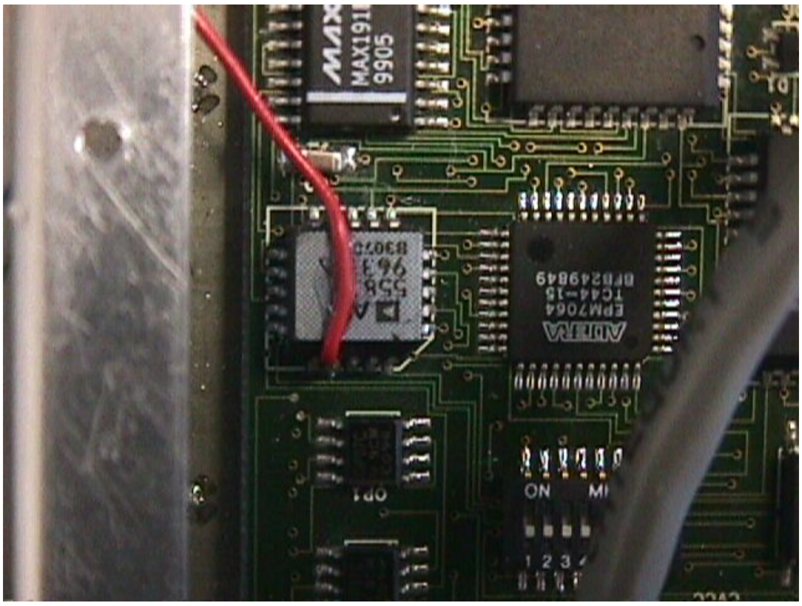

Figure 93: The ***DAC*** providing the signal for the ***Continuous Light LEDs***

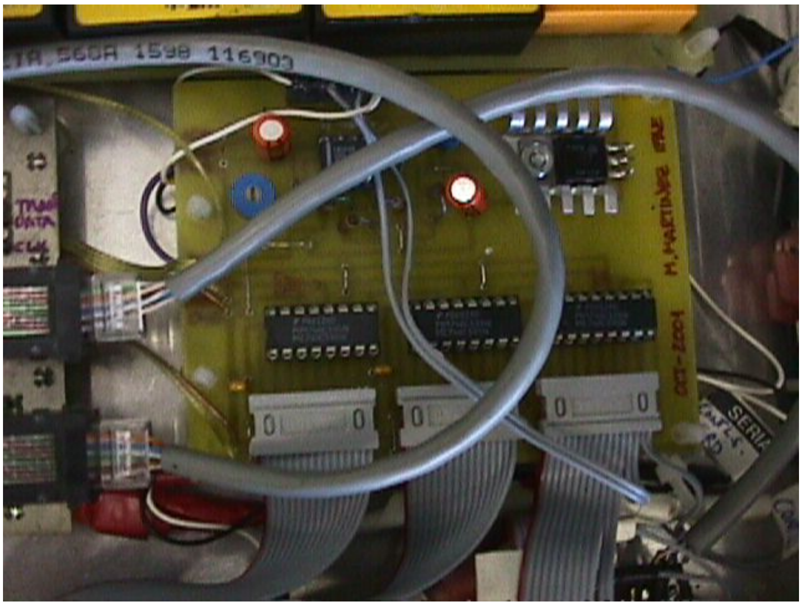

Figure 94: ***Shift Register Board*** situated in the ***Lower Box***

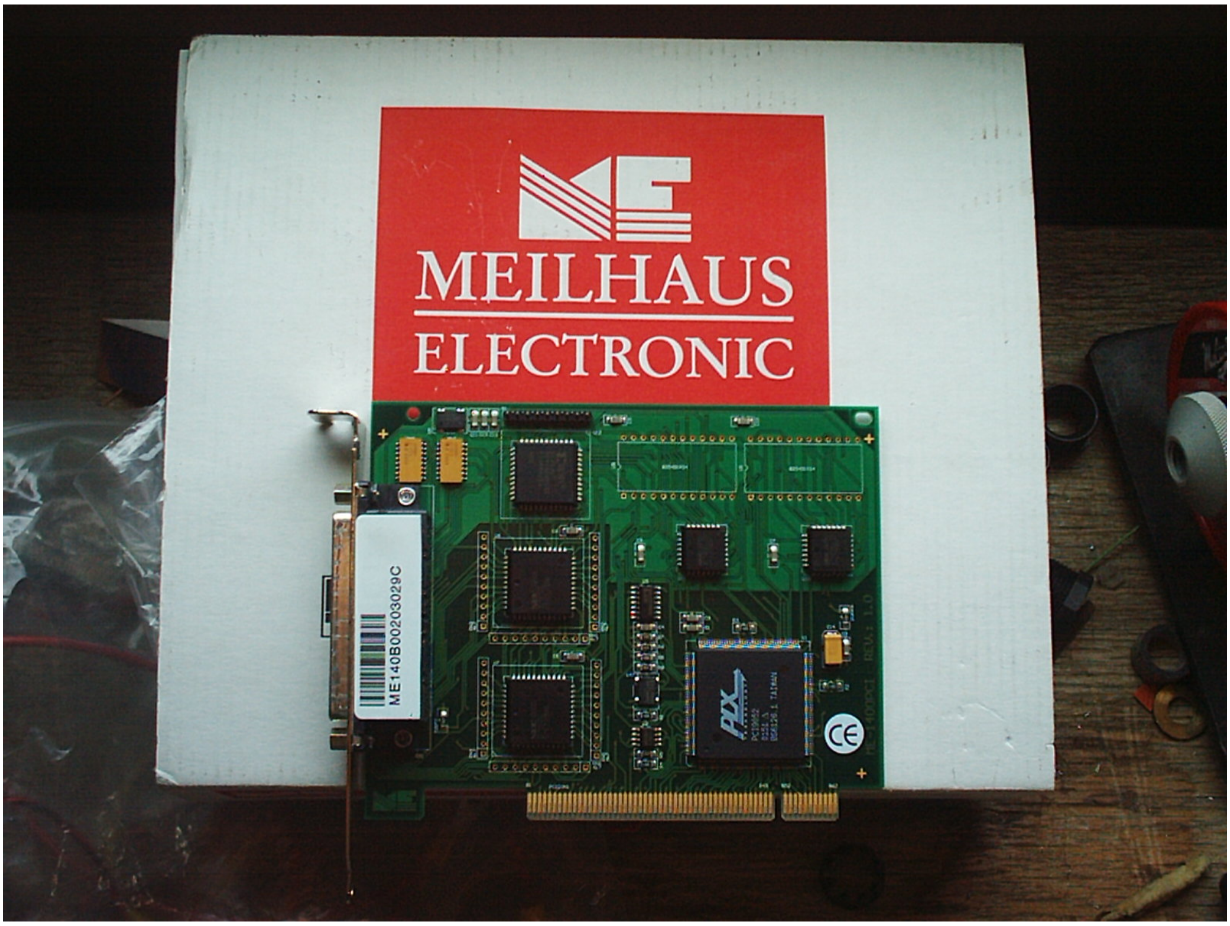

Figure 95: The I/O PCB ***ME1400*** housed in ***pc6***

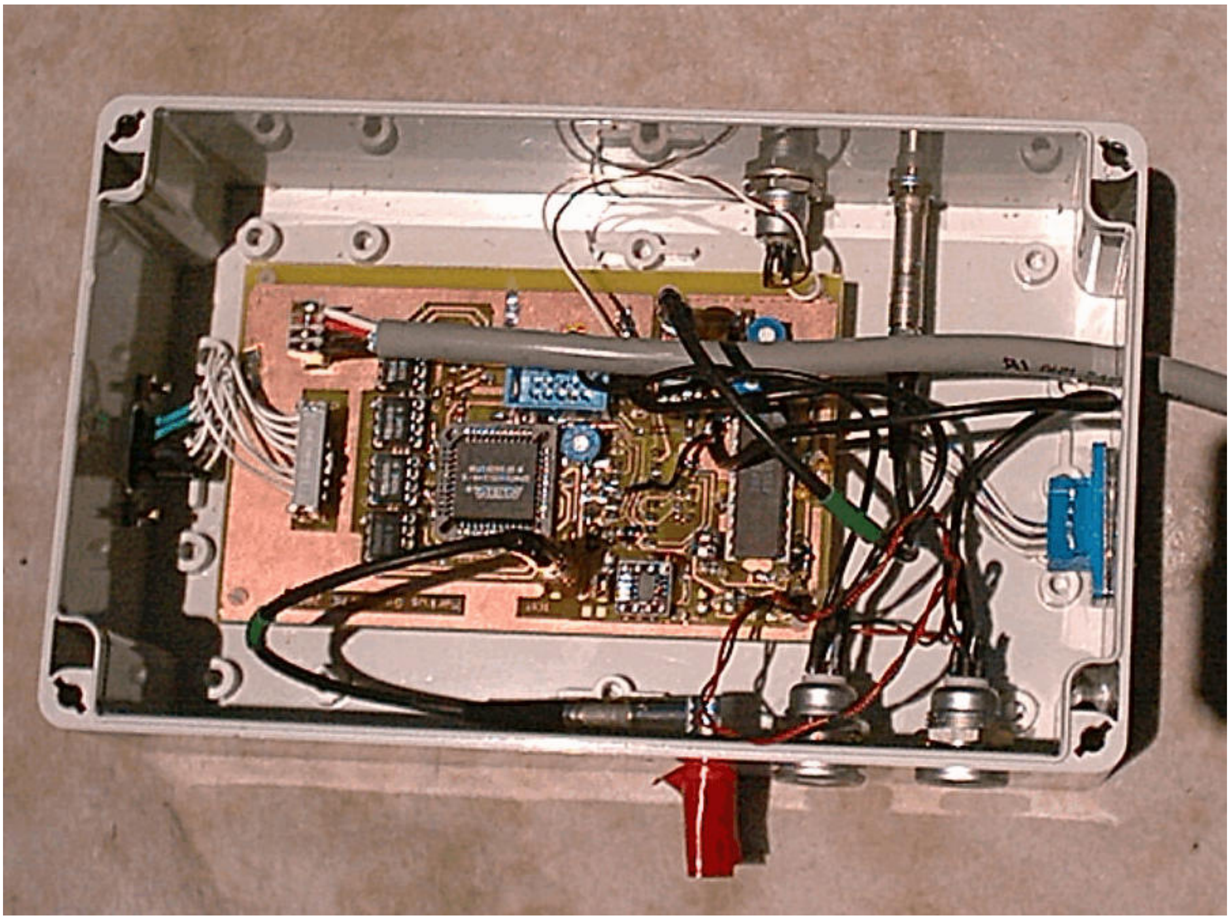

Figure 96: The ***Trigger Board*** housing the optocouplers and the ALTERA chip.

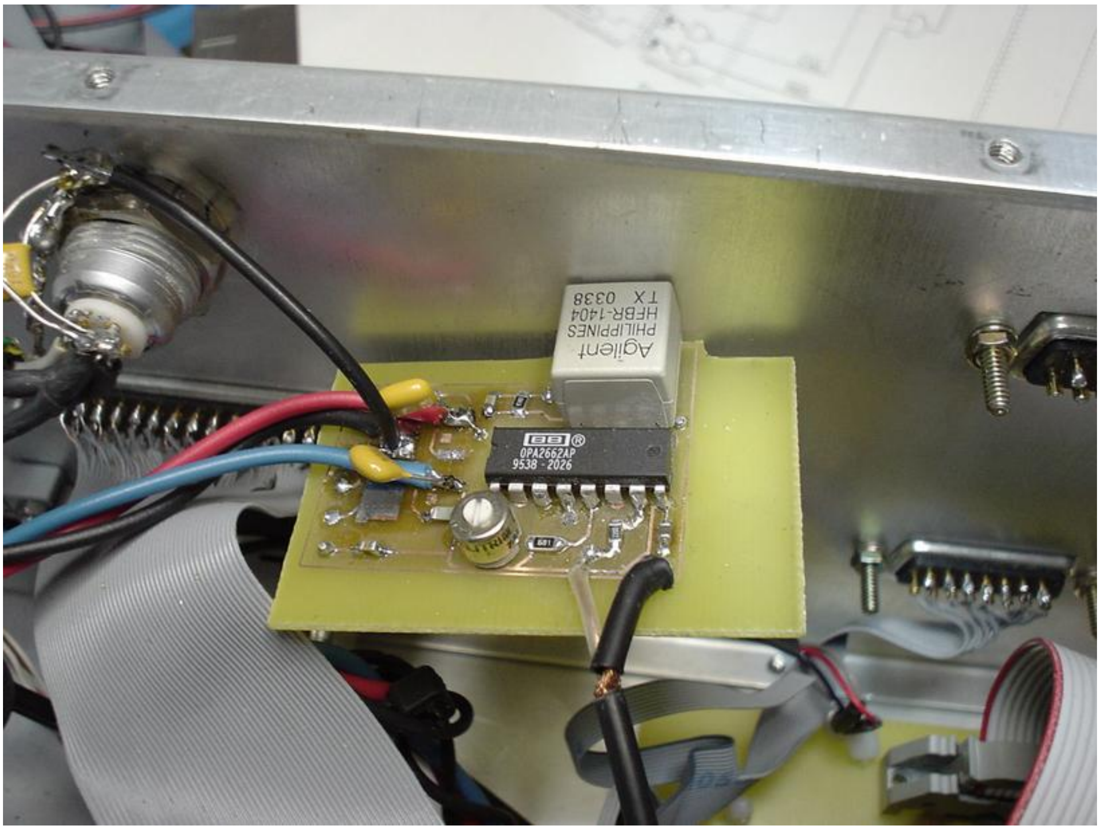

Figure 97: The ***Optical Transmitter Board*** put in place in the ***Trigger Board***

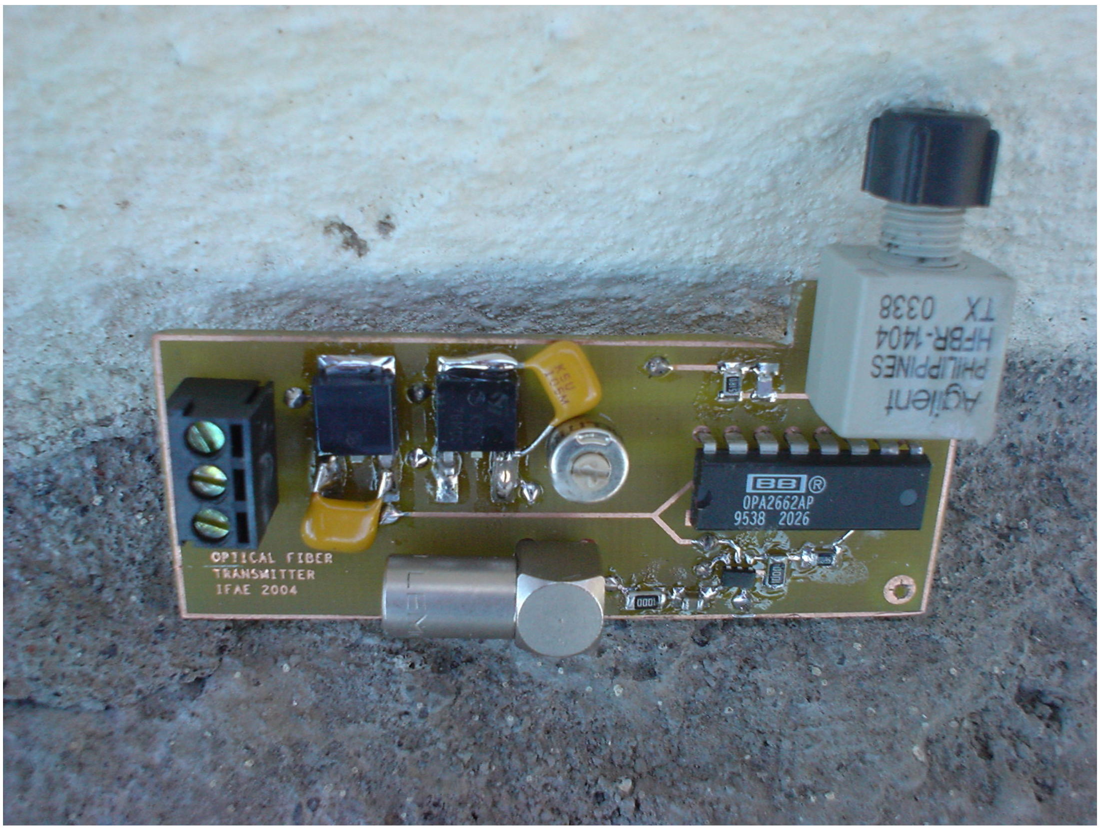

Figure 98: The ***Optical Transmitter Board*** in the ***Trigger Board***

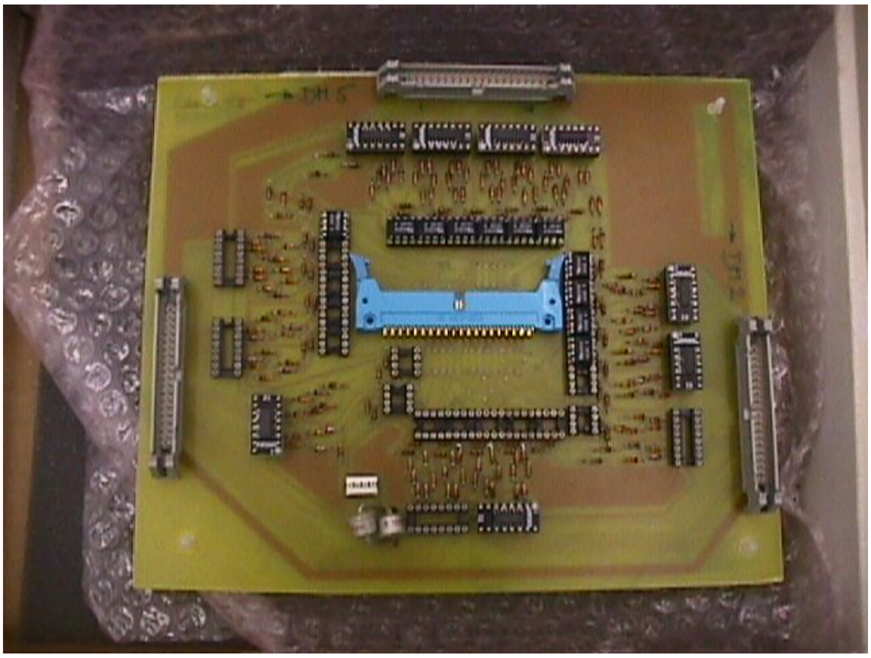

Figure 99: The DM-board transforming the ***ME1400*** digital lines into LVDS

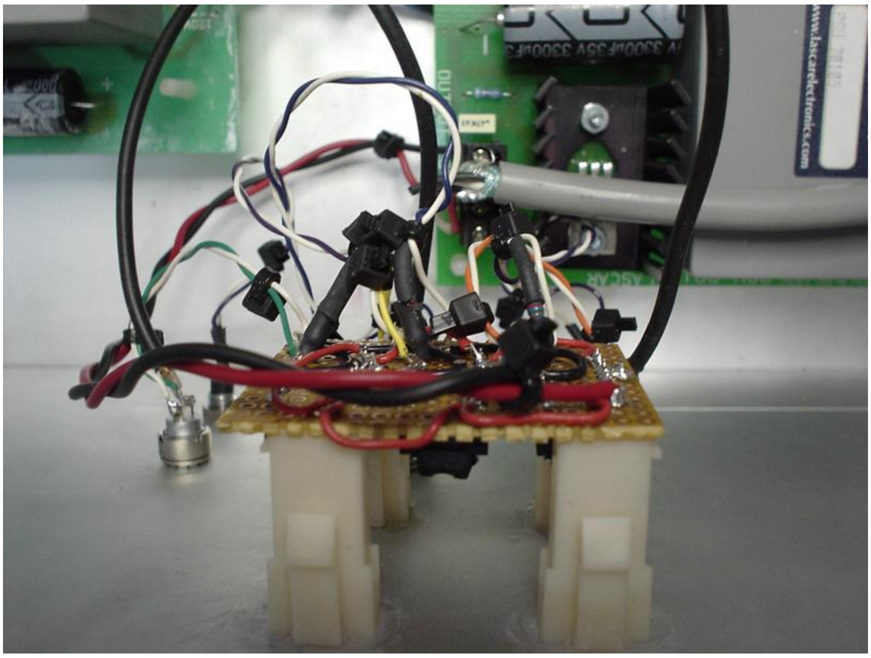

Figure 100: The ***Indicator LEDs*** boards

9 Listing of Power Supplies

Power supplies inside the ***Lower Box***					
Nr	Art.Nr.	provides power for:	input	output	description
1	GM12–1000P (see fig. 106)	600 V-board	12 V	+1000 V GND	switching power supply
2	— (see fig. 105)	Pulser-Board	1000 V	+600 V GND (see fig. 107)	current foldback board schematics in fig. 125 and 126

Table 32: Power supplies inside the ***Lower Box***.

Power supplies inside the ***LV-Box***					
Nr	Art.Nr.	provides power for:	input	output	description
1	ASTEC LPT24 (see fig. 108)	***Shift Registers*** 1000 V supply ***Pulser Board*** ***90V Supply***	230 VAC (see fig. 79) GND (see fig. 77)	+12 V +5 V –5 V GND	switching power supply need ***Minimum Loa*** +12 V: 0.1 A +5 V: 0.3 A
2	SOLA SCL4D12–DN (see fig. 109)	***Nano-Second Amplifier*** (in ***PIN-Diode Box***)	230 VAC	+12 V –12 V GND (see fig. 80)	linear power supply very low ripple
3	GM12–200P (see fig. 103)	90 V-board	12 V	+200 V GND	switching power supply
4	— (see fig. 101 and 102)	***PIN-Diode***	200 V	+90V GND (see fig. 104)	current foldback board schematics in fig. 127

Table 33: LV-power supplies inside the ***LV-Box***.

Power supplies for the ***Trigger Box***					
Nr	Art.Nr.	power for:	input	output	description
1	Lascar PSU 206 (see fig. 111)	***Trigger Board*** ***TTL to Opt. Converter*** ***Indicator LEDs***	230 VAC GND	blue: +5 V (adjust.) green: -5 V (adjust.) yellow: GND (adj. volt.) red: +5 V (fixed) black: GND (5 V fixed)	linear PS max. outputs: • 5 V fixed: 1A • +5V: 0.25A • -5V: 0.25A short-circuit pro
2 3	Lascar PSU 20105 (2x) (see fig. 110)	***DM-Board***	230 VAC GND	red: +5 V (adjust.) white: -5 V (adjust.) black: GND (adj. volt.) red: +5 V (fixed) black: GND (5 V fixed)	2 linear PS in parallel max outputs: each 1 A short-circuit pro

Table 34: Power supplies for the ***Trigger*** electronics.

Spare Power supplies					
Nr	Art.Nr.	situated in:	input	output	description
1	ASTEC LPT24	***LV-Box*** table 33 see fig. 108	230 VAC GND	+12 V +5 V –5 V GND	switching power supply needs ***Minimum Load***: +12 V: 0.1 A +5 V: 0.3 A FOR TESTS USE METAL HOUSING !! DANGER BY TOUCHING !!
2	SOLA SCL10T512DN (equivalent to SOLA SCL4D12-DN)	***LV-Box*** table 33 see fig. 109	230 VAC GND	+12 V –12 V +5 V GND	linear power supply very low ripple
3	GM12–200P	***Upper Box*** table 33 see fig. 103	12 V GND	+200 V GND	switching power supply
4	Lascar PSU 206	***Trigger Box*** table 34	230 VAC GND	5 V (adj.) GND +5 V (fixed) GND	linear PS 1 A (adj.) 1 A (fixed)
5	Lascar PSU 20105	***Trigger Box*** table 34	230 VAC GND	+5 V (fixed) GND	linear PS 1 A

Table 35: Spare power supplies in the ***Control House***.

Figure 101: ***90V Supply*** (front view)

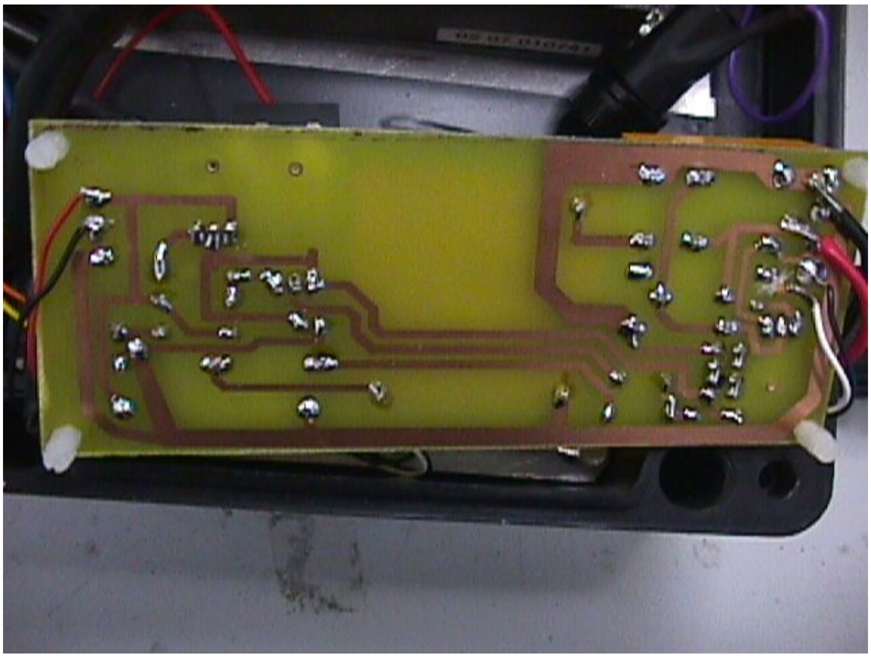

Figure 102: ***90V Supply*** (back view)

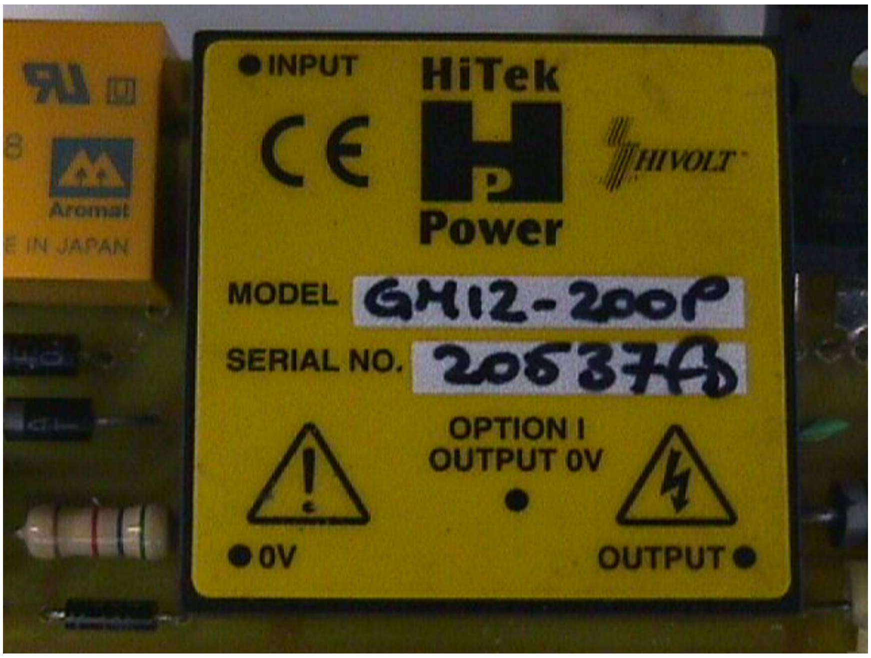

Figure 103: ***90V Supply***: core 200 V switching power supply GM12–200P

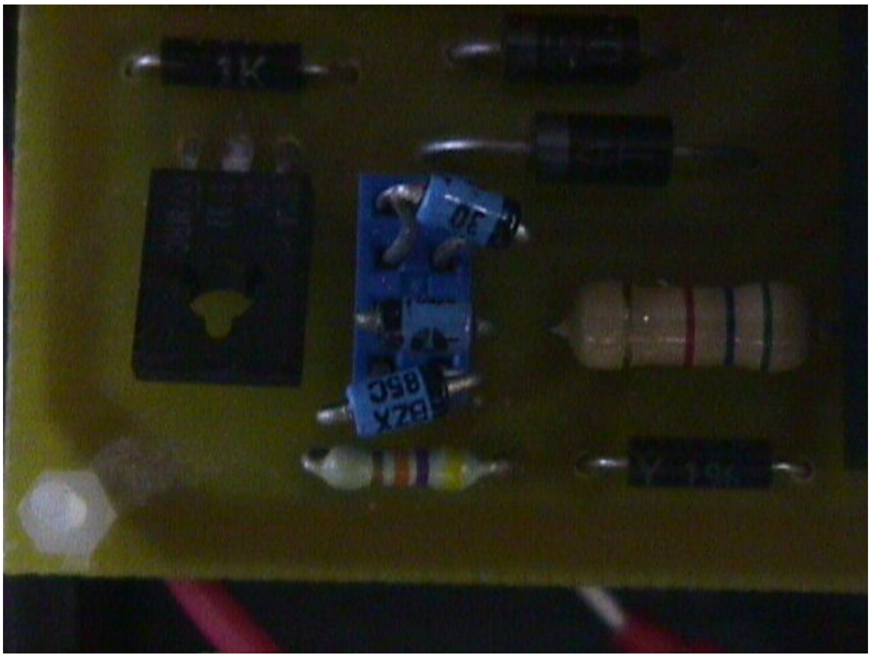

Figure 104: ***90V Supply***: Zener Diodes fixing voltage to 90 V

Figure 105: The ***600 V Supply Board*** situated in the ***Lower Box***

Figure 106: The ***600 V Supply Board***: 1000 V supplies

Figure 107: The ***600 V Supply Board***: Three Zener Diodes 1N5388B stabilizing the voltage to 600 V.

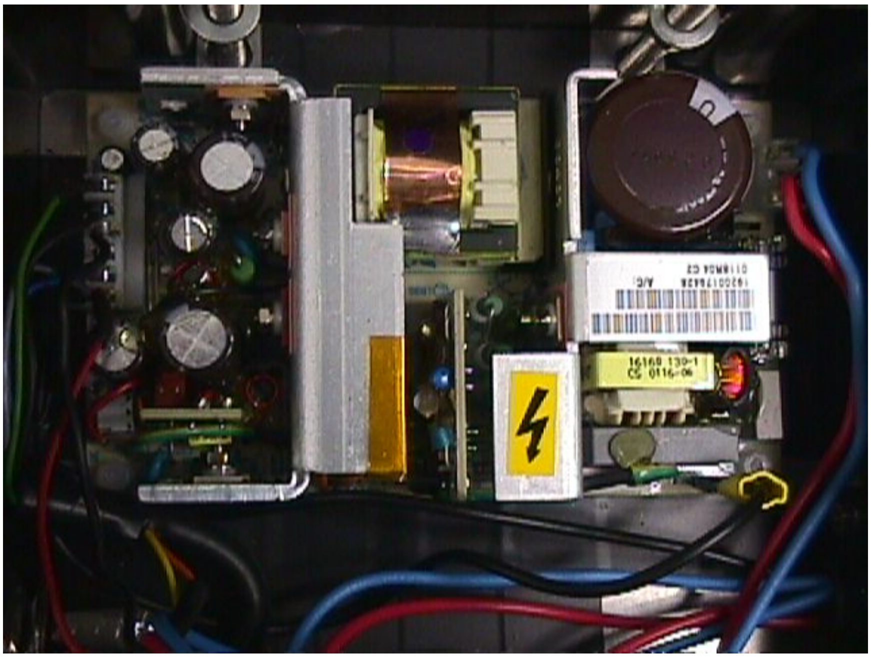

Figure 108: LV-generator ASTEC LPT24

Figure 109: LV-generator SOLA SCL4D12–DN

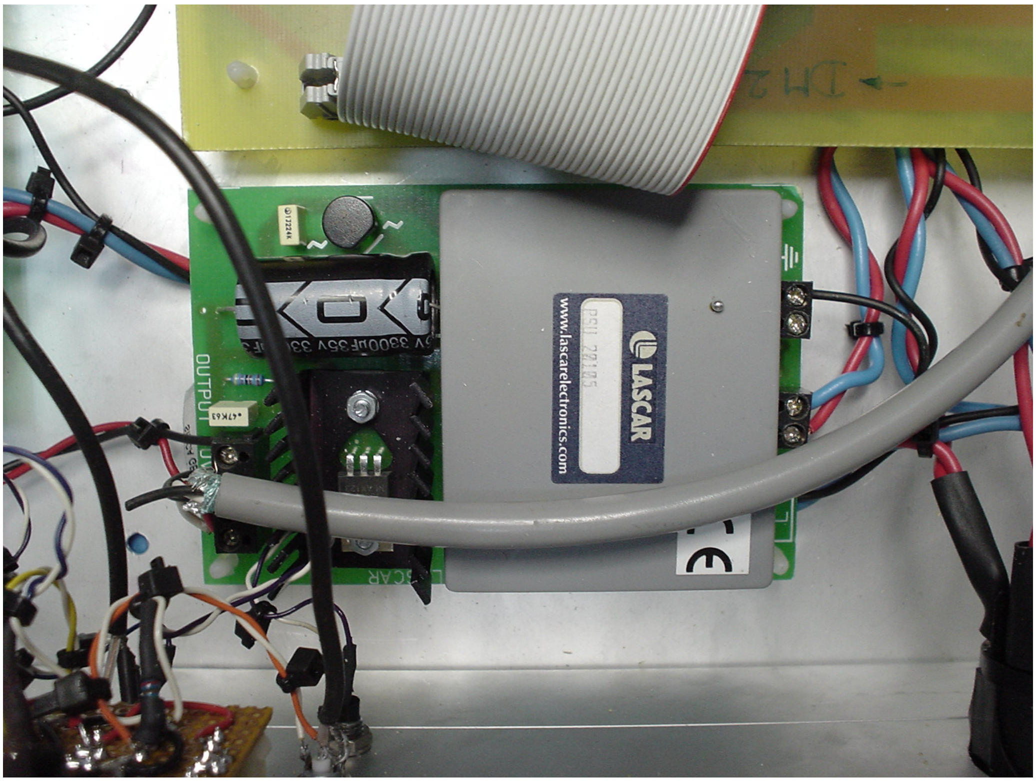

Figure 110: The Voltage Supply PSU20105

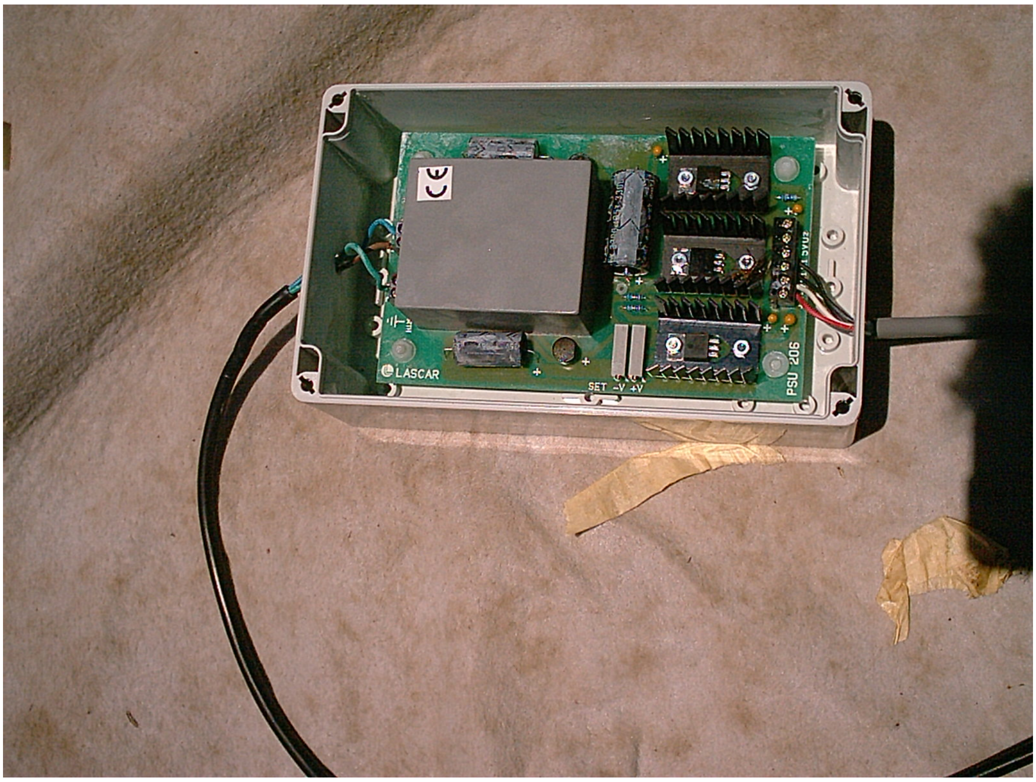

Figure 111: The Voltage Supply PSU206

10 Listing of Fuses

Fuses in the ***Pulser Box***			
Nr	line	place	rating
1	+12 V from LV-connector to ***600V Supply***	in fuseholder ***Lower Box***	1.6 A

Table 36: Fuses inside the ***Pulser Box***.

Fuses in the ***LV-Box***			
Nr	line	place	rating
1	VAC supply to ***LV-Box***	inside ***Cooling Box*** (at ground)	0.5 A FAZ–CO,5
2	12 V powering GM12–200P on the ***90V Supply*** board	in fuseholder upper floor (see fig. 112)	250 mA
3	12 V powering ***Pulser Box***	in fuseholder upper floor (see fig. 116)	2.5 A
4	inside ASTEC LPT24	lower floor (see fig. 114)	2.5 A
5	+12 V from SOLA SCL4D12-DN to the ***Nano-Second Amplifier***	in fuseholder upper floor (see fig. 115)	100 mA
6	–12 V from SOLA SCL4D12-DN to the ***Nano-Second Amplifier***	in fuseholder upper floor	100 mA

Table 37: Fuses inside the ***LV-Box***.

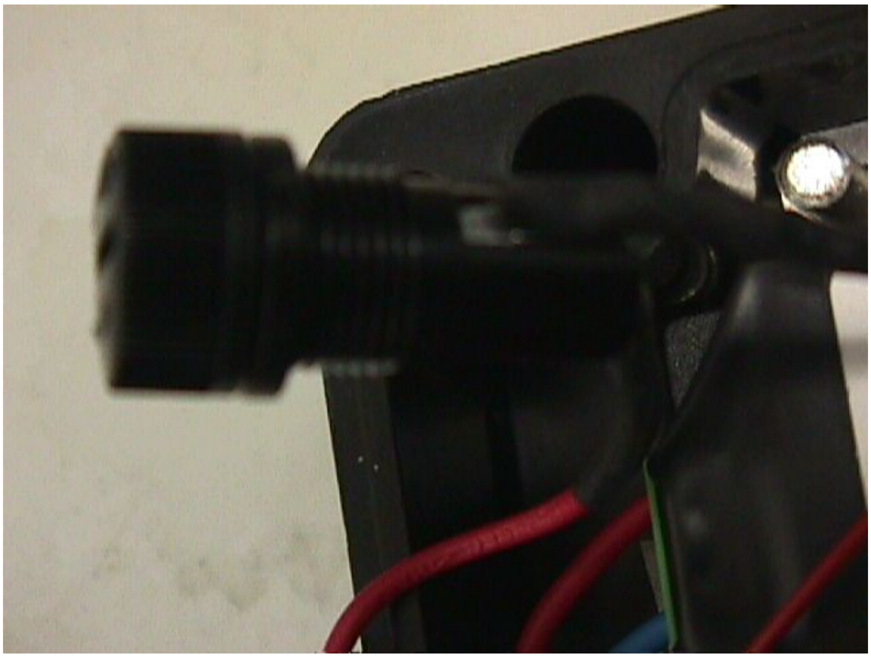

Figure 112: Fuseholder on the 12 V line powering the GM12–200P (***90 V Supply Board***)

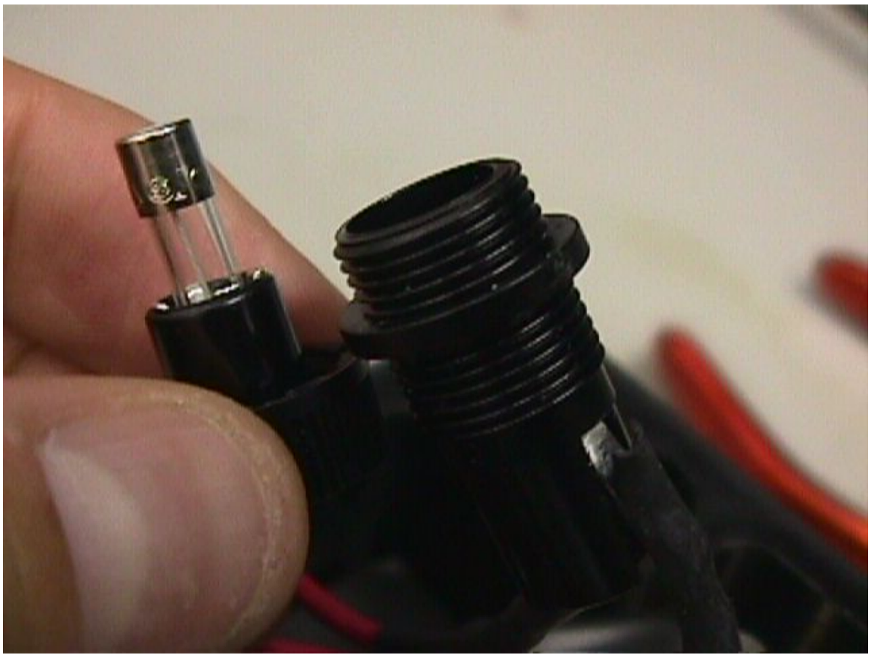

Figure 113: Fuseholder open with the **250 mA** fuse

Figure 114: Fuse inside the ASTEC LPT24: **2.5 A**

Figure 115: Fuse on +12 V line from SOLA SCL4D12–DN to ***Nano-Second Amplifier***: **100 mA**

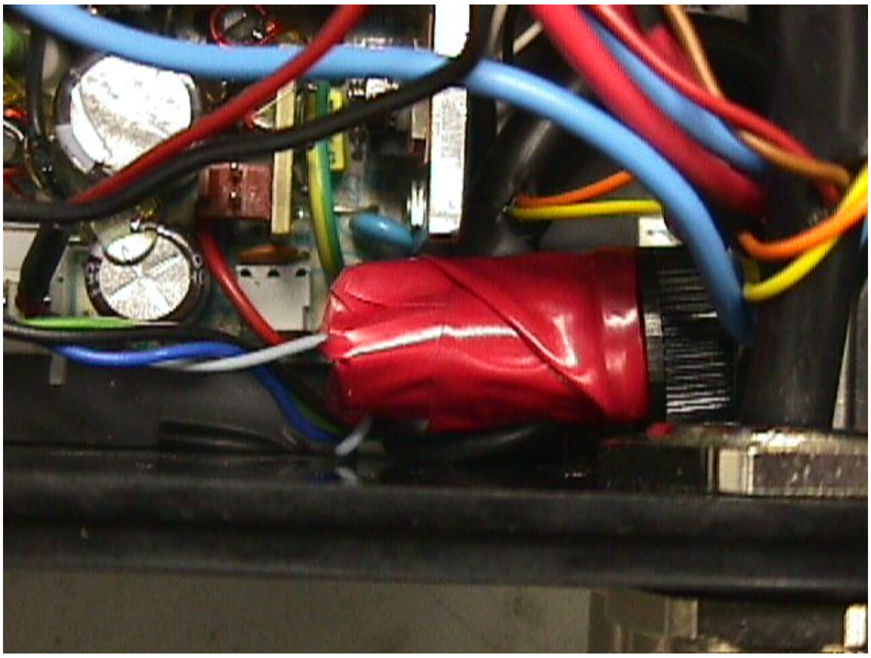

Figure 116: Fuse on the 12 V line from ASTEC power supply to ***Pulser Box***: **2.5 A**

11 Listing of Filters

Filters in the ***Pulser Box***			
Nr	lines	place	strength
1 Ferrite	LV supply (all 4 lines)	after connector (at ground)	5 rings, 2 loops 120 μH
2 Ferrite	***CL*** (all 2 lines)	between ***CL*** circuit and ***Continuous Light LED***	1 ring, 3 loops 40 μH
3 Ferrite	LV to ***Opt. to TTL Converter*** (all 3 lines)	between ***Minimum Load*** and ***Opt. to TTL Converter***	1 ring, 3 loops 40 μH
4 Capacitors	LV to ***Opt. to TTL Converter*** +5 V and –5 V	soldered to ***Opt. to TTL Converter***	100 μF
5 Transient Voltage Supp.	ECL lines in ***Opt. to TTL Converter***	soldered to ***Opt. to TTL Converter***	-6.8 V to +6.8 V
6 Coil	LV to ***Pulser Board*** (+5 V, –5 V)	between ***Minimum Load*** and ***Pulser Board***	~100 mH
7 Ferrite	TTL trigger	between ***Opt. to TTL Converter*** and entry to ***Pulser Board***	1 ring, 5 loops 65 μH

Table 38: Filters inside the ***Pulser Board***. Only the largest capacitors are listed.

Filters in the ***Lower Box***			
Nr	lines	place	strength
1 Ferrite	TTL trigger	between entry and comparator	1 ring, 10 loops 120 μH
2 Tubular	***Shift Registers*** flatband	between ***Shift Registers*** and ***Pulser Board***	
3 EMI beads	power lines ***CAN-BUS Board*** all lines indiv.	at ***CAN-BUS Board*** LV input connector	14 μH

Table 39: Filters inside the ***Lower Box***.

Filters in the ***Upper Box***			
Nr	lines	place	strength
1 Ferrite	TTL trigger	between entry and comparator	1 ring, 10 loops 120 μH
2 Capacitor	600 V line HV-GND	soldered to supply pins	100 nF

Table 40: Filters inside the ***Upper Box***. Only the largest capacitors are listed.

Filters in the ***LV-Box***			
Nr	lines	place	strength
1 Ferrite	LV supply (all 3 lines)	output of SOLA	1 ring, 3 loops 40 μH
2 Ferrite	power supply of ***90V Supply*** (2 lines 12 V,GND)	input of ***90V Supply***	1 ring, 3 loops 40 μH
3 Ferrite	output of ***90V Supply*** (2 lines 90 V,GND)	output of ***90V Supply***	1 ring, 5 loops 65 μH

Table 41: Filters inside the ***LV-Box***.

Filters in the ***PIN-Diode Box***			
Nr	lines	place	strength
1 Ferrite	LV supply (all 5 lines)	behind connector	1 ring, 1 loop 13 μH
2 Capacitor	LV supply (all 5 lines)	behind connector	100 nF

Table 42: Filters inside the ***PIN-Diode Box***.

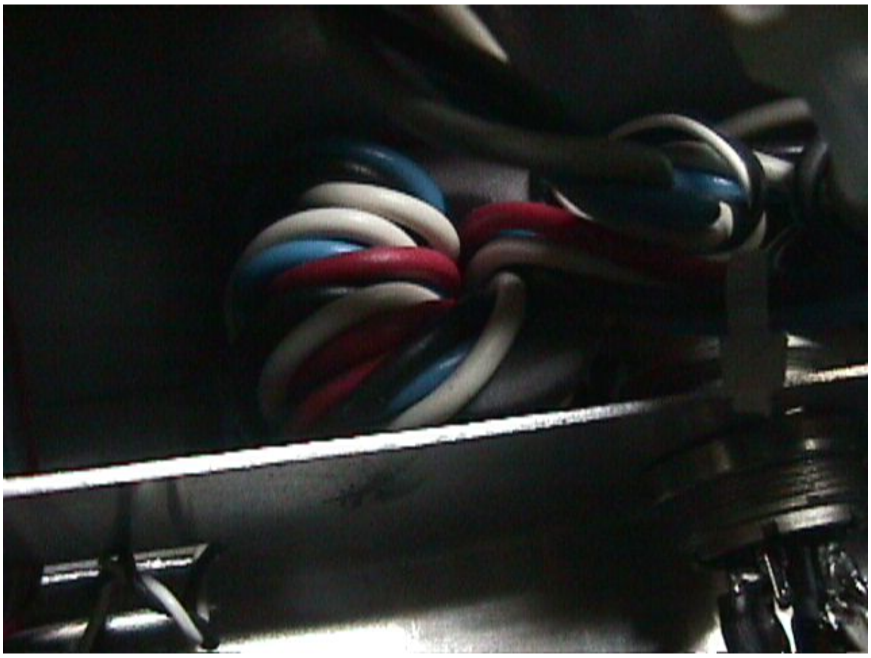

Figure 117: Ferrites to protect the LV lines against pick-up from the ***Pulser Box***: red: +12 V, blue: +5 V, white: –5 V, black: GND

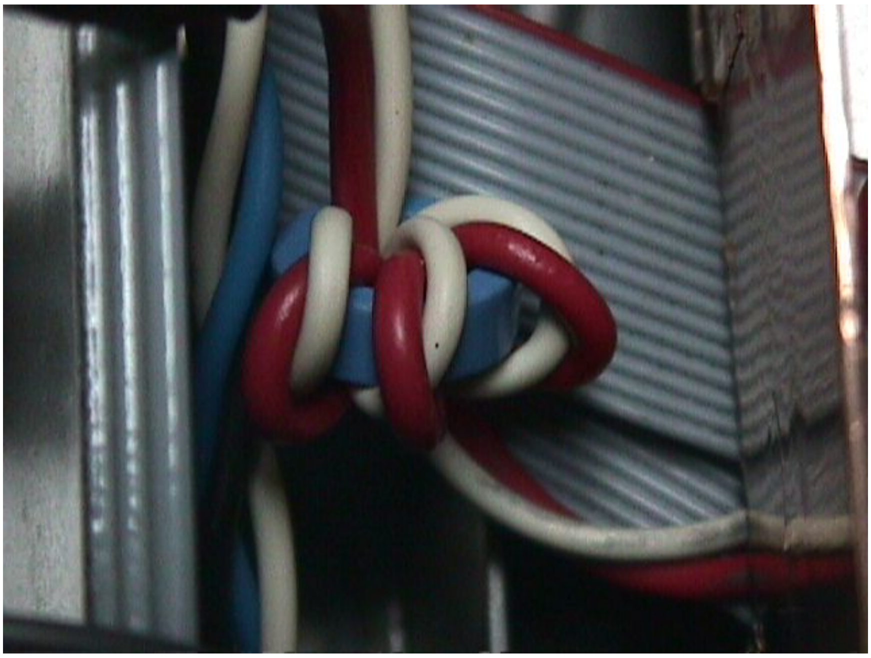

Figure 118: Ferrite to protect the ***CL*** line against pick-up from the ***Pulser Box***: red: variable voltage (0–2.2) V, white: –5 V

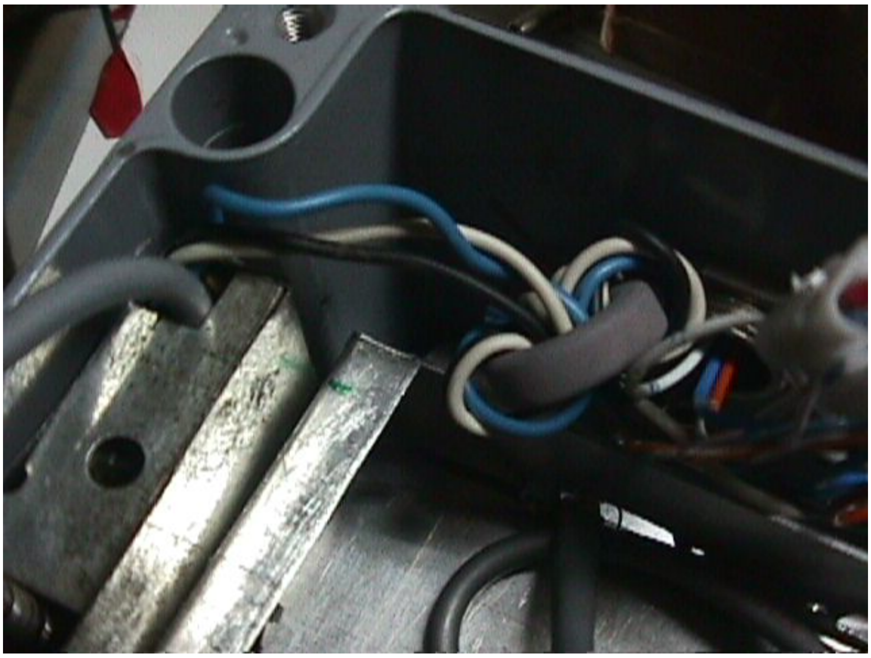

Figure 119: Ferrites to protect the ***Opt. to TTL Converter*** (left) power lines against pick-up from the ***Pulser Board***:
blue: +5 V, white: –5 V, black: GND

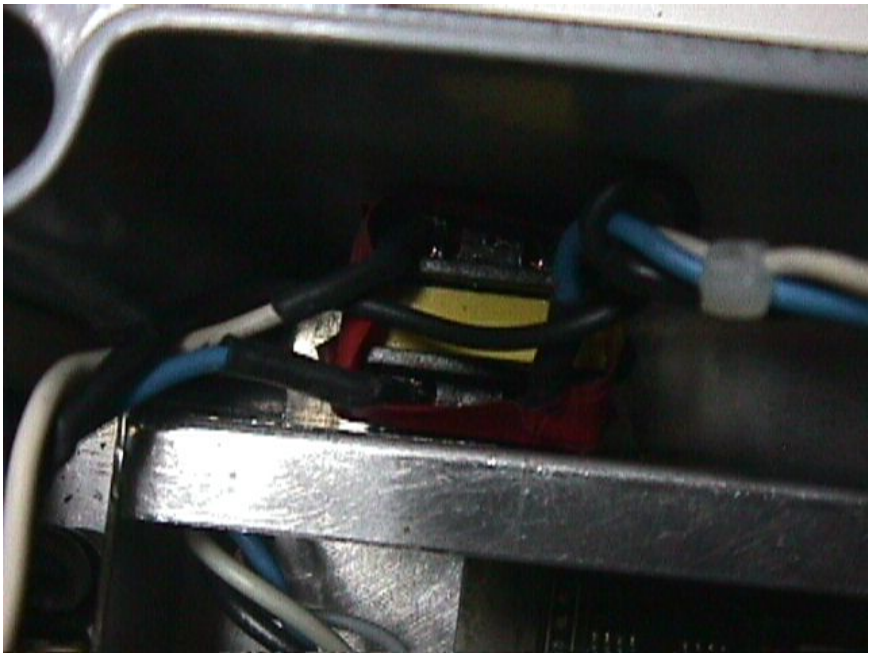

Figure 120: Coil to protect the ***Pulser Box*** power lines against pick-up from the ***Pulser Board***:
blue: +5 V, white: –5 V, black: GND

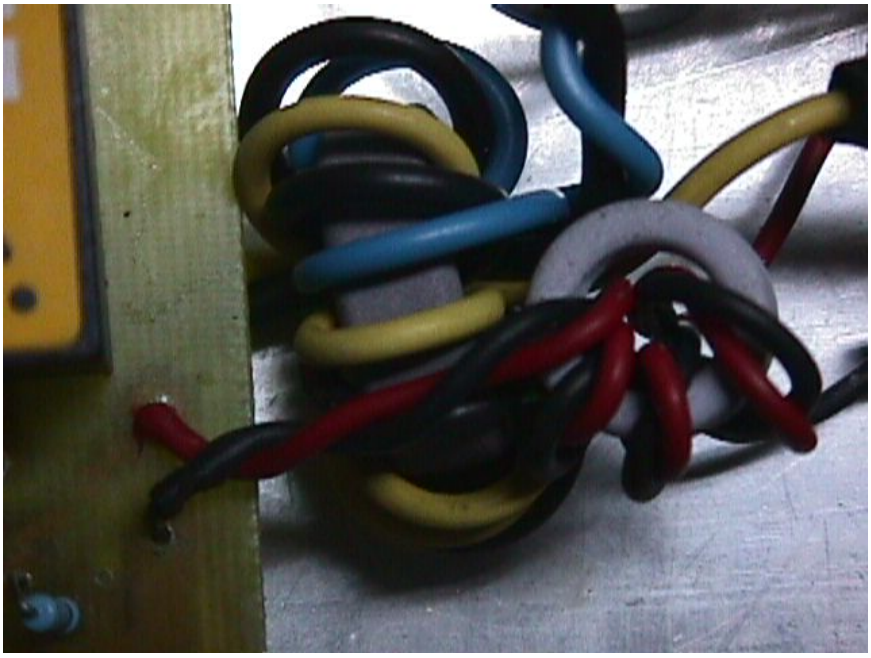

Figure 121: Ferrites to protect the ***Opt. to TTL Converter*** (left) power lines against pick-up from the ***Pulser Board*** and the switching power supply:
blue: +5 V, yellow: +12 V, black: GND, red: +600 V, black: HV–GND

Figure 122: Tubular Cable Shields to protect the ***Shift Registers*** signal lines against pick-up from the ***Pulser Board*** and the switching power supply.

12 Trouble Shooting

12.1 What to do if there are no pulses

Calibration pulses should be directly visible in the ***Central Control*** by the increase in the rate of the Level-1 trigger (usually by 500 Hz). If this increase is not observed, you can check if there are pulses coming out of the calibration box by putting on all ***Pulsed LED***s with the calibration script "MaximumVisibility_at_4KHz.txt". This script switches all pulses at the maximum allowed frequency and is clearly visible by eye from the ***Camera*** access tower at night. If you do not see a blueish light shining from the ***Center of the Mirror Dish***, the ***Pulser Board*** does not send pulses.

If you are really sure that there are no pulses, please perform the following checks:

1. **Check if you told the camera control to send pulses:** You can use the "RESET"-button on the ***Camera Control*** in order to reset the ***Calibration System***. Try again to send

2. **Check if the *Trigger Board* receives voltages:** First, check if the calibration ***Trigger Box*** is connected to power. Then, check if the white cable coming out of that box is properly connected to the ***Trigger Box***. Open the box and check if you can find +5 V (twice red), -5 V (blue) and GND (white) entering into the white cable.

3. **Check if the *Trigger Board* produces the triggers:** Take an oscilloscope and plug a LEMO cable into the empty plug labelled TTL. You should see triggers at the frequency you have chosen. If you see these triggers, take a probe and hold it at the two exits of the empty plug labelled: ECL. You should see the same frequency at *both* exits, one oscillating from -0.8 to -1.8 V and the other one vice versa.
   If you could not see the pulses at TTL, check if the connector from the I/O card in *pc*1 is properly connected to the ***Trigger Box***. If you still see no pulses, replace the ***Trigger Box*** with a spare. Repeat the test with the TTL output. If you still see no pulses, open the ***Trigger Box*** and check with the probe at the leftmost pin of the upper row of the ALTERA chip if there are pulses (at a different frequency) visible. If no, the I/O card is corrupt and has to be exchanged.
   If you see pulses at TTL, but not at ECL, most probably the translator TTL to ECL is corrupt. Exchange the ***Trigger Box*** and try again.

12.2 What to do if there is no Low Voltage in the calibration box

Fuses in the ***LV-Box*** have been installed in a way that different applications are secured via different fuses. This means that if one application has a short circuit, the rest should *continue to work* as usual even if connected to the same power supply. This is the fastest way to check if a power supply fails or an application. Before exchanging a power supply, please make sure that none of the fuses is broken.

Table 37 gives an overview over all fuses found in the ***LV-Box***. Note that one fuse is situated in the ***Cooling Box*** at the ground and can be turned ON and OFF manually. However, the rating of the fuses is such that in case of a short circuit, one of the above fuses should break first. Also note that there are fuses

Acknoledgements

Thanks to Bayarto Lubsandorzhiev for bringing the idea with the avalanche transistors to Munich. Many thanks to Guido Meucci, Nicola Turini and Ralf Stiehler for help provided for the design of the trigger electronics. Eckart Lorenz, Razmik Mirzoyan, Sascha Ostankov and David Paneque were helping throughout the whole designing process of the system. Michele Doro has been an incredible help in installing important parts of the ***Calibration System***. All other people having designed parts of the ***Calibration System*** are mentionned explicitely in the corresponding chapters.

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A Quantum efficiencies *Blind Pixel*s

The following measurements of quantum efficiencies have been performed by David Paneque (first three entries). The absorption of the used filter is taken from the data sheet delivered with the filter. An uncertainty of 1.5% has been assumed in these measurements. The last two rows give the convolution of the quantum efficiency with the absorption of the filter. The corresponding error has been propagated.

A.1 Quantum efficiency *Blind Pixel* #1

PMT serial number: 1911

Wavelength(nm.)	QE(%)	QE error (%)	Abs.filter	QE with filter(%)	QE error w.f.(%)
270	0.491	0.017	221.038	0.0022	0.00008
272	0.647	0.020	215.119	0.0030	0.00010
274	0.85	0.02	209.397	0.0041	0.00011
276	1.17	0.03	203.868	0.0057	0.00017
278	1.53	0.03	198.528	0.0077	0.00019
280	2.04	0.04	193.371	0.0105	0.00026
282	3.02	0.08	188.394	0.0160	0.00049
284	3.89	0.08	183.593	0.0212	0.00054
286	4.78	0.09	178.962	0.0267	0.00064
288	5.81	0.11	174.498	0.0333	0.00080
290	6.76	0.12	170.196	0.0397	0.00092
292	7.84	0.14	166.053	0.0472	0.00110
294	8.80	0.15	162.064	0.0543	0.00123
296	9.87	0.17	158.225	0.0624	0.00142
298	10.98	0.18	154.533	0.0711	0.00158
300	12.00	0.20	150.983	0.0795	0.00178
302	13.0	0.2	147.573	0.0881	0.00189
304	13.8	0.2	144.297	0.0956	0.00199
306	14.8	0.2	141.153	0.1049	0.00212
308	15.6	0.3	138.137	0.1129	0.00275
310	16.5	0.3	135.245	0.1220	0.00288
312	17.2	0.3	132.474	0.1298	0.00299
314	17.9	0.3	129.820	0.1379	0.00310
316	18.6	0.3	127.281	0.1461	0.00322
318	19.2	0.3	124.853	0.1538	0.00333
320	19.8	0.3	122.532	0.1616	0.00345
322	20.5	0.3	120.315	0.1704	0.00357
324	21.1	0.3	118.200	0.1785	0.00369
326	21.8	0.3	116.183	0.1876	0.00382
328	22.4	0.4	114.262	0.1960	0.00457
330	23.0	0.4	112.432	0.2046	0.00470
332	23.3	0.4	110.693	0.2105	0.00480

334	23.8	0.4	109.039	0.2183	0.00492
336	24.1	0.4	107.470	0.2242	0.00502
338	24.5	0.4	105.982	0.2312	0.00513
340	24.8	0.4	104.572	0.2372	0.00522
342	25.1	0.4	103.238	0.2431	0.00532
344	25.3	0.4	101.978	0.2481	0.00541
346	25.5	0.4	100.788	0.2530	0.00549
348	25.7	0.4	99.666	0.2579	0.00557
350	26.0	0.4	98.611	0.2637	0.00567
352	26.1	0.4	97.619	0.2674	0.00573
354	26.3	0.4	96.688	0.2720	0.00581
356	26.5	0.4	95.816	0.2766	0.00589
358	26.7	0.4	95.001	0.2811	0.00596
360	26.9	0.4	94.240	0.2854	0.00603
362	27.1	0.4	93.533	0.2897	0.00610
364	27.3	0.4	92.875	0.2939	0.00616
366	27.4	0.5	92.266	0.2970	0.00701
368	27.5	0.5	91.704	0.2999	0.00707
370	27.4	0.5	91.186	0.3005	0.00710
372	27.5	0.5	90.710	0.3032	0.00715
374	27.6	0.5	90.276	0.3057	0.00719
376	27.5	0.6	89.881	0.3060	0.00810
378	27.6	0.6	89.523	0.3083	0.00814
380	27.5	0.6	89.201	0.3083	0.00816
382	27.4	0.6	88.912	0.3082	0.00818
384	27.5	0.6	88.656	0.3102	0.00821
386	27.5	0.6	88.431	0.3110	0.00823
388	27.5	0.6	88.236	0.3117	0.00825
390	27.6	0.6	88.068	0.3134	0.00828
392	27.5	0.6	87.926	0.3128	0.00828
394	27.5	0.6	87.809	0.3132	0.00829
396	27.4	0.6	87.716	0.3124	0.00829
398	27.4	0.6	87.645	0.3126	0.00830
400	27.3	0.5	87.596	0.3117	0.00738
402	27.3	0.5	87.566	0.3118	0.00738
404	27.2	0.5	87.554	0.3107	0.00737
406	27.1	0.5	87.560	0.3095	0.00736
408	27.0	0.5	87.582	0.3083	0.00735
410	27.0	0.5	87.620	0.3082	0.00734
412	26.9	0.5	87.671	0.3068	0.00733
414	26.8	0.5	87.735	0.3055	0.00731
416	26.8	0.5	87.812	0.3052	0.00731
418	26.7	0.5	87.900	0.3038	0.00729
420	26.7	0.5	87.997	0.3034	0.00728
422	26.6	0.5	88.104	0.3019	0.00726
424	26.7	0.5	88.220	0.3027	0.00726
426	26.6	0.5	88.343	0.3011	0.00724

428	26.5	0.5	88.473	0.2995	0.00722
430	26.4	0.5	88.609	0.2979	0.00720
432	26.3	0.5	88.750	0.2963	0.00718
434	26.3	0.5	88.896	0.2959	0.00716
436	26.2	0.5	89.046	0.2942	0.00714
438	26.1	0.5	89.199	0.2926	0.00712
440	26.0	0.5	89.355	0.2910	0.00710
442	25.9	0.5	89.512	0.2893	0.00707
444	25.7	0.5	89.672	0.2866	0.00704
446	25.6	0.5	89.832	0.2850	0.00702
448	25.5	0.5	89.993	0.2834	0.00700
450	25.4	0.5	90.154	0.2817	0.00697
452	25.2	0.5	90.315	0.2790	0.00694
454	25.1	0.5	90.474	0.2774	0.00692
456	25.0	0.5	90.633	0.2758	0.00690
458	24.8	0.4	90.790	0.2732	0.00602
460	24.7	0.4	90.945	0.2716	0.00600
462	24.6	0.4	91.097	0.2700	0.00597
464	24.4	0.4	91.247	0.2674	0.00594
466	24.2	0.4	91.394	0.2648	0.00591
468	24.1	0.4	91.538	0.2633	0.00589
470	23.9	0.5	91.678	0.2607	0.00671
472	23.6	0.4	91.815	0.2570	0.00582
474	23.4	0.4	91.948	0.2545	0.00579
476	23.2	0.4	92.077	0.2520	0.00576
478	23.0	0.4	92.201	0.2495	0.00573
480	22.8	0.4	92.322	0.2470	0.00570
482	22.6	0.4	92.437	0.2445	0.00567
484	22.4	0.4	92.549	0.2420	0.00564
486	22.1	0.4	92.655	0.2385	0.00561
488	21.9	0.4	92.757	0.2361	0.00558
490	21.6	0.3	92.854	0.2326	0.00476
492	21.3	0.3	92.947	0.2292	0.00472
494	21.1	0.3	93.034	0.2268	0.00469
496	20.7	0.3	93.116	0.2223	0.00464
498	20.4	0.3	93.194	0.2189	0.00460
500	20.1	0.3	93.267	0.2155	0.00456
502	19.8	0.3	93.335	0.2121	0.00452
504	19.4	0.3	93.398	0.2077	0.00447
506	19.1	0.3	93.456	0.2044	0.00444
508	18.7	0.3	93.510	0.2000	0.00439
510	18.3	0.3	93.559	0.1956	0.00435
512	17.9	0.3	93.604	0.1912	0.00430
514	17.5	0.3	93.644	0.1869	0.00426
516	17.2	0.3	93.679	0.1836	0.00422
518	16.8	0.3	93.711	0.1793	0.00418
520	16.5	0.2	93.738	0.1760	0.00339

522	16.1	0.2	93.762	0.1717	0.00334
524	15.8	0.2	93.782	0.1685	0.00331
526	15.4	0.2	93.798	0.1642	0.00326
528	15.1	0.2	93.810	0.1610	0.00322
530	14.8	0.2	93.819	0.1578	0.00318
532	14.5	0.2	93.825	0.1545	0.00315
534	14.2	0.2	93.828	0.1513	0.00311
536	13.9	0.2	93.828	0.1481	0.00308
538	13.7	0.2	93.826	0.1460	0.00306
540	13.5	0.2	93.820	0.1439	0.00303
542	13.25	0.20	93.813	0.1412	0.00301
544	13.03	0.19	93.803	0.1389	0.00291
546	12.82	0.19	93.792	0.1367	0.00288
548	12.63	0.19	93.779	0.1347	0.00286
550	12.43	0.19	93.764	0.1326	0.00284
552	12.23	0.18	93.748	0.1305	0.00274
554	12.04	0.18	93.730	0.1285	0.00272
556	11.82	0.18	93.712	0.1261	0.00270
558	11.62	0.17	93.693	0.1240	0.00260
560	11.40	0.17	93.673	0.1217	0.00257
562	11.16	0.17	93.653	0.1192	0.00255
564	10.94	0.16	93.632	0.1168	0.00245
566	10.62	0.16	93.612	0.1134	0.00241
568	10.27	0.15	93.592	0.1097	0.00230
570	9.88	0.15	93.572	0.1056	0.00225
572	9.45	0.14	93.552	0.1010	0.00213
574	8.99	0.14	93.533	0.0961	0.00208
576	8.49	0.13	93.515	0.0908	0.00195
578	7.97	0.12	93.498	0.0852	0.00181
580	7.45	0.12	93.482	0.0797	0.00175
582	6.93	0.11	93.467	0.0741	0.00162
584	6.45	0.10	93.453	0.0690	0.00149
586	5.99	0.10	93.441	0.0641	0.00144
588	5.59	0.09	93.431	0.0598	0.00132
590	5.23	0.09	93.422	0.0560	0.00128
592	4.92	0.09	93.416	0.0527	0.00125
594	4.64	0.09	93.411	0.0497	0.00122
596	4.39	0.09	93.408	0.0470	0.00119
598	4.16	0.09	93.407	0.0445	0.00117
600	4.00	0.06	93.408	0.0428	0.00091
602	3.81	0.06	93.411	0.0408	0.00089
604	3.63	0.05	93.417	0.0389	0.00079
606	3.47	0.05	93.424	0.0371	0.00077
608	3.31	0.05	93.434	0.0354	0.00075
610	3.15	0.05	93.446	0.0337	0.00074
612	2.99	0.04	93.460	0.0320	0.00064
614	2.85	0.04	93.477	0.0305	0.00063

616	2.71	0.04	93.495	0.0290	0.00061
618	2.59	0.04	93.515	0.0277	0.00060
620	2.47	0.04	93.537	0.0264	0.00058
622	2.35	0.04	93.561	0.0251	0.00057
624	2.24	0.03	93.587	0.0239	0.00048
626	2.12	0.03	93.614	0.0226	0.00047
628	2.02	0.03	93.642	0.0216	0.00046
630	1.91	0.03	93.672	0.0204	0.00044
632	1.81	0.03	93.703	0.0193	0.00043
634	1.71	0.03	93.734	0.0182	0.00042
636	1.62	0.02	93.766	0.0173	0.00034
638	1.52	0.02	93.798	0.0162	0.00032
640	1.43	0.02	93.830	0.0152	0.00031
642	1.35	0.02	93.862	0.0144	0.00030
644	1.261	0.020	93.893	0.0134	0.00029
646	1.180	0.018	93.924	0.0126	0.00027
648	1.101	0.017	93.952	0.0117	0.00025
650	1.026	0.016	93.979	0.0109	0.00024
652	0.949	0.015	94.004	0.0101	0.00022
654	0.882	0.014	94.026	0.0094	0.00020
656	0.818	0.013	94.045	0.0087	0.00019
658	0.751	0.012	94.061	0.0080	0.00017
660	0.695	0.012	94.072	0.0074	0.00017
662	0.641	0.011	94.079	0.0068	0.00016
664	0.586	0.010	94.080	0.0062	0.00014
666	0.538	0.010	94.075	0.0057	0.00014
668	0.494	0.009	94.064	0.0053	0.00012
670	0.453	0.008	94.046	0.0048	0.00011
672	0.410	0.008	94.020	0.0044	0.00011
674	0.376	0.007	93.985	0.0040	0.00010
676	0.343	0.007	93.941	0.0037	0.00009
678	0.309	0.007	93.886	0.0033	0.00009
680	0.282	0.006	93.821	0.0030	0.00008
682	0.256	0.006	93.744	0.0027	0.00008
684	0.230	0.005	93.654	0.0025	0.00006
686	0.209	0.005	93.550	0.0022	0.00006
688	0.189	0.005	93.432	0.0020	0.00006
690	0.169	0.005	93.299	0.0018	0.00006
692	0.152	0.004	93.148	0.0016	0.00005
694	0.137	0.004	92.980	0.0015	0.00005
696	0.123	0.004	92.794	0.0013	0.00005
698	0.112	0.004	92.587	0.0012	0.00005

A.2 Quantum efficiency *Blind Pixel* #2

PMT serial number: 1611

Wavelength(nm.)	QE(%)	QE error (%)	Abs.filter	QE with filter(%)	QE error w.f.(%)
270	0.314	0.006			
272	0.384	0.007			
274	0.483	0.008			
276	0.654	0.011			
278	0.861	0.015			
280	1.18	0.02			
282	1.85	0.03			
284	2.49	0.04			
286	3.17	0.05			
288	4.01	0.07			
290	4.80	0.08			
292	5.72	0.09			
294	6.57	0.11			
296	7.55	0.12			
298	8.58	0.14			
300	9.53	0.15			
302	10.50	0.17			
304	11.36	0.18			
306	12.31	0.20			
308	13.2	0.2			
310	14.1	0.2			
312	14.8	0.2			
314	15.6	0.2			
316	16.3	0.3			
318	17.0	0.3			
320	17.7	0.3			
322	18.4	0.3			
324	19.1	0.3			
326	19.8	0.3			
328	20.4	0.3			
330	21.0	0.3			
332	21.5	0.3			
334	21.9	0.3			
336	22.3	0.3			
338	22.7	0.4			
340	23.1	0.4			
342	23.4	0.4			
344	23.7	0.4			
346	24.0	0.4			
348	24.2	0.4			
350	24.5	0.4			
352	24.7	0.4			
354	25.0	0.4			
356	25.2	0.4			

358	25.5	0.4
360	25.7	0.4
362	25.9	0.4
364	26.2	0.4
366	26.3	0.4
368	26.4	0.4
370	26.4	0.4
372	26.2	0.4
374	26.3	0.4
376	26.3	0.4
378	26.2	0.4
380	26.1	0.4
382	26.1	0.4
384	26.2	0.4
386	26.2	0.4
388	26.3	0.4
390	26.3	0.4
392	26.3	0.4
394	26.2	0.4
396	26.2	0.4
398	26.1	0.4
400	26.1	0.4
402	26.0	0.4
404	26.0	0.4
406	25.8	0.4
408	25.8	0.4
410	25.7	0.4
412	25.7	0.4
414	25.6	0.4
416	25.6	0.4
418	25.5	0.4
420	25.5	0.4
422	25.4	0.4
424	25.4	0.4
426	25.3	0.4
428	25.2	0.4
430	25.2	0.4
432	25.1	0.4
434	25.0	0.4
436	24.9	0.4
438	24.8	0.4
440	24.7	0.4
442	24.6	0.4
444	24.5	0.4
446	24.4	0.4
448	24.3	0.4
450	24.1	0.4

452	24.0	0.4
454	23.8	0.4
456	23.7	0.4
458	23.6	0.4
460	23.4	0.3
462	23.3	0.3
464	23.2	0.3
466	23.0	0.3
468	22.9	0.3
470	22.7	0.3
472	22.5	0.3
474	22.3	0.3
476	22.1	0.3
478	21.9	0.3
480	21.7	0.3
482	21.5	0.3
484	21.3	0.3
486	21.1	0.3
488	20.8	0.3
490	20.6	0.3
492	20.3	0.3
494	20.0	0.3
496	19.7	0.3
498	19.4	0.3
500	19.1	0.3
502	18.8	0.3
504	18.4	0.3
506	18.0	0.3
508	17.7	0.3
510	17.3	0.3
512	16.9	0.2
514	16.5	0.2
516	16.2	0.2
518	15.8	0.2
520	15.4	0.2
522	15.0	0.2
524	14.7	0.2
526	14.3	0.2
528	14.0	0.2
530	13.60	0.20
532	13.30	0.19
534	12.99	0.19
536	12.70	0.19
538	12.43	0.18
540	12.19	0.18
542	11.95	0.17
544	11.73	0.17

546	11.50	0.17
548	11.30	0.17
550	11.09	0.16
552	10.89	0.16
554	10.69	0.16
556	10.48	0.15
558	10.28	0.15
560	10.08	0.15
562	9.88	0.14
564	9.68	0.14
566	9.41	0.14
568	9.12	0.13
570	8.81	0.13
572	8.46	0.12
574	8.09	0.12
576	7.68	0.11
578	7.24	0.11
580	6.78	0.10
582	6.32	0.09
584	5.86	0.09
586	5.42	0.08
588	5.02	0.07
590	4.66	0.07
592	4.34	0.06
594	4.06	0.06
596	3.81	0.06
598	3.59	0.05
600	3.29	0.05
602	3.11	0.05
604	2.94	0.04
606	2.79	0.04
608	2.65	0.04
610	2.51	0.04
612	2.37	0.03
614	2.24	0.03
616	2.12	0.03
618	2.01	0.03
620	1.91	0.03
622	1.81	0.03
624	1.72	0.02
626	1.62	0.02
628	1.54	0.02
630	1.45	0.02
632	1.365	0.020
634	1.284	0.019
636	1.206	0.018
638	1.133	0.016

640	1.060	0.015
642	0.991	0.014
644	0.924	0.013
646	0.860	0.012
648	0.799	0.012
650	0.741	0.011
652	0.682	0.010
654	0.631	0.009
656	0.583	0.008
658	0.533	0.008
660	0.491	0.007
662	0.451	0.007
664	0.410	0.006
666	0.376	0.005
668	0.343	0.005
670	0.314	0.005
672	0.283	0.004
674	0.258	0.004
676	0.235	0.003
678	0.212	0.003
680	0.192	0.003
682	0.174	0.003
684	0.156	0.002
686	0.141	0.002
688	0.1279	0.0019
690	0.1140	0.0017
692	0.1027	0.0015
694	0.0928	0.0014
696	0.0832	0.0013
698	0.0757	0.0012

A.3 Quantum efficiency *Blind Pixel* #3

PMT serial number: 1613

Wavelength(nm.)	QE(%)	QE error (%)	Abs.filter	QE with filter(%)	QE error w.f.(%)
270	0.243	0.011			
272	0.270	0.011			
274	0.321	0.013			
276	0.429	0.015			
278	0.574	0.017			
280	0.82	0.02			
282	1.38	0.05			
284	1.91	0.05			
286	2.51	0.06			
288	3.26	0.06			

290	4.00	0.07
292	4.87	0.09
294	5.68	0.10
296	6.63	0.11
298	7.64	0.13
300	8.60	0.14
302	9.58	0.16
304	10.48	0.17
306	11.47	0.19
308	12.36	0.20
310	13.3	0.2
312	14.1	0.2
314	15.0	0.2
316	15.8	0.3
318	16.6	0.3
320	17.2	0.3
322	18.0	0.3
324	18.8	0.3
326	19.5	0.3
328	20.2	0.3
330	20.9	0.3
332	21.4	0.3
334	21.9	0.3
336	22.3	0.4
338	22.8	0.4
340	23.2	0.4
342	23.5	0.4
344	23.8	0.4
346	24.1	0.4
348	24.3	0.4
350	24.6	0.4
352	24.8	0.4
354	25.1	0.4
356	25.3	0.4
358	25.5	0.4
360	25.7	0.4
362	26.0	0.4
364	26.2	0.4
366	26.3	0.4
368	26.4	0.4
370	26.4	0.4
372	26.6	0.4
374	26.7	0.5
376	26.7	0.6
378	26.6	0.6
380	26.5	0.5
382	26.5	0.5

384	26.6	0.5
386	26.7	0.5
388	26.7	0.5
390	26.8	0.5
392	26.7	0.5
394	26.7	0.5
396	26.6	0.5
398	26.6	0.5
400	26.6	0.5
402	26.5	0.5
404	26.5	0.5
406	26.4	0.5
408	26.3	0.5
410	26.3	0.5
412	26.2	0.5
414	26.2	0.5
416	26.1	0.5
418	26.1	0.5
420	26.0	0.5
422	26.0	0.5
424	26.0	0.4
426	25.9	0.4
428	25.9	0.5
430	25.8	0.5
432	25.8	0.5
434	25.7	0.5
436	25.6	0.5
438	25.5	0.5
440	25.5	0.5
442	25.3	0.5
444	25.2	0.5
446	25.1	0.5
448	25.0	0.4
450	24.9	0.4
452	24.7	0.4
454	24.6	0.4
456	24.4	0.4
458	24.3	0.4
460	24.2	0.4
462	24.0	0.4
464	23.9	0.4
466	23.7	0.4
468	23.6	0.4
470	23.4	0.4
472	23.3	0.4
474	23.1	0.4
476	22.9	0.4

478	22.7	0.4
480	22.4	0.4
482	22.2	0.4
484	21.9	0.3
486	21.7	0.3
488	21.4	0.3
490	21.1	0.3
492	20.8	0.3
494	20.5	0.3
496	20.2	0.3
498	19.8	0.3
500	19.5	0.3
502	19.2	0.3
504	18.8	0.3
506	18.4	0.3
508	18.0	0.3
510	17.6	0.3
512	17.2	0.3
514	16.9	0.3
516	16.5	0.2
518	16.2	0.2
520	15.8	0.2
522	15.4	0.2
524	15.1	0.2
526	14.8	0.2
528	14.5	0.2
530	14.1	0.2
532	13.9	0.2
534	13.6	0.2
536	13.32	0.20
538	13.08	0.19
540	12.85	0.19
542	12.64	0.19
544	12.43	0.18
546	12.22	0.18
548	12.03	0.18
550	11.82	0.17
552	11.62	0.17
554	11.41	0.17
556	11.18	0.17
558	10.96	0.16
560	10.72	0.16
562	10.45	0.15
564	10.20	0.15
566	9.83	0.15
568	9.44	0.14
570	9.03	0.13

572	8.57	0.13
574	8.10	0.12
576	7.61	0.11
578	7.13	0.11
580	6.65	0.10
582	6.19	0.10
584	5.77	0.09
586	5.38	0.09
588	5.04	0.08
590	4.74	0.08
592	4.48	0.08
594	4.24	0.07
596	4.03	0.07
598	3.83	0.07
600	3.49	0.05
602	3.32	0.05
604	3.16	0.05
606	3.02	0.04
608	2.87	0.04
610	2.73	0.04
612	2.59	0.04
614	2.46	0.04
616	2.34	0.03
618	2.23	0.03
620	2.11	0.03
622	2.01	0.03
624	1.91	0.03
626	1.81	0.03
628	1.71	0.03
630	1.62	0.02
632	1.53	0.02
634	1.44	0.02
636	1.36	0.02
638	1.280	0.019
640	1.201	0.018
642	1.125	0.017
644	1.051	0.016
646	0.981	0.015
648	0.913	0.014
650	0.848	0.013
652	0.782	0.012
654	0.725	0.011
656	0.671	0.011
658	0.614	0.010
660	0.567	0.009
662	0.522	0.009
664	0.476	0.008

666	0.436	0.008
668	0.400	0.007
670	0.366	0.007
672	0.331	0.006
674	0.302	0.006
676	0.275	0.005
678	0.248	0.005
680	0.225	0.005
682	0.205	0.004
684	0.184	0.004
686	0.167	0.004
688	0.151	0.004
690	0.135	0.003
692	0.121	0.003
694	0.110	0.003
696	0.099	0.003
698	0.090	0.003

B Cornings of pixels in the ***Camera***

The following list contains an (incomplete) summary of the data and measurements taken at IFAE. The first entries document the state of the ***Camera*** before the access on July 5^{th}, 2004 and the last entries the modifications due to the exchanged pixels

	BEFORE 5 JULY 2004				AFTER 5 JULY 2004			
ID	BaseNr	PMTNr	Corning Blue	Corning Red	BaseNr	PMTNr	Corning Blue	Corning Red
1	n/a	n/a	n/a	n/a				
2	262	2307	12.0	1.6				
3	233	1701	12.2	8.7				
4	116	2003	12.6	6.8				
5	136	1521	12.7	10.3				
6	157	2047	12.8	8.7				
7	181	1879	n/a	n/a				
8	278	2151	10.8	1.3				
9	340	2301	12.0	1.	637	2334	9.0	0.4
10	235	1860	12.2	7.7				
11	236	1710	12.3	9.8				
12	51	1970	11.7	5.9				
13	118	1504	12	7.4				
14	143	1815	12.1	7.4				
15	141	1995	12	7				
16	158	1784	12.6	7.2				
17	159	1868	12.2	6.8				
18	177	1878	12.6	6.9				
19	176	1836	12.6	6.6				
20	92	1771	11.3	2.3	647	2190	11.5	1.8
21	554	1347	11.1	4.9				
22	517	1745	11.2	7.1				
23	234	1865	12.1	7.7				
24	238	2006	12.8	8.9				
25	237	1523	12.7	11.9				
26	123	2109	12.8	1.6				
27	126	2053	13	9.3				
28	131	1941	13	5.8				
29	139	1247	12	9				
30	142	1811	12.4	6.5				
31	140	1994	12	6.1				
32	161	2033	12.1	8.1				
33	19	1627	12	6.7				
34	156	2018	12.2	7				
35	269	1925	12	7.1				
36	514	1664	12.5	7.8				
37	180	2007	12.4	6.9				

38	324	1062	10.3	0.9				
39	326	1633	10.8	3.3				
40	540	1884	11.4	7.1				
41	99	1318	11.7	5.8				
42	225	1835	12.1	4.4				
43	222	1898	12	8.1				
44	224	1990	12.4	6				
45	223	1670	13	6.3				
46	129	1783	12.7	6				
47	127	2002	12.8	8				
48	122	1317	12.3	7.5	60	2191	10.5	0.6
49	124	1992	12.1	7.2				
50	144	1810	12.1	5.6				
51	145	1864	12.4	7.3				
52	146	1983	12.3	8				
53	147	1683	12.4	9.1				
54	72	2051	12.9	9.2	652	2147	11.7	1.4
55	9	1861	12.8	6.9				
56	5	1715	12	9.1				
57	160	1978	12.5	6.4				
58	251	1450	12.2	6.1				
59	249	1877	12.3	6.2				
60	245	1693	12.3	7.7				
61	243	2021	12.6	5.1				
62	525	1482	11.6	7.9				
63	482	1643	11.9	6.9				
64	31	1922	11.8	3.3				
65	325	1143	10.7	3.7				
66	323	1760	10.9	5.8				
67	230	1855	12.1	8				
68	229	1856	12.5	7.3				
69	227	1998	12.4	7.3				
70	226	1676	12.1	9.1				
71	228	1776	12.2	4				
72	132	1931	13.1	8.2				
73	138	1982	12.5	8.7				
74	137	2054	12.4	9.1				
75	135	1932	12.6	8.2				
76	133	2055	12.5	9				
77	151	1984	12.1	7.8				
78	148	1866	12.5	7.5				
79	150	2093	12.3	1.3				
80	149	1785	12	6.9				
81	152	1689	12.4	8.7				
82	32	1782	12.4	7.6				
83	69	1976	12	5.6				
84	172	2056	12.3	10.4				

85	173	1270	12.1	6.1				
86	45	2266	11.3	0.9				
87	232	1853	12	7.7				
88	246	1888	12	7.4				
89	244	2034	12.4	6.9				
90	242	2042	12.3	7				
91	247	1777	12	3.3				
92	562	1884	11.4	7.1				
93	52	1318	11.7	5.8				
94	561	1928	11.9	7.2				
95	86	1790	11.4	5.4				
96	87	1253	11.1	7.4				
97	515	1720	11.9	6.6				
98	100	1846	11.8	6.9	46	2178	9.2	0.0
99	239	1781	12.4	6.9				
100	485	1851	11.5	7.3				
101	240	1022	12.3	8.7				
102	565	1894	11	6.5				
103	241	1996	12	5.8				
104	189	2071	11.8	6.1				
105	128	1812	12.5	6.6				
106	185	1355	11.6	8.7				
107	130	1910	12.3	6.8				
108	108	1246	11.2	7.0				
109	134	1824	12.4	7.4				
110	162	1483	11.5	7.1				
111	155	1704	12.1	8.8				
112	170	1390	11	7				
113	154	1981	12.1	8.3				
114	84	1297	11.6	3.5				
115	153	1926	12	7.4				
116	567	1700	11.4	8.7				
117	179	1742	12	7.6				
118	530	1748	11.7	7.6				
119	176	1836	12.6	6.6				
120	524	1319	11.4	5.9				
121	175	1859	12.3	6.8				
122	51	2247	10.9	0.4				
123	248	1624	12.1	7.5				
124	521	1298	11.8	5.7				
125	654	2242	12.5	1.5	658	2248	12.2	1.6
126	501	1927	12.1	7.4	563	1801	11.5	6.2
127	501	1927	12.1	7.4				
128	4	1848	11.7	7.3				
129	7	1741	11.4	8.5				
130	53	1796	11.5	6.9				
131	510	1342	11.2	7.3				

132	527	1831	11.8	6.8				
133	537	2032	11.3	6.6				
134	539	1642	11.5	6.5				
135	506	1737	11.1	5.7				
136	97	1318	11.7	5.8				
137	93	1631	11.2	6.2				
138	505	1765	11.6	5.8				
139	529	1770	11.8	6.1				
140	98	1744	11.4	7.2				
141	21	1538	11.6	6				
142	107	1310	11.1	7.7				
143	109	1902	11.9	6.7				
144	110	1844	11.4	4.3				
145	102	1635	11.5	7.2				
146	103	1985	11.6	7				
147	106	1743	11.9	7.4				
148	101	1919	11	5.4				
149	169	1799	11.6	6.5				
150	168	1991	11.9	5.9				
151	167	1825	11.5	5.5				
152	166	1630	11.8	7				
153	165	1916	11.4	7				
154	163	1411	11.9	6.5				
155	164	1598	11	5.6				
156	569	1573	11.7	5.6				
157	564	1747	11.9	7.8				
158	641	n/a	n/a	n/a				
159	522	1778	11.4	5.7				
160	526	1899	11	5.9				
161	536	1924	11.9	5.9				
162	490	2083	11.6	5.8				
163	496	1883	11	6.7	645	2278	11.4	1.2
164	543	1517	11.6	7.9				
165	523	1005	11	7.7				
166	560	1519	11.6	9.5				
167	20	1719	11.4	6.4				
168	519	1766	11.5	6.6				
169	70	2070	11.9	7.1				
170	215	1345	10.9	6.3				
171	212	1604	10.8	7.4				
172	213	1274	10.3	4				
173	231	1746	10.9	6.2				
174	20	1719	11.4	6.4				
175	12	1843	11.5	3.8				
176	29	1646	11.7	7.5				
177	65	1647	11.9	8				
178	91	2040	11.6	7				

179	94	1541	10.4	6
180	486	2037	11.6	6.5
181	484	1483	11.5	7.1
182	96	1891	11.7	4.7
183	95	1944	11.6	9.7
184	528	1847	11.7	6.1
185	535	1383	11.5	6.7
186	121	1840	11.7	6.2
187	117	1820	11.6	6.7
188	115	1257	11.3	6.1
189	114	1509	11.3	4.9
190	112	1316	11.2	5.8
191	113	1819	11.5	6.4
192	30	1637	11.7	6.5
193	105	1818	11.8	7.1
194	190	1904	11.2	8.1
195	188	2084	11.9	5.5
196	186	1577	11.3	7.1
197	184	1685	11.2	6.5
198	191	1341	11	6.7
199	183	1988	11.4	7
200	187	2041	11.5	7.5
201	171	1622	11.5	6.5
202	30	1637	11.7	6.5
203	6	1962	11.6	6.8
204	82	1993	11.7	5.6
205	17	2039	11.4	6.9
206	15	1895	11.6	6.6
207	509	1789	11.3	7.4
208	572	1857	11.5	6.1
209	544	1830	11.8	6.8
210	478	1619	11.6	8.1
211	80	1829	11.9	7.6
212	22	1764	11.2	6.2
213	573	1576	11.1	6.9
214	504	1587	11.4	5.8
215	71	1753	11.6	7
216	57	1447	11.3	5.7
217	25	1804	11.5	4.1
218	401	1211	10.1	2.4
219	397	1434	9.5	1.1
220	281	1514	10	6.5
221	217	1729	10.8	5.9
222	214	1103	10.4	6.4
223	216	2029	10.4	7.3
224	221	1013	10.3	7.5
225	63	2249	11.8	1.2

226	219	1280	10.4	4.2				
227	547	1224	11.5	6.4				
228	328	116	10.3	6.9				
229	330	1393	10.3	7.1				
230	303	1016	10.6	4.4				
231	302	1752	10.8	7.4				
232	301	1539	10.6	6.9				
233	306	1489	10.5	5.3				
234	305	1301	10.5	2				
235	498	2067	11.3	6.3				
236	120	1697	11.7	7.6				
237	209	1370	10.9	8.2				
238	196	1437	10.6	9.1				
239	206	1241	10.8	6.3				
240	205	1462	10.7	5.9				
241	202	1251	10.9	7.2				
242	203	1249	10.5	5.4				
243	204	2059	10.8	9.1				
244	119	2035	11.1	5.3				
245	182	1762	11.2	5.0				
246	318	1372	10.6	7.2				
247	317	1278	10.6	4.5				
248	316	1425	10.9	5.3				
249	314	1332	10.6	9				
250	201	1736	10.3	5.9				
251	195	1335	10.6	9.1				
252	487	1012	10.7	7.4				
253	104	1842	11.5	4.8				
254	3	1972	11.8	5.5				
255	300	1733	10.8	3.9				
256	294	1594	10.4	7.1				
257	293	1239	10.6	6.3				
258	295	1281	10.6	4.3				
259	296	1492	10.5	6.2				
260	320	1260	10.3	5.1				
261	322	1428	n/a	n/a				
262	11	1291	11.4	4.9	660	2337	11.1	1.2
263	199	1392	10.7	7.8				
264	194	1256	10.9	6.3	648	2227	10.6	0.4
265	193	1582	10.5	5.7				
266	197	1867	10.7	4.2				
267	211	1261	10.3	7.8				
268	198	1264	10.2	8.6				
269	219	1280	10.4	4.2				
270	218	1079	10.2	6.7				
271	493	1727	11.4	6.7				
272	366	1414	10.9	5.2				

273	389	1322	11.5	7.1
274	385	1271	8.9	0.2
275	268	1187	8.3	1.2
276	390	1093	8.9	6
277	341	2159	13.7	4.1
278	384	1002	8.4	0.9
279	396	1349	9.6	1.7
280	392	1767	10	6.8
281	400	1074	9	3.8
282	360	2129	12.2	1.8
283	382	1092	9.9	6.3
284	398	1487	9	4.1
285	395	1772	10	2.4
286	394	2058	10.1	7.2
287	391	1735	9.5	2.2
288	393	1757	10	6.6
289	304	1486	10.8	6.1
290	329	1803	10.8	2.6
291	327	1499	10.3	5.2
292	266	2199	11.6	1.4
293	309	1221	9.8	4
294	310	1325	10.1	2.6
295	312	1327	9.8	3
296	311	1376	9.6	6.6
297	308	1364	9.2	7.6
298	307	1379	9.7	5.6
299	210	1371	10.2	7.3
300	210	1371	10.2	7.3
301	208	1385	10.9	7.8
302	378	2114	12.1	1.5
303	256	1357	10	3.3
304	258	2089	9.8	0.6
305	255	1478	9.6	5.9
306	321	1980	10.9	7.0
307	319	1401	10.3	6.3
308	315	1303	10.2	3.9
309	254	1329	9.4	2.4
310	253	1222	9.8	5.8
311	212	1604	10.8	7.4
312	380	2116	12.3	1.5
313	275	1225	9.6	4.1
314	257	1455	9.5	4.5
315	279	1465	9	4.5
316	297	1387	10.3	6.6
317	298	1412	10.4	6
318	299	1485	10.9	6
319	282	1951	9.9	8.8

320	276	1554	10	5.6				
321	259	1275	10.1	4.1				
322	387	1038	8.1	4.6				
323	356	2131	12.1	1.4				
324	277	1331	10.1	2.1				
325	280	1989	10.1	5.5				
326	260	1199	9.3	3.4				
327	274	1474	10.1	6				
328	261	1107	9.4	3.6				
329	273	1058	9.6	7.3				
330	313	1408	10.6	6.4				
331	200	1054	10.7	7.1				
332	8	1020	10.2	8.1				
333	332	2134	11.5	1.1				
334	334	2144	11.9	2.8				
335	371	2118	11.9	1.3				
336	358	2122	11.8	1.6				
337	352	2121	13.1	1.6				
338	372	2119	10.9	1.6				
339	286	2207	10.4	1.1				
340	289	2208	11.7	1.3				
341	290	2211	11.5	1.3				
342	284	1206	10.6	1.2				
343	383	2069	10.5	8.1	34	2162	9.5	0.6
344	381	1515	11.5	8				
345	338	2149	11.9	1.9				
346	368	n/a	n/a	n/a				
347	345	2152	10.3	2.4				
348	361	1059	8	1.4				
349	388	1612	11	6.1				
350	359	2130	12.1	1.9				
351	377	2113	12.0	1.6				
352	350	2180	12.1	1.5				
353	333	2146	11.2	1.0				
354	373	2185	11.2	1.4				
355	336	2271	12.4	1.3				
356	287	2275	11.0	1.1				
357	335	2135	11.6	1.1				
358	291	2203	11.4	1.4				
359	283	2200	10.6	1.8				
360	288	2274	11.0	1.1				
361	272	2195	11.8	1.6				
362	263	2197	12.4	1.4				
363	376	2184	12.4	1.4				
364	362	117	12.2	7.9				
365	346	2173	9.8	2.0				
366	374	2182	11.7	1.4				

367	364	121	9.8	7.6				
368	354	2126	11.4	1.1				
369	351	2123	12.0	1.4				
370	357	2132	11.7	1.3				
371	355	2127	10.9	0.8				
372	370	2217	11.2	3.4				
373	339	2150	10.6	0.9				
374	365	1367	10	6.2				
375	292	2204	10.0	0.4				
376	265	2198	10.6	1.1				
377	342	2214	11.2	1.4				
378	369	2216	12.0	1.2				
379	285	2201	11.3	1.4				
380	347	2179	12.5	2.2				
381	344	2161	12.0	2.0				
382	375	2181	11.4	1.6				
383	267	2187	12.0	2.2				
384	386	1936	13.6	8.5				
385	353	2124	12.6	1.9				
386	270	2188	10.9	1.0				
387	379	2115	12.0	1.8				
388	363	1052	10	5.8				
389	343	2163	11.5	1.7	89	2268	11.4	1.1
390	337	2148	11.6	2.4				
391	348	2152	10.3	2.4				
392	399	1042	8.5	4.6				
393	349	2176	11.7	1.2				
394	367	1231	n/a	n/a				
395	264	2192	12.1	1.2				
396	271	2194	11.9	2.0	10	2255	10.5	0.6
397	331	2133	12.1	1.5				
398	416	400	11.4	11.9	78	466	9.5	1.0
399	580	361	9.9	6.8				
400	465	282	12.9	17.4				
401	556	420	12.4	18.6				
402	423	303	11.3	2.3				
403	437	371	10.8	7.7				
404	403	251	11.2	2.2				
405	451	445	9.2	4.6				
406	438	393	10.7	4				
407	512	314	13.6	11.7				
408	470	111	11.6	5				
409	610	291	11.2	10.6				
410	434	384	11.1	17.7				
411	520	309	11.6	6.9				
412	624	235	10.4	6.3				

413	599	335	12	6.7
414	508	318	12	1.9
415	432	369	10.6	15.8
416	618	231	11.2	4.9
417	404	428	11.6	24.7
418	581	357	10.2	12
419	582	399	11.3	9.7
420	583	375	9.1	19.3
421	427	382	11.6	13
422	620	230	11	1.6
423	459	462	10.6	4.4
424	571	354	12.5	2.8
425	578	376	12	16.5
426	588	287	n/a	n/a
427	532	313	11.5	8.1
428	608	302	11.2	1.7
429	450	453	10.2	6.2
430	566	348	11.8	8.1
431	469	411	10.8	14.5
432	584	358	11.1	2.5
433	607	387	11	12.9
434	623	242	11.5	7.4
435	612	297	11.9	7.9
436	476	260	9.5	5.1
437	614	164	11.3	6.5
438	442	443	11.2	12.3
439	402	286	11.4	8.4
440	615	234	10.1	2.2
441	590	178	11	5
442	489	170	10.8	2.9
443	414	427	9.3	10.4
444	611	345	12.6	13.1
445	593	173	9.9	5.6
446	473	401	9.8	8.0
447	605	390	10.4	5.9
448	597	341	11.3	8.1
449	435	353	12	6.8
450	503	338	11	6.9
451	440	366	11.7	12.3
452	457	332	12	9.1
453	441	368	9.1	2.7
454	619	238	11.2	2.7
455	419	415	10.6	4.2
456	534	306	12.3	4.9
457	417	416	10.9	10.9
458	483	339	9.7	7.2
459	436	352	11.2	18.3

460	462	285	12.2	6.1
461	616	250	12.5	7.7
462	626	239	9	2.7
463	456	469	11.6	17.6
464	533	308	11.3	3.8
465	454	398	10.8	12.6
466	495	442	10.7	9.3
467	455	328	12.1	9.2
468	541	134	11.9	7
469	466	117	12.2	7.9
470	609	292	11.6	14.6
471	574	441	11.5	13.6
472	513	133	10.3	0.9
473	475	118	11.8	8.1
474	559	442	10.7	9.3
475	410	252	10.4	3
476	430	426	11.9	24.7
477	621	295	11.2	19.5
478	595	180	10.7	6.2
479	551	452	10.4	6.9
480	594	436	10.4	11.7
481	426	380	11.3	11.3
482	477	267	11.6	7.3
483	443	457	10.1	12.8
484	420	406	9.4	11.3
485	464	275	12.3	3.9
486	407	290	11.2	4.4
487	549	451	9.6	5.9
488	622	435	10.5	7.3
489	630	245	11.7	7.1
490	463	279	10.5	1.4
491	422	372	11.5	12.6
492	601	389	10.4	9.6
493	596	350	12.1	10.7
494	516	320	13	13.5
495	568	344	10.9	1.9
496	439	356	11	9.8
497	433	351	11	5.6
498	507	324	12.5	6.2
499	460	329	12.3	14
500	518	322	12.8	5.4
501	545	326	12.2	8.4
502	603	365	10.6	16.2
503	461	470	11.6	15.1
504	449	404	11.6	9.7
505	431	379	11.6	13
506	471	367	10.9	12.3

507	531	327	11.9	7.4				
508	488	340	n/a	n/a				
509	629	244	12.1	7.2				
510	613	296	12.4	9.6				
511	421	410	11.6	21.1				
512	445	421	10.2	2.3				
513	625	438	11.4	13.5				
514	446	423	11.9	14.3				
515	444	455	9.6	3.5				
516	474	278	11.1	6.7				
517	576	346	n/a	n/a				
518	558	123	9.7	6.2				
519	467	262	12.4	8.3				
520	560	405	9.6	6.3				
521	591	175	10.6	5.8				
522	479	439	10.3	4.6				
523	555	273	11.1	1.8				
524	600	349	10.7	6.2				
525	425	304	13.3	11.1				
526	480	461	9.7	1.8				
527	592	151	10.8	5.4				
528	497	289	n/a	n/a				
529	448	281	12.3	12.9				
530	557	276	12.6	4.3				
531	453	330	11.9	15.5				
532	499	307	n/a	n/a				
533	548	311	10.2	3.2				
534	491	454	11	9.9				
535	428	305	10.8	4.8				
536	472	401	9.8	8				
537	577	446	11.6	9.9				
538	632	203	10.8	4.4				
539	640	187	9.9	5.6				
540	546	321	12.4	13.5				
541	447	436	10.4	11.7				
542	424	383	11.6	18.7				
543	617	255	11.1	6.5				
544	598	385	10.5	11.7				
545	413	223	11.1	12.7				
546	589	310	n/a	n/a				
547	570	347	11.6	7.3				
548	553	402	11.2	14.9				
549	586	378	9.7	6.8				
550	585	394	11.3	12.3	50	176	10.9	4.8
551	587	377	11.7	7.1				
552	452	349	10.7	6.2				
553	627	440	10.2	2.3				

554	412	403	11.1	16.9				
555	494	317	n/a	n/a				
556	602	373	11.8	14.6				
557	511	325	12.2	20.5				
558	492	396	10.5	7				
559	502	316	11.1	6.6	36	188	11.2	5.7
560	631	225	10.1	6.6				
561	606	294	12.3	13.5				
562	552	274	11.6	11				
563	458	397	9.9	4.2				
564	579	362	10.5	10.6				
565	418	418	11.3	6.5				
566	542	132	11.8	6.5				
567	411	240	10.7	1.7				
568	415	414	11.1	8.2				
569	406	247	11.8	5.1				
570	575	152	10.5	5.6				
571	604	293	11.8	9.1				
572	409	249	9.6	0.6				
573	429	370	11.1	19.1				
574	628	444	11	5.7				
575	408	246	11.8	6				
576	468	127	11.4	3.9				
577	405	248	10.2	2.6				

C Electronic Circuits

C.1 *Pulser Board*

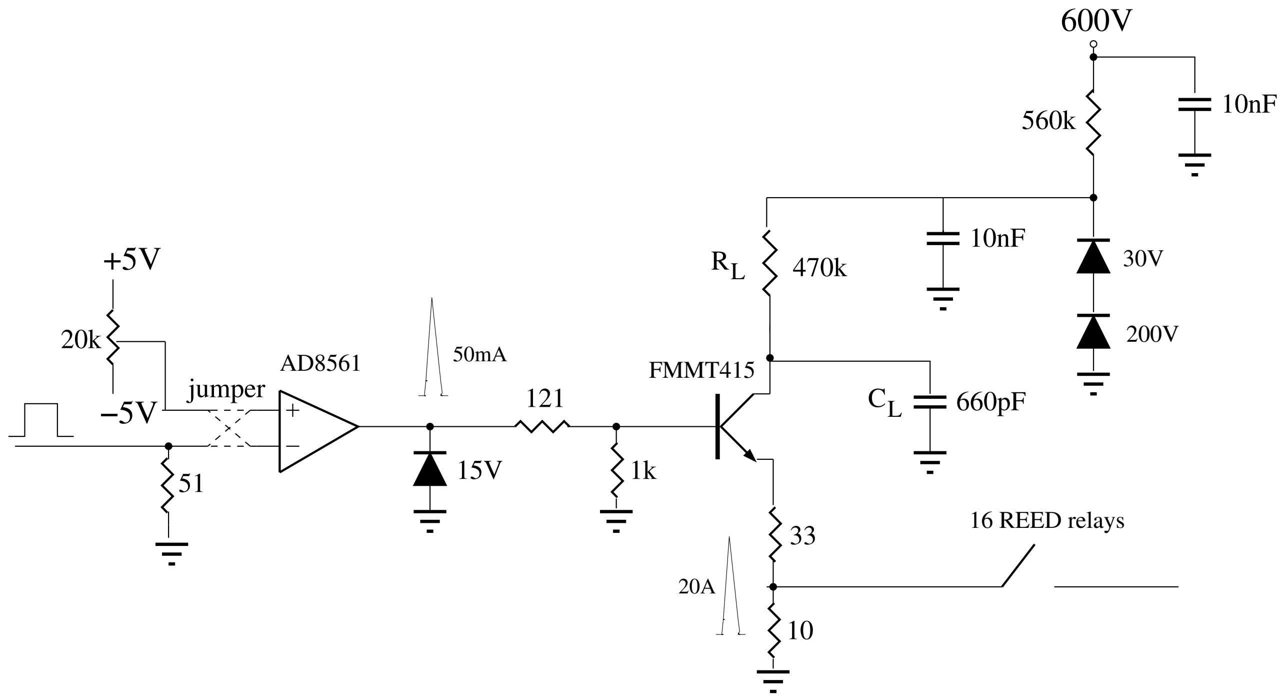


Figure 123: Schematic of the trigger circuit in the ***Pulser Board***: A TTL or NIM signal switches the comparator AD8561 (the polarity is interchangeable with two jumpers). When the comparator changes its state, the ***Avalanche Transistor*** FMMT415 gets switched. (with collector voltage held at 230 V by the zener diodes. The transistor switch discharges the capacitors C_L creating a very fast signal of about 1–2 ns with an amplitude of about 180 V. This signal travels to the 16 ***Pulsed LED*** slots which get switched depending on whether the corresponding relay is closed.

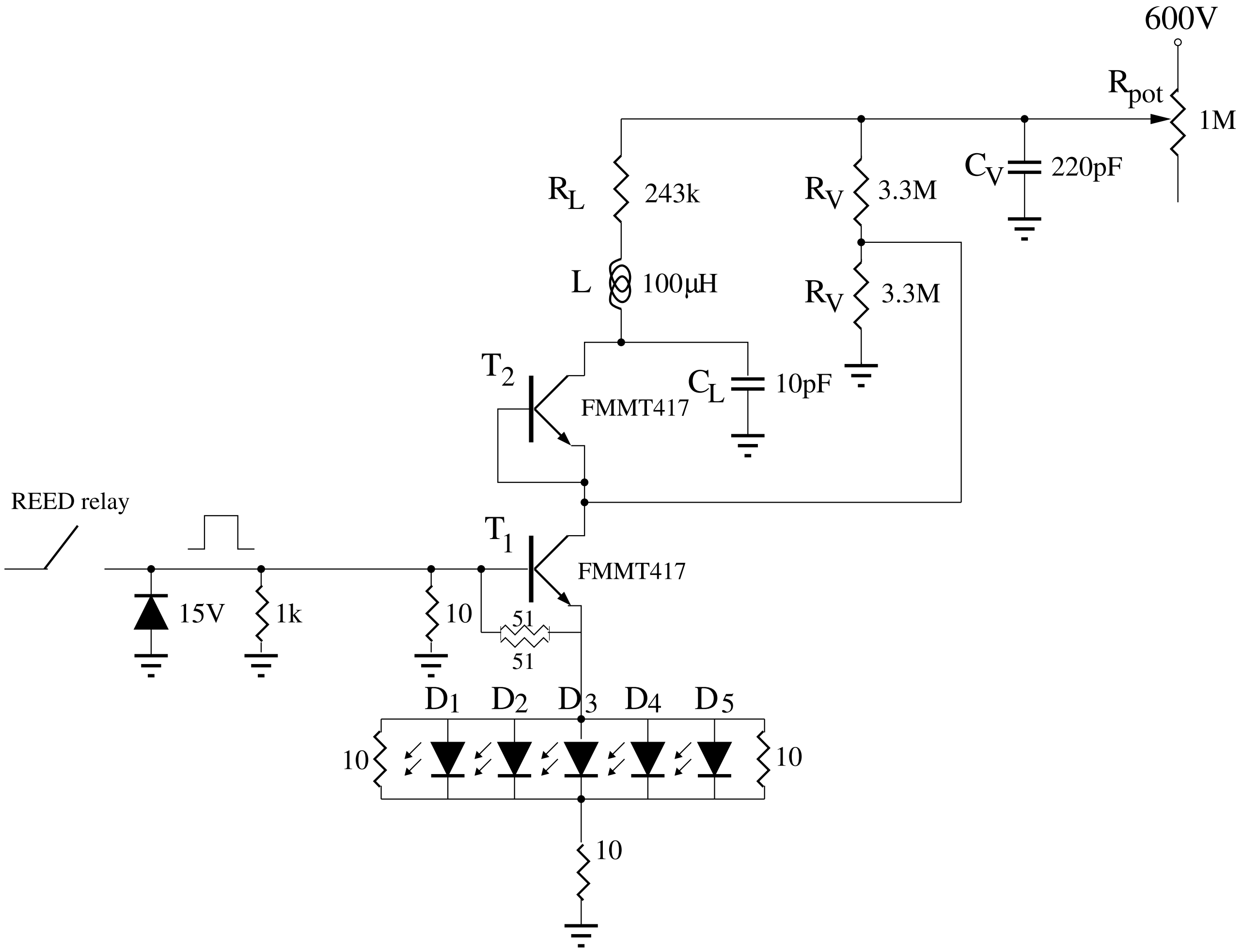
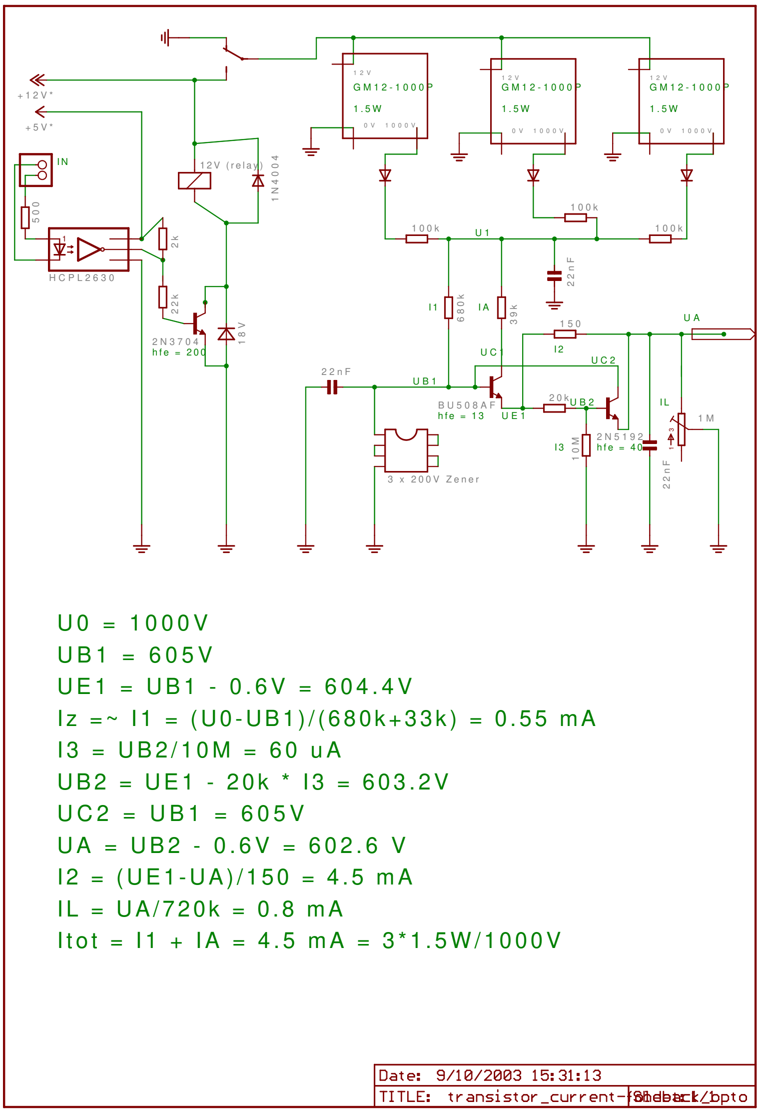


Figure 124: Schematic of the ***Avalanche Transistor*** Circuit (one slot): A fast signal switches the avalanche transistor T_1, with collector voltage held at 300 V by the voltage divider R_V. The transistor switch causes T_2 to break through, discharge capacitor C_L and drawing some current through the load resistance R_L and thus through the diodes D_1 to D_5. (Note that in some slots, only 1,2 or 4 diodes are situated). The response time of transistor T_2 depends on the collector voltage and can be adjusted with R_{pot}. This way, different slots can be synchronized in time. After about 2 ns, the transistor has recovered and the circuit is closed again. Values for R_L, C_L, R_V and R_{pot} are given for the blue and green ***Pulsed LED*** slots. The slots housing UV LEDs have the following values: $R_L = 100k$, $C_L = 33pF$, $R_V = 2.2M$, $R_{pot} = 500k$.

C.2 Voltage Supply Boards



( )

Figure 125: Schematics of the ***600V Supply***

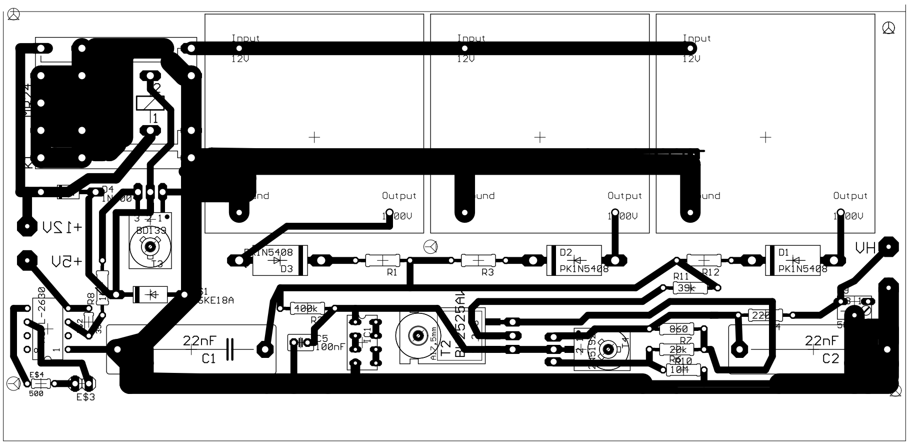


Figure 126: The ***600V Supply*** Board

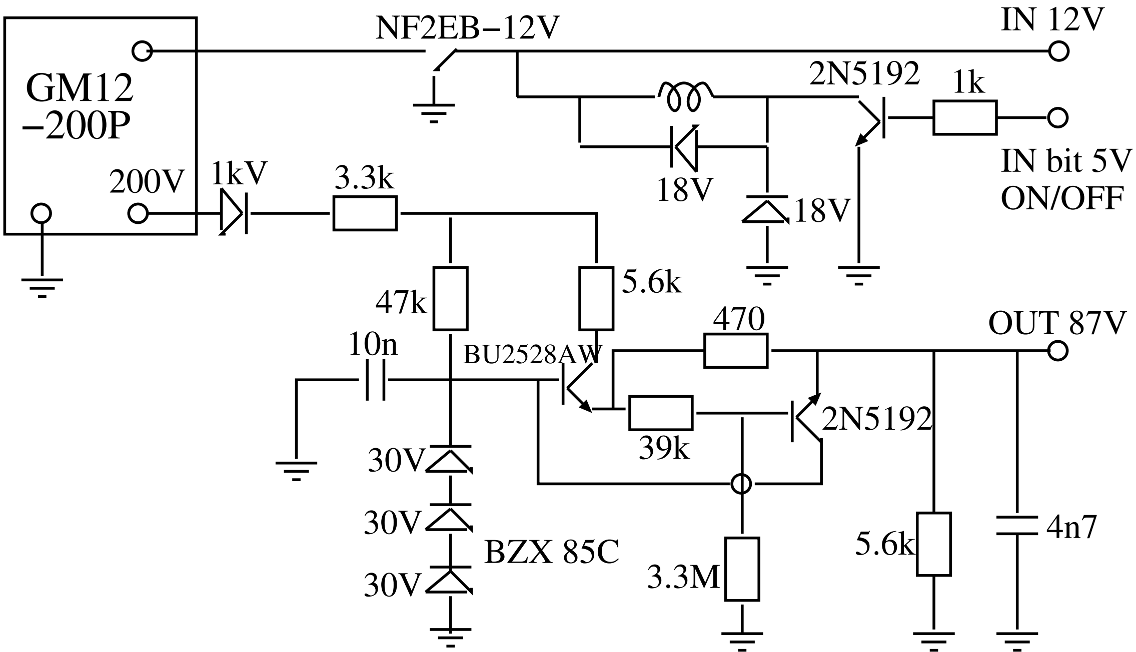
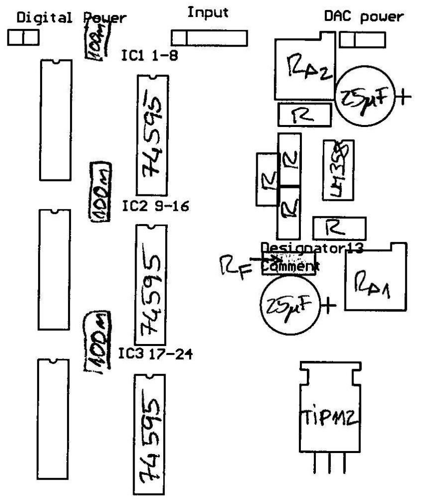


Figure 127: Schematics of the ***90V Supply***

C.3 *Shift Register Board*



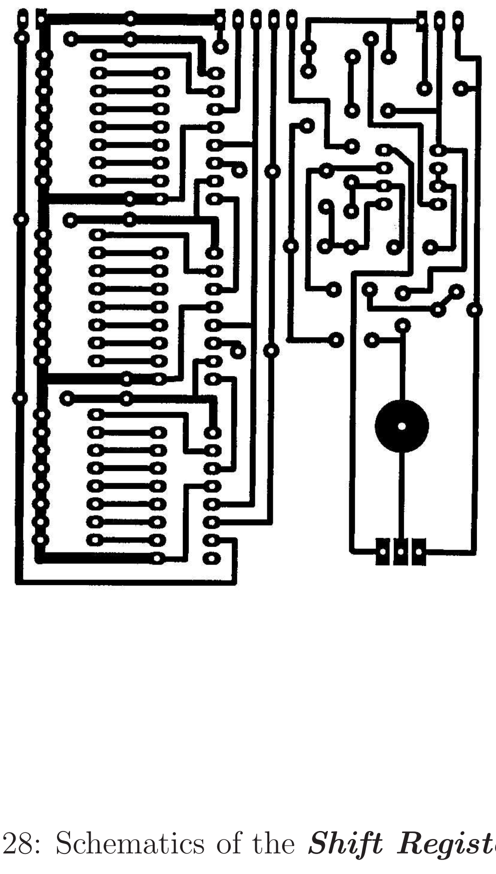


Figure 128: Schematics of the ***Shift Register Board***

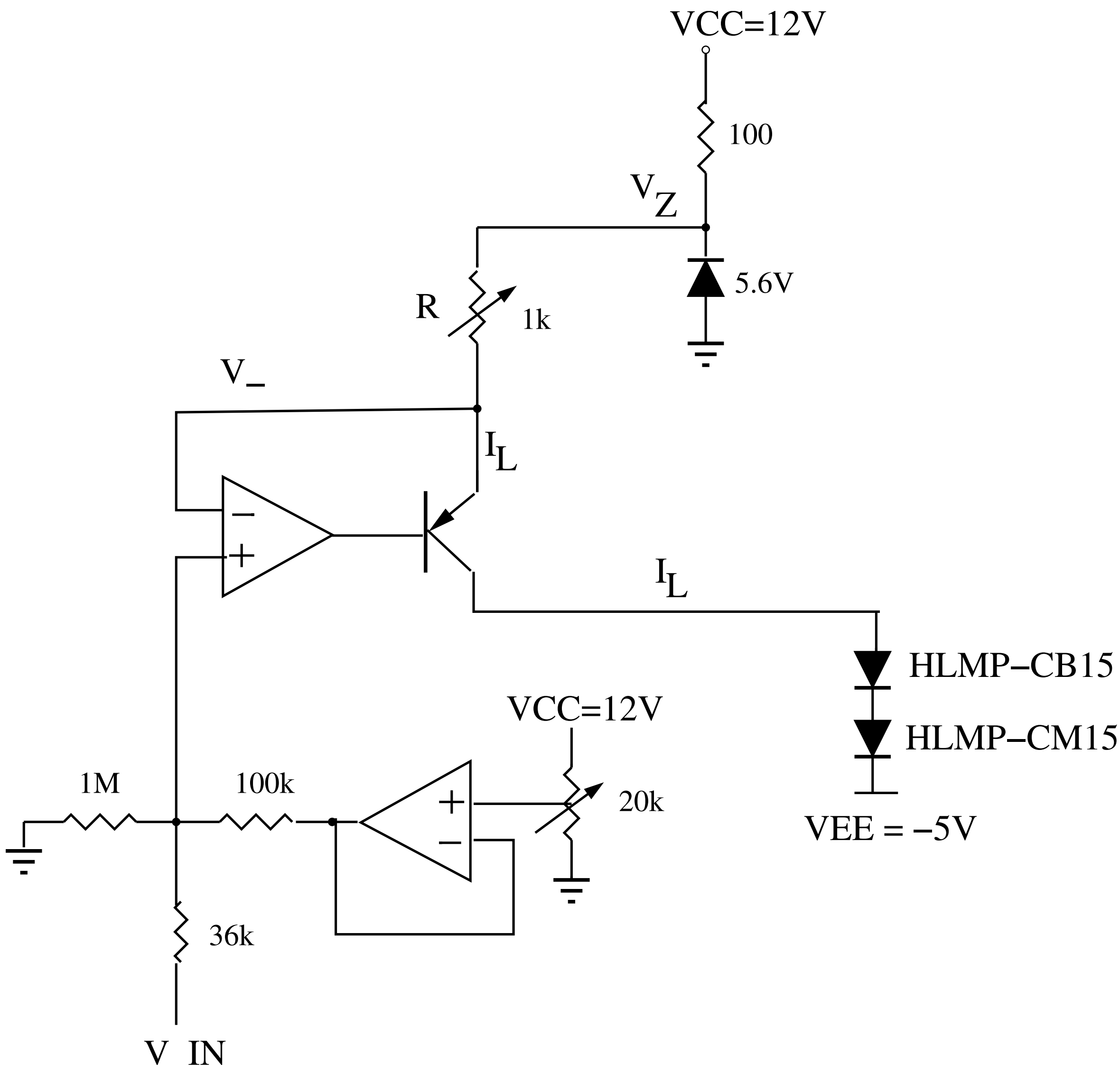


Figure 129: Schematic of the ***CL*** Circuit on the ***Shift Register Board***. The ***DAC*** voltage V_{IN} varies between 0 and 2.5 V. The resistencies on both sides of the non-inverting input of the OP-AMP shift this voltage (linearly) to reach about 5.6 V at its highest level. This fixes the voltage V_{-} of the inverting input which drives a current $I_L = (V_Z - V_{-})/R$ through the potentiometer R. The OP-AMP feedback is ensured by the use of a PNP transistor which transmits the current to the blue and the green LED with variable voltage. Note that at the highest current ($\sim$30 mA), the voltage drop over the two LEDs makes $\sim$7.4 V.

C.4 *Blind Pixel*

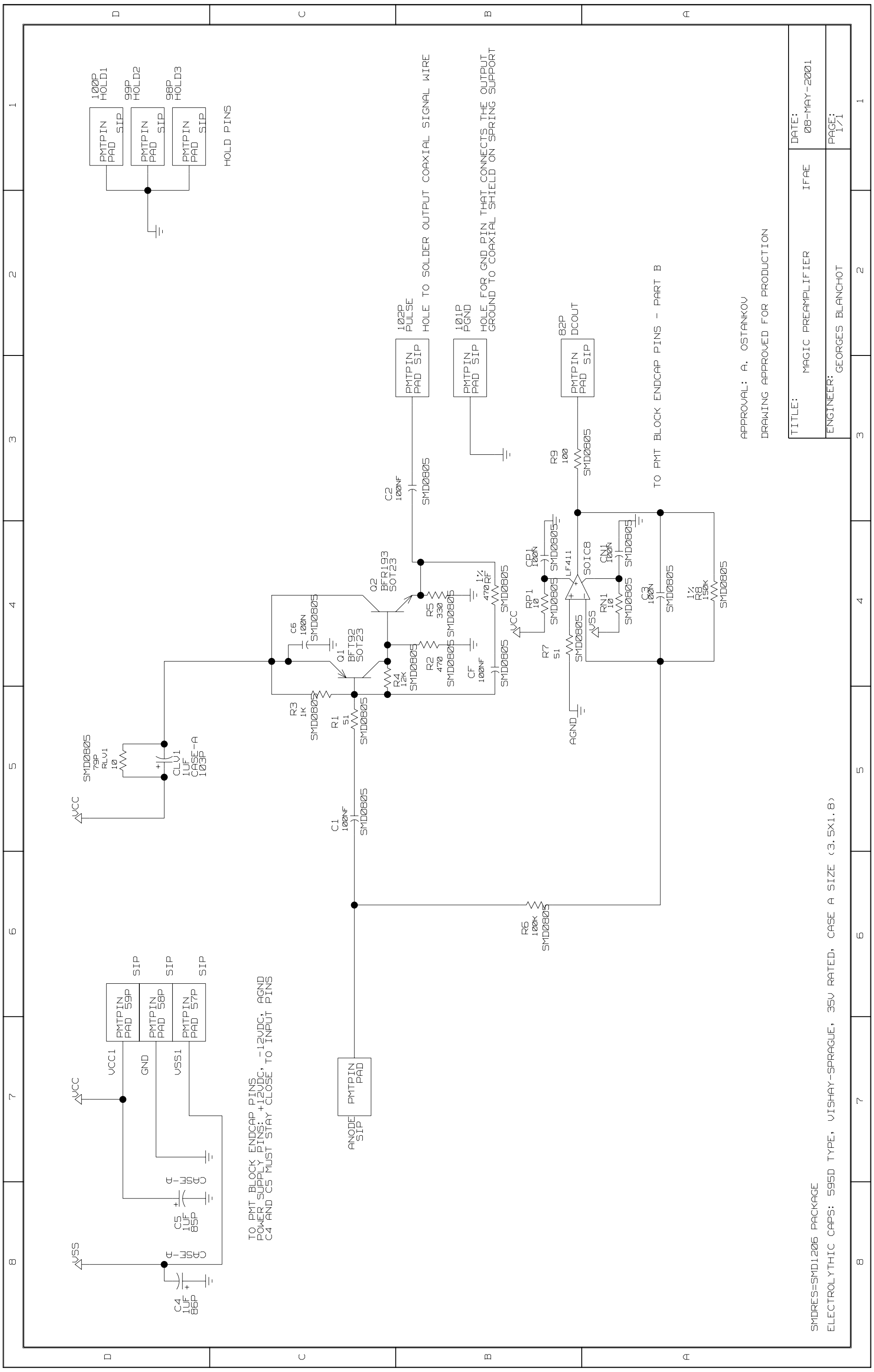


Figure 130: Schematics of the modified pre-amplifier used for the ***Blind Pixel***s: The lower part reading the DC-currents has been replaced by a simple 1 MΩ connection to ground. Additionally, the 470 Ω resistancy RF has been replaced by a 1.2 kΩ resistancy, thus triplicating the gain.

C.5 *PIN-Diode Box*

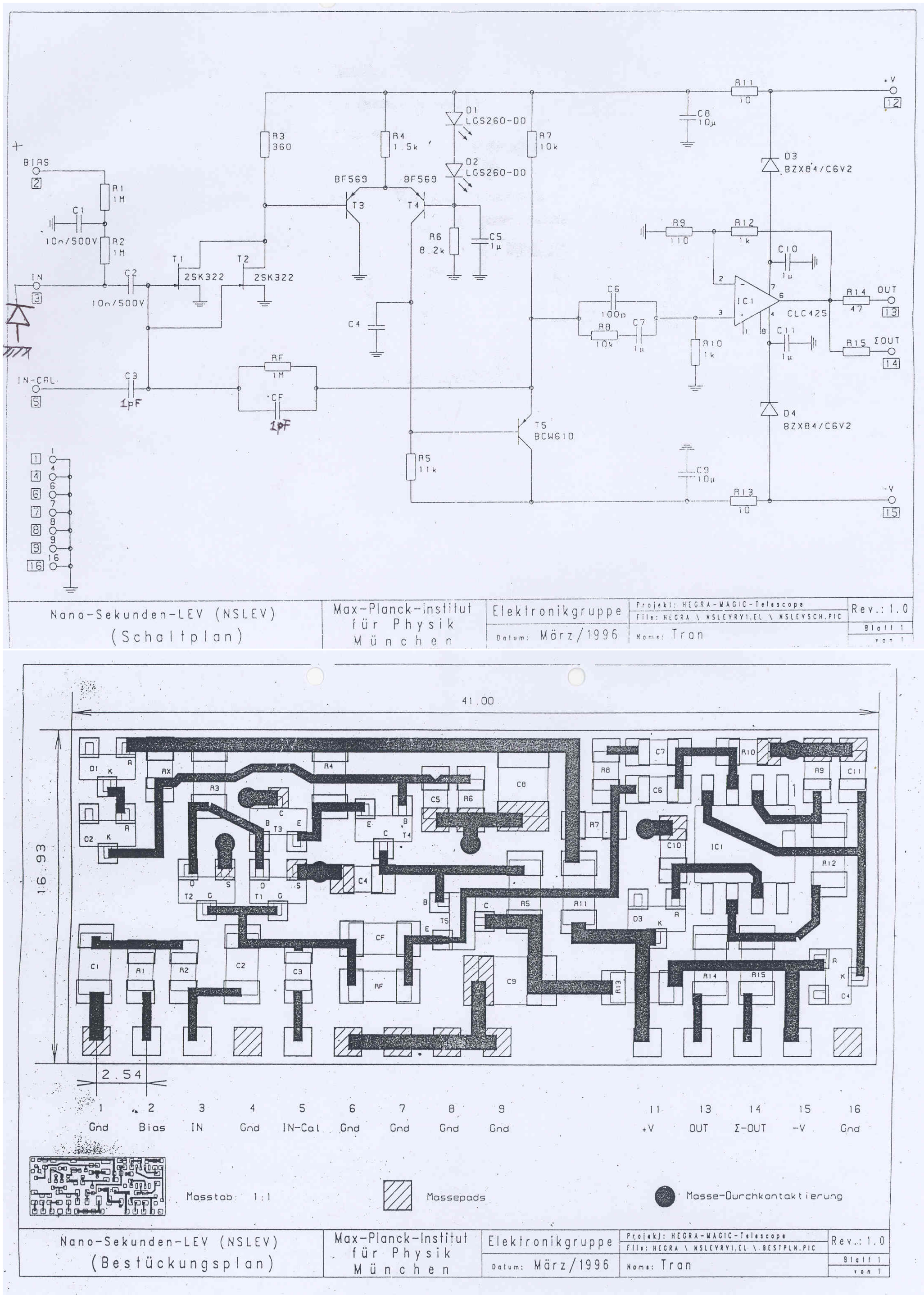


Figure 131: Schematics of the ***Nano-Second Amplifier*** used for the ***PIN-Diode***

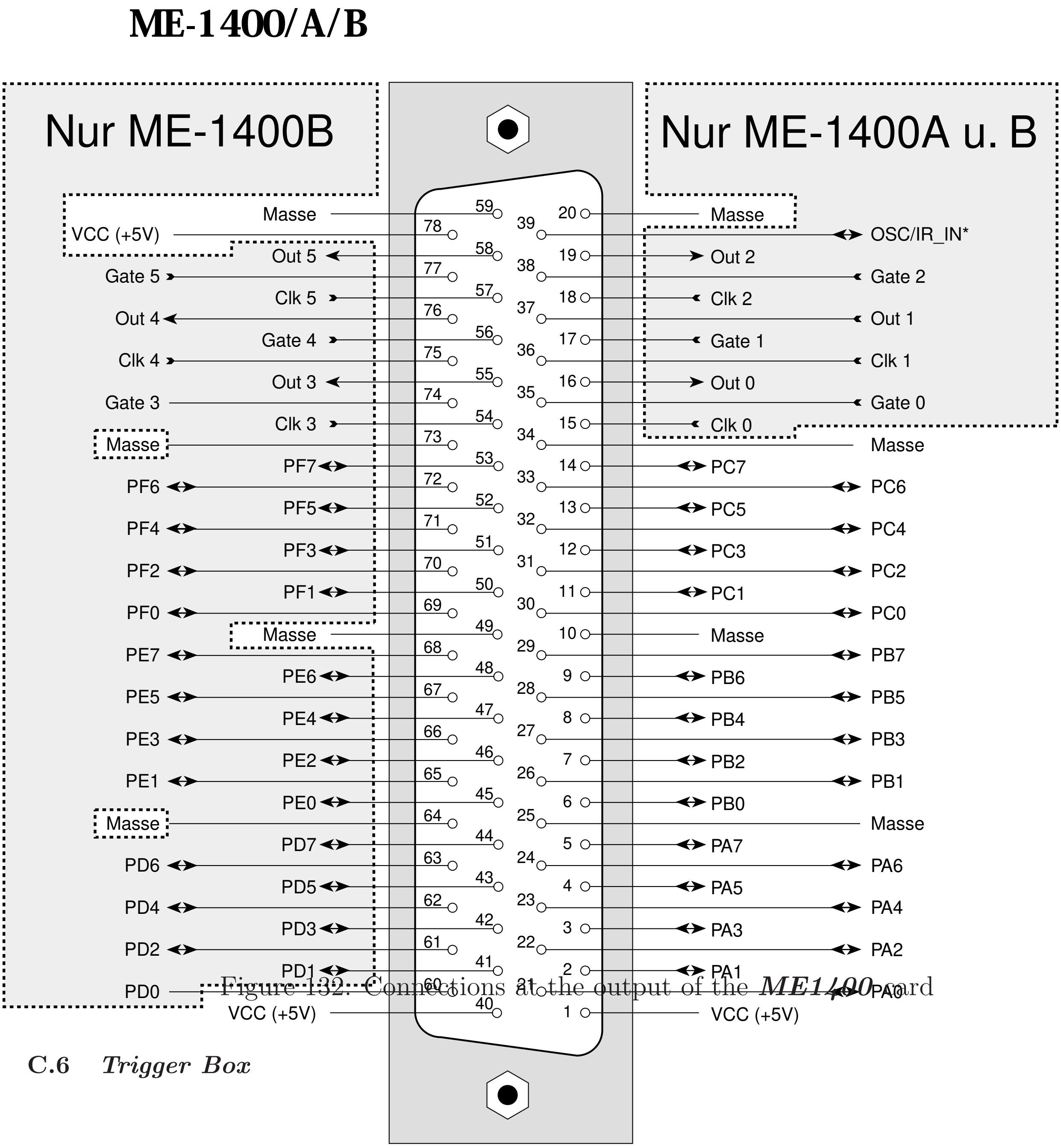
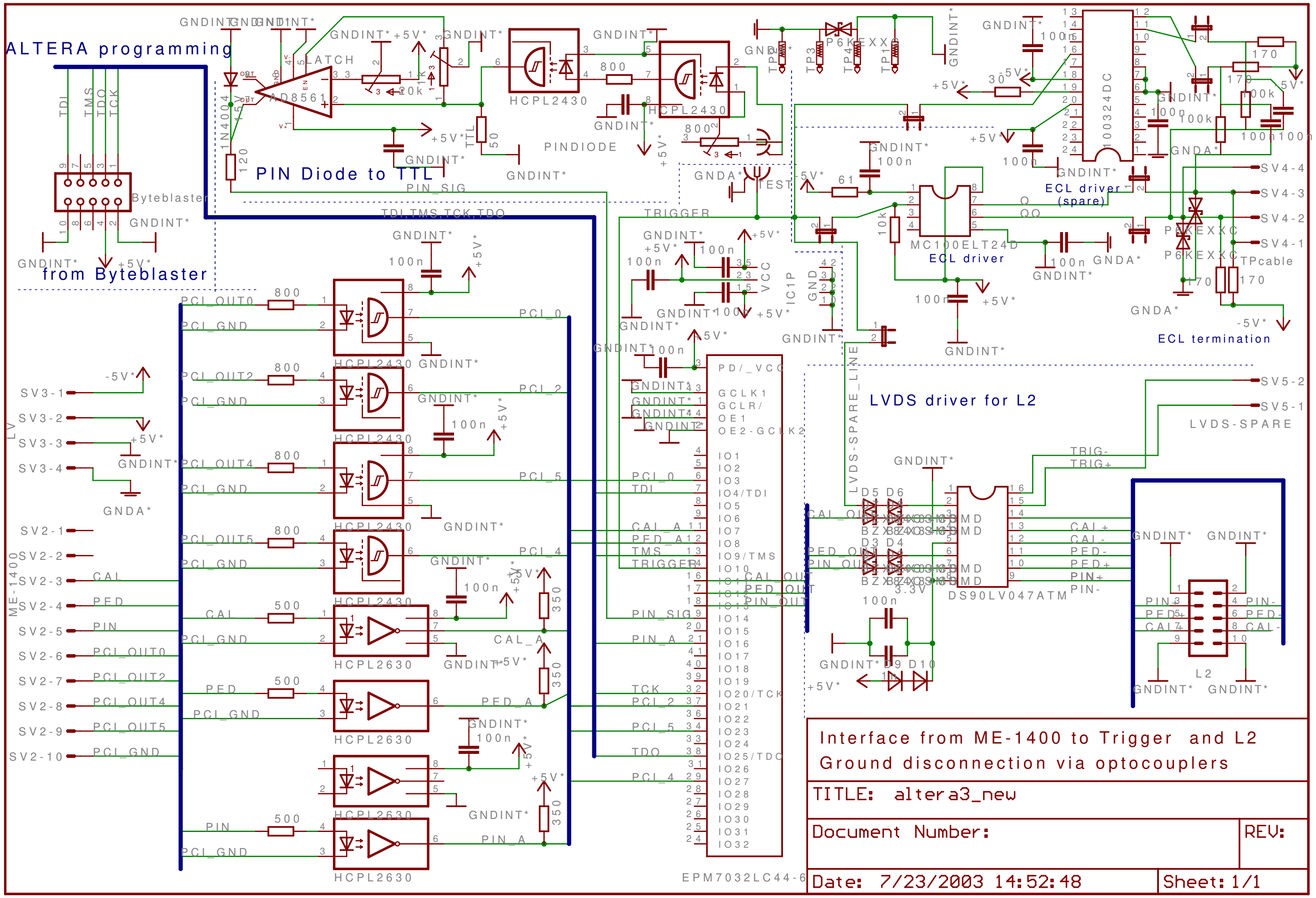


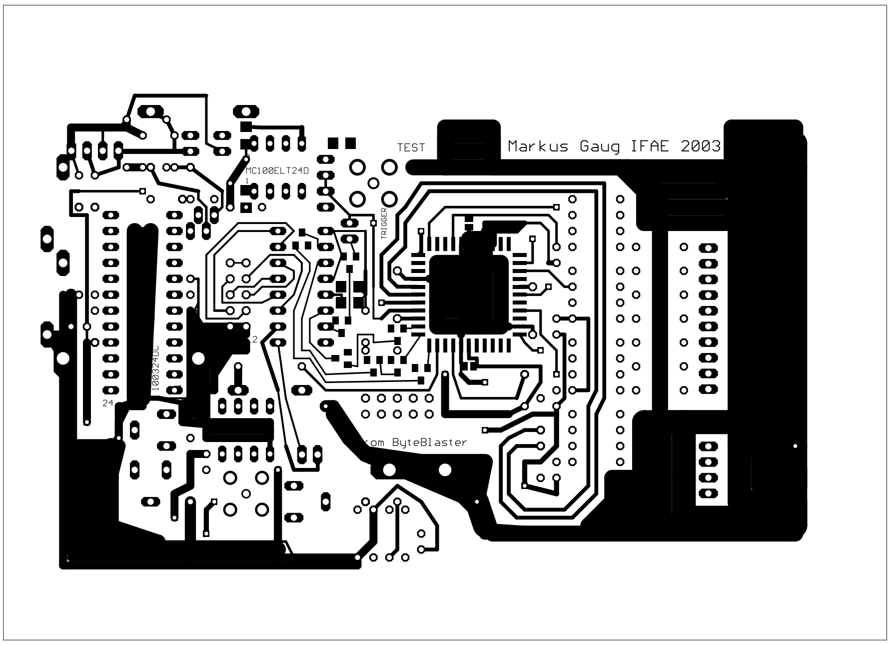
Figure 132: Connections at the output of the *ME1400* card

C.6 *Trigger Box*



9/05/2003 18:11:49 f=0.93 /mnt/users/markus/eagle/Board_Altera/altera3_new.sch (Sheet: 1/1)

Figure 133: Schematics of the ***Trigger Board***



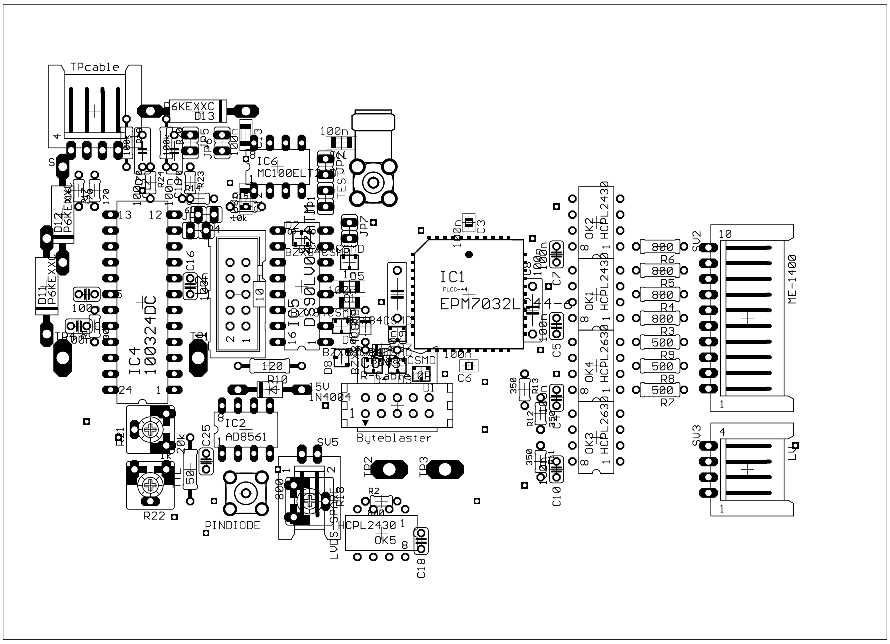
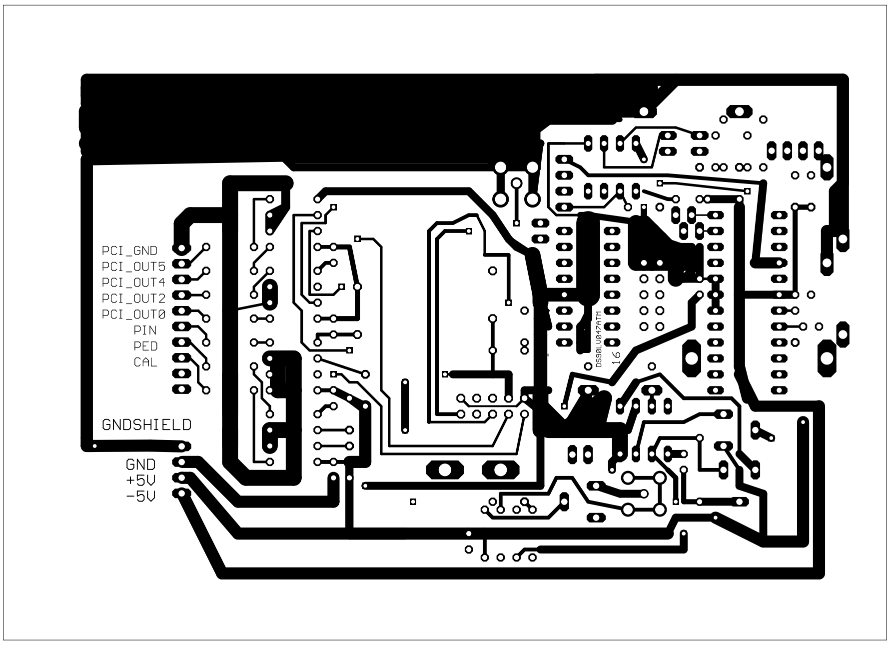


Figure 134: Schematics of the ***Trigger Board*** in the ***Control House*** (top side)



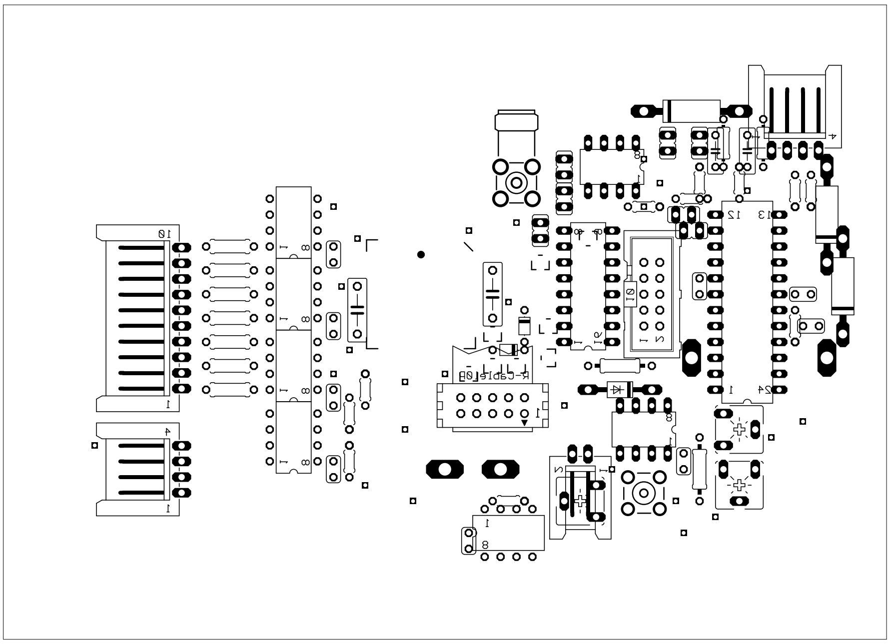
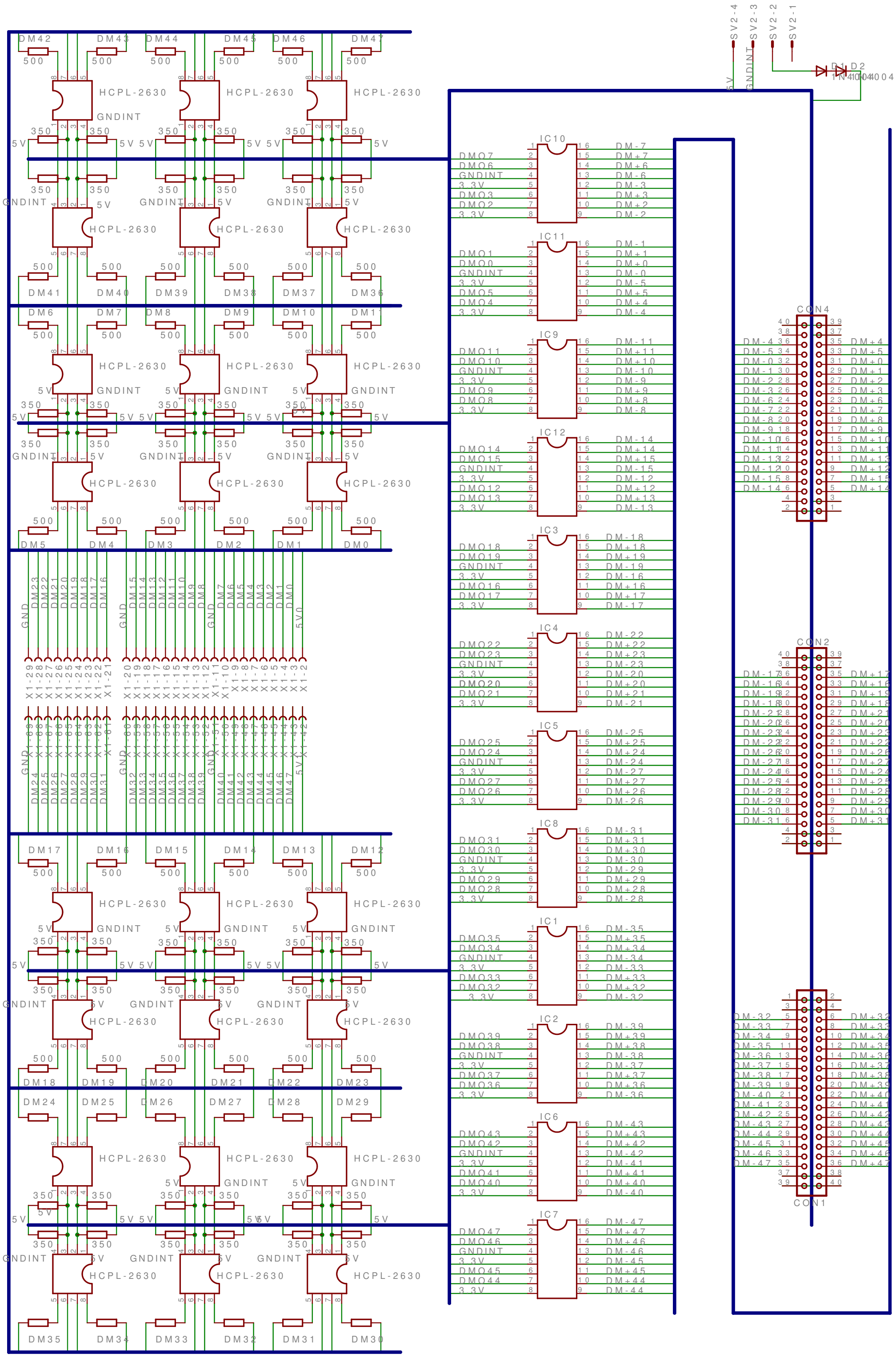


Figure 135: Schematics of the ***Trigger Board*** in the ***Control House*** (bottom side)



6/03/2003 /mnt/users/markus/eagle/Board_Altera/DM1

Figure 136: Schematics of the ***Digital Module*** in the ***Control House***

C.7 Optical Transmission

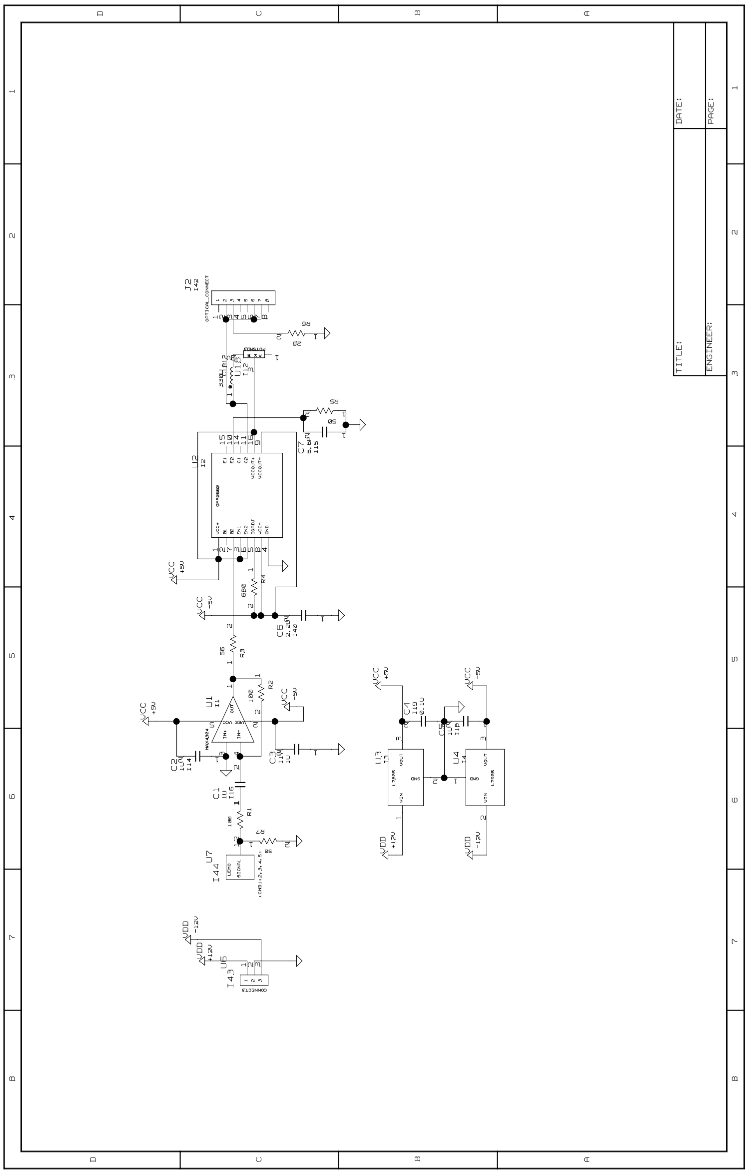


Figure 137: Schematic of the ***Optical Transmitter Board***

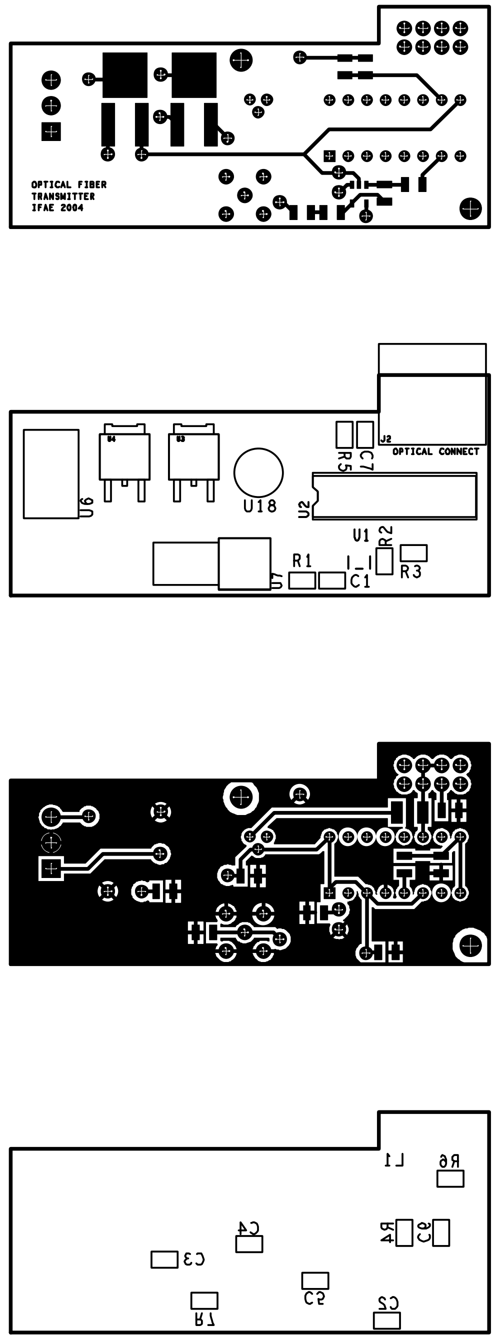


Figure 138: The ***Optical Transmitter Board*** (top and bottom side)

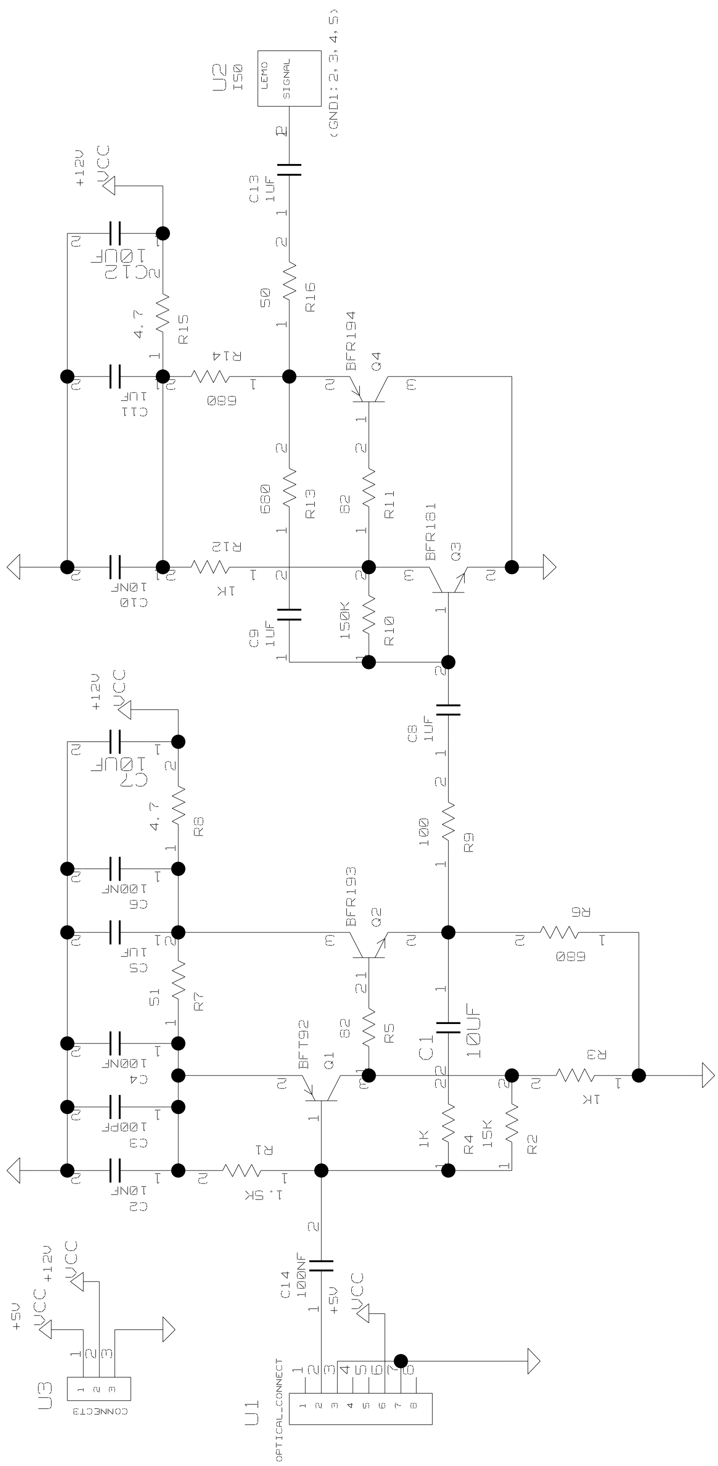


Figure 139: Schematic of the small ***Optical Receiver Board*** in the ***Pulser Box***

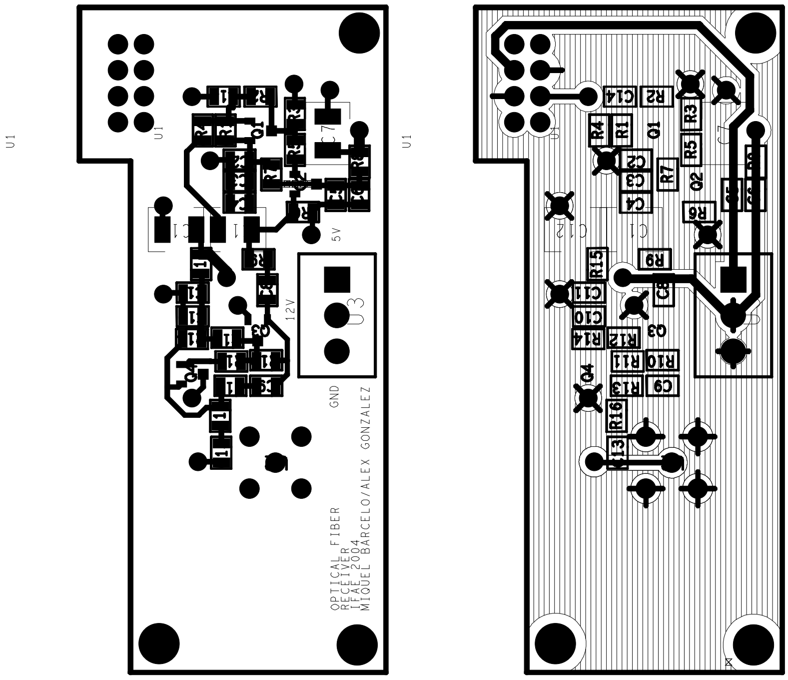


Figure 140: The ***Optical Transmitter Board*** (top and bottom side)

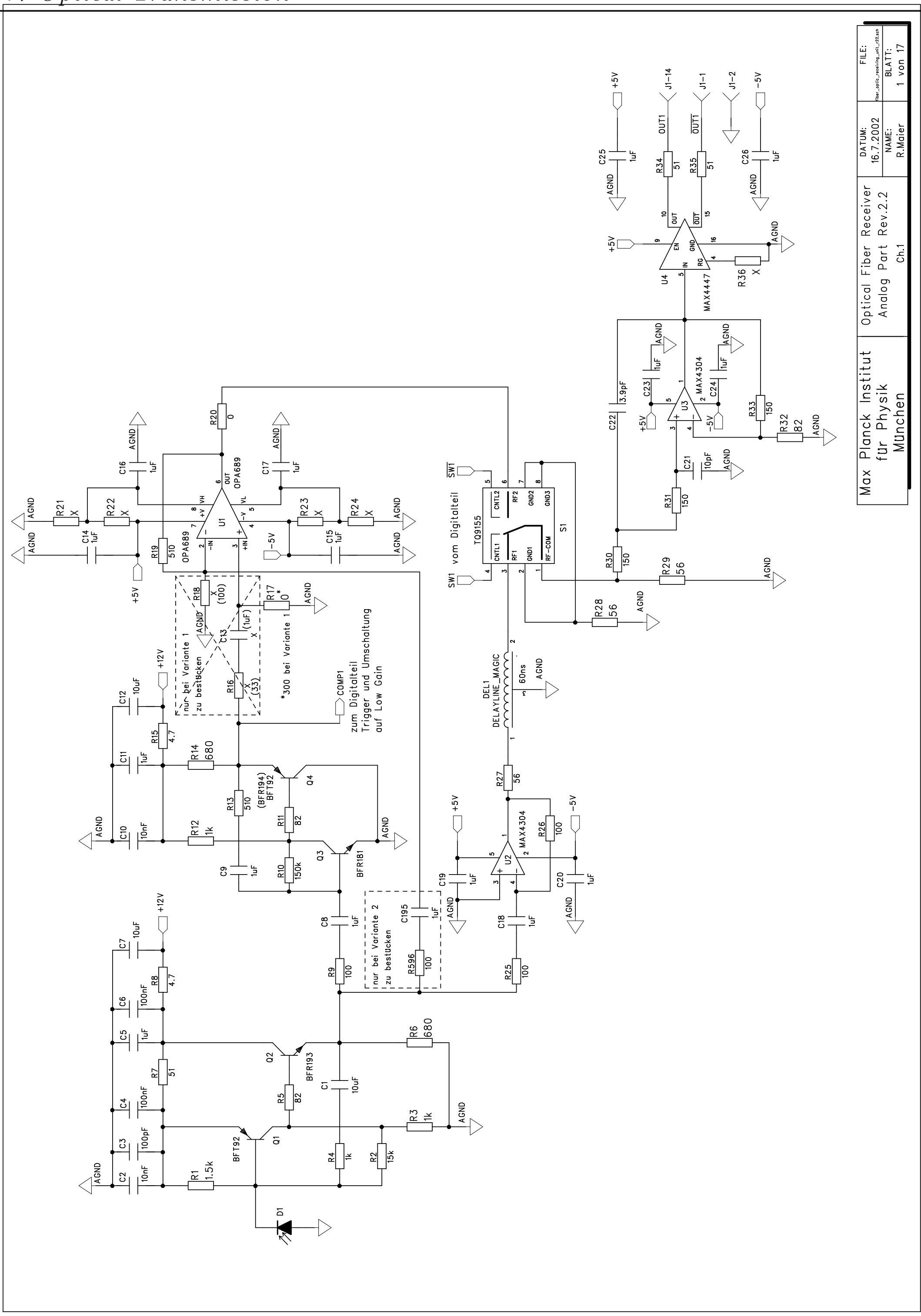


Figure 141: Schematics of the modified ***Optical Receiver Board*** (analogue part): The diode D1 has been replaced by a HFBR-2406 optical receiver, connected to VCC via a 10 Ω resistor and GND. A 100 nF bypass capacitor has been connected from pin 6 to pin 3 of the HFBR-2406. The output signal is additionally AC-coupled to the rest of the circuit. At a different place, R20 has been replaced by a 50 Ω resistancy, whereupon the signal is led outside the board to be delayed in a dedicated delay line. The signal from the delay line enters again before R29 and R30. The GaAs switch S1 has been removed.

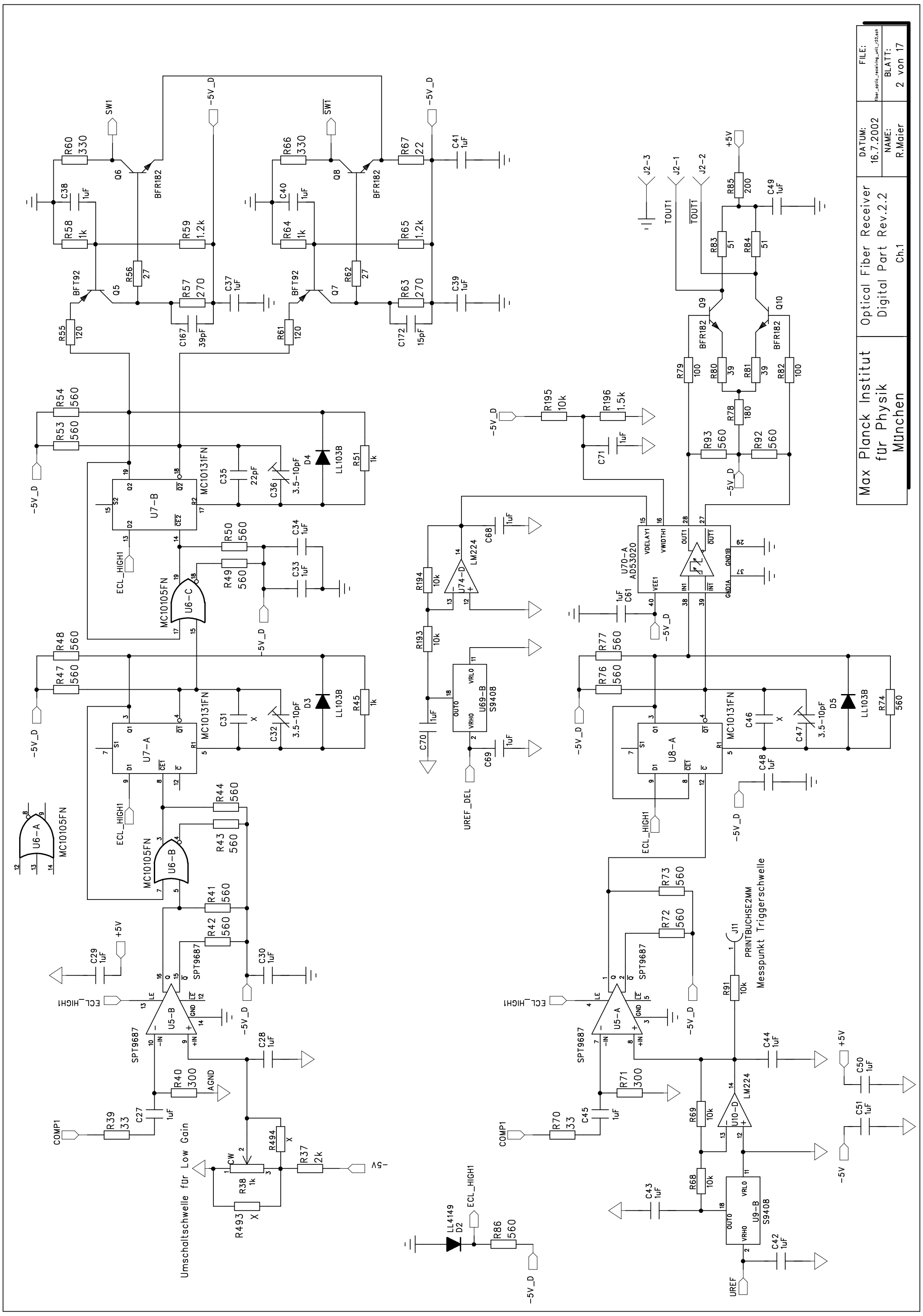


Figure 142: Schematics of the modified ***Optical Receiver Board*** (digital part): C47 has been replaced by a 4.7 nF capacitance, the lines $TOUT1$ and $\overline{TOUT1}$ are led to the ***Trigger Board*** via a twisted pair calbe and terminated there with 100 Ω.

D Coding

D.1 ALTERA *MAX7000S* program

```
%
        MAGIC TRIGGER BOARD CALIBRATION
%

TITLE "magic_trigger";

subdesign magic_trigger
(
        PCI_Clock[5..0]:                                                OUTPUT;

        PCI_Out[5..0]:                                                  INPUT;
        Pin, Cal, Ped:                                                  INPUT;
        Pin_sig:                                                        INPUT;
        Ped_out, Cal_out, Pin_out, Trigger:                             OUTPUT;
)

BEGIN

        Ped_out = Ped AND (!PCI_Out[5] AND PCI_Out[2]);
        Cal_out = Cal AND (!PCI_Out[5] AND PCI_Out[2]);
        Trigger = Cal AND (!PCI_Out[4] AND PCI_Out[0]);
        Pin_out = Pin AND Pin_sig;

END;
```

D.2 *ME1400* drivers

The following drivers have been written by Javi Lopez. They handle the communication with the ***ME1400*** I/O card in ***pc6***. The programs are installed and compiled on ***pc6*** in the directories

`/home/control/CaCo/drivers/subsys_procs/`
`/home/control/CaCo/drivers/subsys_driver/`

D.2.1 calibio_procs.H

```
#include <linux/spinlock.h>
#include <subsys_procs/incl/me1400.h>

class IOBoard
{

 private:

    int fd; // file descriptor for Input/Output card

    int quartzFrecuency;

    int pulseFrecuency;      // Hz
    double trainFrecuency;   // Hz
    int numberofPulses;      //
    int delay;               // ns

    int SetupTimer(int timernumber, int modenumber);
    int LoadCounter(int timernumber, int counter);

    // Variables for DIO
    me1400_rw_port_type portA;
    me1400_rw_port_type portB;
    me1400_rw_port_type portC;
    me1400_rw_port_type portD;
    me1400_rw_port_type portE;
    me1400_rw_port_type portF;

    int vetopattern;

 public:

    int SetOnDigitalIO(char port, int bit);
    int SetOffDigitalIO(char port, int bit);

    IOBoard() {fd=-1;}

    int Init(const char *dev="/dev/me1400", int quartzFrecuency_ = 1);
    int Close();

// Trigger generator funtions

    int SetPulseFrecuency(int pulseFrecuency_);
    int SetTrainFrecuency(double trainFrecuency_);
    int SetNumberofPulses(int numberofPulses_);
    int SetDelay(int delay_);

    int SetVeto(char veto[]);

    int StartFiring();
    int StopFiring();
};
```

D.2.2 calibio_procs.C

The following code have been written by Javi Lopez. It is installed and compiled on ***pc6*** in the directory

/home/control/CaCo/drivers/subsys_procs/

```
#include "calibio_procs.H"
#include <logtools/timestamp.h>

#include <fcntl.h>
#include <stdio.h>
#include <math.h>
#include <unistd.h>
#include <sys/ioctl.h>
#include <signal.h>

#include <iostream.h>  // cout

#define NUMBEROFTIMERS 6
#define MHZ 1000000

int IOBoard::Init(const char *dev, int quartzFrecuency_)
{

// Initialize class members
    quartzFrecuency = quartzFrecuency_*1000000; // Frecuency in Hz
    pulseFrecuency = -1;
    trainFrecuency = -1.;
    numberofPulses = -1;
    delay = -1;

    int timerconnections = 0x00; // Deafalut value
    int freq;

// Open de device
    fd = open(dev, O_RDWR, 0);

    if(fd < 0){
        cerr << GetTimeStamp() << " ERROR IOBoard::Init -> Opening device '"
        << dev << "' (rc=" << fd << ")" << endl;
        return -1;
    }

// Setup connections for the timer
    switch (quartzFrecuency_)
    {
        case 1  : freq = TIMER_A_CONNECT_1MHZ; break;
        case 10 : freq = TIMER_A_CONNECT_10MHZ; break;
        default:
            cerr << GetTimeStamp()
                 << " ERROR IOBoard::Init -> Not valid frecuency in InitIOBoard" << endl;
            return -1;
    }

    timerconnections =
        freq    |
        TIMER_A_CONNECT_SUBDCLK0;

    if(ioctl(fd , ME1400_SETUP_TIMER_MODE, &timerconnections)!=0) return -1;

    int setup = IRQCLK_QUARZOUT;
    if(ioctl(fd , ME1400_SETUP_IRQ_CLOCKOUT, &setup)!=0) return -1;

    me1400_setup_port_type setup_a;
    me1400_setup_port_type setup_b;
```

```
    // Setup for the first three ports
    setup_a.select = PORT_CTRL_A;  //We want to setup the first three ports
    setup_a.value = PORT_MODE_AAA; //Set all ports to write mode
    if(ioctl(fd , ME1400_SETUP_PORT, &setup_a) != 0) return -1;

    // Setup for the second three ports
    setup_b.select = PORT_CTRL_B;  //We want to setup the second three ports
    setup_b.value = PORT_MODE_AAA; // Set all ports to write mode
    if(ioctl(fd , ME1400_SETUP_PORT, &setup_b) != 0) return -1;

    portA.port = PORT_A_A;
    portB.port = PORT_A_B;
    portC.port = PORT_A_C;
    portD.port = PORT_B_A;
    portE.port = PORT_B_B;
    portF.port = PORT_B_C;

    portA.value = 0;
    portB.value = 0;
    portC.value = 0;
    portD.value = 0;
    portE.value = 0;
    portF.value = 0;

    vetopattern = 0;

    return 0;
}

int IOBoard::Close()
{
  if(close(fd))
  {
     cerr << GetTimeStamp() << " ERROR IOBoard::Close -> Cannot close device." << endl;
     return -1;
  }

  return 0;
}

int IOBoard::SetupTimer(int timernumber, int modenumber)
{

    me1400_setup_timer_type setup;
    unsigned char timer;
    unsigned char mode;

    switch (timernumber)
    {
        case 1 : timer = TIMER_CTRL_SC0; break; // Timer 0 selection
        case 2 : timer = TIMER_CTRL_SC1; break; // Timer 1 selection
        case 3 : timer = TIMER_CTRL_SC2; break; // Timer 2 selection
        case 4 : timer = TIMER_CTRL_SC0; break; // Timer 0 selection
        case 5 : timer = TIMER_CTRL_SC1; break; // Timer 1 selection
        case 6 : timer = TIMER_CTRL_SC2; break; // Timer 2 selection
        default:
            cerr << GetTimeStamp() << " ERROR IOBoard::SetupTimer -> Not valid timer number" << endl;
            return -1;
    }

    switch (modenumber)
    {
        case 0 : mode = TIMER_CTRL_M0; break; // Mode 0 selection
        case 1 : mode = TIMER_CTRL_M1; break; // Mode 1 selection
        case 2 : mode = TIMER_CTRL_M2; break; // Mode 2 selection
        case 3 : mode = TIMER_CTRL_M3; break; // Mode 3 selection
```

```
        case 4 : mode = TIMER_CTRL_M4; break; // Mode 4 selection
        case 5 : mode = TIMER_CTRL_M5; break; // Mode 5 selection
        default:
            cerr << GetTimeStamp() << " ERROR IOBoard::SetupTimer -> Not valid mode number" << endl;
            return 1;
    }

    if (timernumber < 4)
        setup.select = TIMER_CTRL_A; // One of the first three timer
    else
        setup.select = TIMER_CTRL_B;

    setup.value =
        timer          |
        TIMER_CTRL_LM  |  // Write first lower byte, then higher byte
        mode           |
        TIMER_CTRL_BIN;   // Configure as binary counter

    return ioctl(fd , ME1400_SETUP_TIMER, &setup);
}

int IOBoard::LoadCounter(int timernumber, int counter)
{

    me1400_rw_timer_type module;
    me1400_timer_enum_type timer;
    unsigned char lsb;
    unsigned char msb;

// Check the counter is not overflow
    if (counter > 1<<16)
    {
        cerr << GetTimeStamp()
             << " ERROR IOBoard::LoadCounter -> Counter overflow in timer number "
             << timernumber << endl;
        return -1;
    }

    switch (timernumber)
    {
        case 1 : timer = TIMER_A_1; break; // Timer 0 selection
        case 2 : timer = TIMER_A_2; break; // Timer 1 selection
        case 3 : timer = TIMER_A_3; break; // Timer 2 selection
        case 4 : timer = TIMER_B_1; break; // Timer 0 selection
        case 5 : timer = TIMER_B_2; break; // Timer 1 selection
        case 6 : timer = TIMER_B_3; break; // Timer 2 selection
        default:
            cerr << GetTimeStamp()
                 << " ERROR IOBoard::LoadCounter -> Not valid timer number" << endl;
            return 1;
    }

    // Transform the counter in the two bytes needed by the timer

    msb = counter >> 8;
    lsb = counter - msb*(1<<8);

    module.timer = timer;
    module.value = lsb;  // Lower byte
    if (ioctl(fd , ME1400_WRITE_TIMER, &module)!=0) return -1;
    module.value = msb;  // Higher byte
    return ioctl(fd , ME1400_WRITE_TIMER, &module);
}

int IOBoard::SetOnDigitalIO(char port, int bit)
{
```

```
    switch (port)
    {
        case 65:
            portA.value = portA.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portA)!=0) return -1;
            break;
        case 66:
            portB.value = portB.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portB)!=0) return -1;
            break;
        case 67:
            portC.value = portC.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portC)!=0) return -1;
            break;
        case 68:
            portD.value = portD.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portD)!=0) return -1;
            break;
        case 69:
            portE.value = portE.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portE)!=0) return -1;
            break;
        case 70:
            portF.value = portF.value | (0x01 << bit);
            if(ioctl(fd, ME1400_WRITE_PORT, &portF)!=0) return -1;
            break;
        default:
            cerr << GetTimeStamp()
                 << " ERROR IOBoard::SetDigitalIO -> Out of renge: Wrong port = "
                 << port << endl;
            return 1;
    }

    return 0;
}

int IOBoard::SetOffDigitalIO(char port, int bit)
{

    switch (port)
    {
        case 65:
            if ((portA.value & (0x01 << bit)) >> bit == 1)
            {
                portA.value = portA.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portA)!=0) return -1;
            }
            break;
        case 66:
            if ((portB.value & (0x01 << bit)) >> bit == 1)
            {
                portB.value = portB.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portB)!=0) return -1;
            }
            break;
        case 67:
            if ((portC.value & (0x01 << bit)) >> bit == 1)
            {
                portC.value = portC.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portC)!=0) return -1;
            }
            break;
        case 68:
            if ((portD.value & (0x01 << bit)) >> bit == 1)
            {
                portD.value = portD.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portD)!=0) return -1;
```

```
            }
            break;
        case 69:
            if ((portE.value & (0x01 << bit)) >> bit == 1)
            {
                portE.value = portE.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portE)!=0) return -1;
            }
            break;
        case 70:
            if ((portF.value & (0x01 << bit)) >> bit == 1)
            {
                portF.value = portF.value ^ (0x01 << bit);
                if(ioctl(fd, ME1400_WRITE_PORT, &portF)!=0) return -1;
            }
            break;
        default:
            cerr << GetTimeStamp()
                 << " ERROR IOBoard::SetDigitalIO -> Out of renge: Wrong port = "
                 << port << endl;
            return 1;
    }

    return 0;
}

int IOBoard::SetPulseFrecuency(int pulseFrecuency_)
{
    pulseFrecuency = pulseFrecuency_;

    return 0;
}
int IOBoard::SetTrainFrecuency(double trainFrecuency_)
{
    trainFrecuency = trainFrecuency_;

    return 0;
}

int IOBoard::SetNumberofPulses(int numberofPulses_)
{
    numberofPulses = numberofPulses_;

    return 0;

}
int IOBoard::SetDelay(int delay_)
{
    delay = delay_;

    return 0;
}

int IOBoard::StartFiring()
{

    if (quartzFrecuency > pulseFrecuency &&
        pulseFrecuency % 2 != 0 &&
        pulseFrecuency % 5 != 0)
    {
#ifdef ERRORS
        cerr << GetTimeStamp()
             << " ERROR IOBoard::StartFiring -> Out of range: pulseFrecuency  = "
             <<  pulseFrecuency << " must be multiple of 2 and 5 = " << quartzFrecuency << endl;
#endif
        return 1;
    }
```

```
    if (pulseFrecuency < trainFrecuency )
    {
#ifdef ERRORS
        cerr << GetTimeStamp()
             << " ERROR IOBoard::StartFiring -> Out of range: trainFrecuency  = "
             <<  trainFrecuency << " bigger than pulseFrecuency = " << pulseFrecuency << endl;
#endif
        return 1;
    }

   if ( delay % (1000000000/quartzFrecuency) != 0)
    {
#ifdef ERRORS
        cerr << GetTimeStamp()
             << " ERROR IOBoard::StartFiring -> Out of range: delay = "
             << delay << " not multiple of 10E9/quartzFrecuency = "
             <<  1000000000/quartzFrecuency << endl;
#endif
        return 1;
    }

   if ( trainFrecuency > pulseFrecuency/numberofPulses )
   {
#ifdef ERRORS
       cerr << GetTimeStamp()
            << " ERROR IOBoard::StartFiring -> Out of range: trainFrecuency "
            << trainFrecuency << " bigger than pulseFrecuency/numberofPulses = "
            << pulseFrecuency/numberofPulses << endl;
#endif
        return 1;
    }



// Setup the timers
   SetupTimer(1,2);  //Send 100ns pulses to the calibration box
//    SetupTimer(1,3); //Send long pulses to the calibration box
    SetupTimer(2,5);
    SetupTimer(3,1);
    SetupTimer(4,3);
    if (trainFrecuency > 0)
        SetupTimer(5,1);
    else
        SetupTimer(5,4);    // to send just one train of pulses
    SetupTimer(6,1);


// Load the counters in every timer
    if (LoadCounter(1,quartzFrecuency/pulseFrecuency)) return -1;
//
// send short pulses to calib box
//
    if (LoadCounter(3,1)) return -1;

    if (trainFrecuency > 0)
    {
        if (LoadCounter(4,(int)(pulseFrecuency/trainFrecuency))) return -1;
    }
    else
    {
        if (LoadCounter(4,1)) return -1;
    }
    if (LoadCounter(5,numberofPulses)) return -1;
    if (LoadCounter(6,numberofPulses)) return -1;

    return 0;
```

```
}

int IOBoard::StopFiring()
{

    int status = 0;

// Setup the timers
    for (int i=1; i<NUMBEROFTIMERS; i++)
        if (!status) status = SetupTimer(i,1); // Put all the counters wainting a shot in the gate
                                //  to be triggered (mode 1)

    return status;
}


int IOBoard::SetVeto(char veto[])
{

    const int numberofvetos = 3;
    char port[numberofvetos];
    int bit[numberofvetos];

    port[0] = 'C'; // Pedestal
    bit[0]  = 6;
    port[1] = 'C'; // Calibration
    bit[1]  = 7;
    port[2] = 'F'; // Pin Diode
    bit[2]  = 7;

//i -------------------------------------------------------------------
//i   Due to the fact that it's used an opto couple in the hardware aware
//i   of sending the levels of calibration the '0' in software is the the '1'
//i   in the hardware (that's means ON) and viceversa

    for (int i=0; i<numberofvetos; i++)
    {
        if (veto[i] == '0')
        {
            SetOnDigitalIO(port[i],bit[i]);
        }
        else if (veto[i] == '1')
        {
            SetOffDigitalIO(port[i],bit[i]);
        }
        else
        {
#ifdef ERRORS
            cerr << GetTimeStamp()
                 << " ERROR IOBoard::SetVeto -> Out of range: veto[" << i << "] = "
                 << veto[i] << endl;
#endif
        return 1;
        }
    }

    return 0;
}
```

D.2.3 calibio_subsys_driver.C

The following code have been written by Javi Lopez. It is installed and compiled on ***pc6*** in the directory

`/home/control/CaCo/drivers/subsys_driver/`

```
#include <iostream.h>
#include <string.h>
#include <errno.h>
#include <fcntl.h>

#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

#include <sys/time.h>  //gettimeofday

#include <logtools/timestamp.h>
#include <SubsysIO/ListenFromDevice.hxx>
#include <subsys_procs/calibio_procs.H>

//---------------------------------------------------------------------
// IO board to produce trigger signals
//---------------------------------------------------------------------

IOBoard io;

// -----------------------------------------------------------
//  Variables resposable of the report rate of the driver
// -----------------------------------------------------------
const int control_reaction_time =   15000;   //time in microseconds
int calibio_automatic_report      = 2000000;
int calibio_process_time          = calibio_automatic_report/2;

int main()
{

//---------------------------------------------------------------------
// Driver status
//---------------------------------------------------------------------
    int driverStatusAct = 0; // initialitaze driver status to 'OK'
    int driverStatusMon = 0; // initialitaze driver status to 'OK'

//---------------------------------------------------------------------
// Communication through pipes with Calibration Control
//---------------------------------------------------------------------

    char* calibioCmdPath    = "../../comm/CaCo_fifos/calibio_cmd";
    char* calibioReportPath = "../../comm/CaCo_fifos/calibio_report";

//the file descriptors for the pipe to report
    int calibio_report_fd;
// Pipe for sending reports
    calibio_report_fd=open(calibioReportPath,O_WRONLY);

// Pipe for receiving commands
    ListenFromDevice * calibio_cmd;
    calibio_cmd=new ListenFromDevice(calibioCmdPath);
    calibio_cmd->AutomaticallyReceive();

//---------------------------------------------------------------------
// Report and command
//---------------------------------------------------------------------

//buffer for the report sent periodically to upper control
```

```
    char calibioReportString[MAXBUFFER];
    char calibioTmpReportString[MAXBUFFER];

    int positionofbarran;
// Time stamp
    struct timeval actualTimeInSecAnduSec;   // actual time
    struct tm *actualTime;

// Command from upper control
    char lastCmd[MAXBUFFER];

// Initialation of the communication through CANbus
    const char *dev="/dev/me1400";
    int quartzFrecuency = 10;        //MHz
    driverStatusAct = io.Init(dev,quartzFrecuency);

// General variables usied in the calib_procs functions
    char str[9];

    double trainFrecuency   = -666.;
    int    pulseFrecuency   = -666 ;
    int    numberofPulses   = -666 ;
    int    delay            = -666 ;

    char vetopattern[3];

    char dmport;
    int  dmbit;
//
    int autoReportInmsec;

    while(true){
// Wait for a command from calibio_cmd only within period
// calibio_report_period_minus_read. If commands were sent since last time
// before reaching this poit again, we'll have the latest --which is what
// we want (the previous command may have been chosen with outdated hv or
// current values). If in this time no command arrives lastCmd will be 0

        strcpy(lastCmd,
               calibio_cmd->ReturnNewOrWhatArrivesWithinTimeout
               (calibio_automatic_report-control_reaction_time)
               );


        if(strncmp(lastCmd,"0",1)){

//interpret command:
//SETAR
//SHUTD
//SETPF
//SETTF
//SETNP
//SETDL
//SETVT
//SETDM
//CLRDM
//START
//STOP!

            if (!strncmp(lastCmd,"SETAR",5))
            {
                sscanf(&lastCmd[6],"%05d",&autoReportInmsec);

                if (autoReportInmsec*1000 < control_reaction_time)
                {
#ifdef ERRORS
                    cerr << GetTimeStamp()
```

```
                    << "_ERROR_calibio_subsys_driver_->_Wrong_calibio_automatic_report_=_"
                    << calibio_automatic_report << endl;
#endif
                driverStatusAct = 1;
            }
            else
            {
                calibio_automatic_report = autoReportInmsec*1000;
                calibio_process_time     = calibio_automatic_report/2;
                driverStatusAct = 0;
            }
        }
        else if (!strncmp(lastCmd,"SHUTD",5))
        {
            io.StopFiring();
            io.SetVeto("000");
            io.Close();
            break;
        }
        else if(!strncmp(lastCmd,"SETPF",5))
        {
// Extract the arguments for the function from the stream
// Protocol -> SETTPF:pulseFrecuency
            sscanf(&lastCmd[6],"%08d",&pulseFrecuency);

            driverStatusAct = io.SetPulseFrecuency(pulseFrecuency);
        }
        else if (!strncmp(lastCmd,"SETTF",5))
        {
// Extract the arguments for the function from the stream
// Protocol -> SETTTF:trainFrecuency
            sscanf(&lastCmd[6],"%8s",&str);
            trainFrecuency = atof(str);

            driverStatusAct = io.SetTrainFrecuency(trainFrecuency);
        }
        else if (!strncmp(lastCmd,"SETNP",5))
        {
// Extract the arguments for the function from the stream
// Protocol -> SETTNP:numberofPulses
            sscanf(&lastCmd[6],"%05d",&numberofPulses);

            driverStatusAct = io.SetNumberofPulses(numberofPulses);

        }       else if (!strncmp(lastCmd,"SETDL",5))
        {
// Extract the arguments for the function from the stream
// Protocol -> SETTNP:numberofPulses
            sscanf(&lastCmd[6],"%07d",&delay);

            driverStatusAct = io.SetDelay(delay);

        }
        else if (!strncmp(lastCmd,"SETVT",5))
        {
// Extract the arguments for the function from the stream
// Protocol -> SETTVT:PED#CAL#PIN
            sscanf(&lastCmd[6],"%1s%1s%1s",&vetopattern[0],
                                          &vetopattern[1],
                                          &vetopattern[2]);

            driverStatusAct = io.SetVeto(vetopattern);
        }
        else if (!strncmp(lastCmd,"START",5))
        {
            driverStatusAct = io.StartFiring();
        }
```

```
            else if (!strncmp(lastCmd,"STOP!",5))
            {
                driverStatusAct = io.StopFiring();
            }
            else if (!strncmp(lastCmd,"SETDM",5))
            {
// Extract the arguments for the function from the stream
// Protocol -> SETDM: port#bit
                sscanf(&lastCmd[6],"%1s%1d",&dmport,
                                            &dmbit);

                driverStatusAct = io.SetOnDigitalIO(dmport, dmbit);
            }
            else if (!strncmp(lastCmd,"CLRDM",5))
            {
// Extract the arguments for the function from the stream
// Protocol -> SETDM: port#bit
                sscanf(&lastCmd[6],"%1s%1d",&dmport,
                                            &dmbit);

                driverStatusAct = io.SetOffDigitalIO(dmport, dmbit);
            }
            else
            {
#if ERRORS
                cerr << GetTimeStamp()
                     << " ERROR calibio_subsys_driver -> WRONG_CMD = "
                     << lastCmd << endl;
#endif
                driverStatusAct = 1;
            }

            usleep(calibio_process_time);
        }

//-----------------------------------
// send a report
//-----------------------------------

//Get the time from the computer clock to report timestamp
        gettimeofday(&actualTimeInSecAnduSec,NULL);
                                    // gets number of sec from 1 Jan 1970
        actualTime = localtime(&actualTimeInSecAnduSec.tv_sec);
                                    // tranform time_t in a struct tm
// Build calibio report
        if (driverStatusMon >= 0)
            sprintf(calibioTmpReportString, "IO +");
        else
            sprintf(calibioTmpReportString, "IO -");
        strcpy(calibioReportString,calibioTmpReportString);
        sprintf(calibioTmpReportString, "%02d", abs(driverStatusMon));
        strcat(calibioReportString,calibioTmpReportString);
        if (driverStatusAct >= 0)
            sprintf(calibioTmpReportString, " +%02d", abs(driverStatusAct));
        else
            sprintf(calibioTmpReportString, " -%02d", abs(driverStatusAct));
        strcat(calibioReportString,calibioTmpReportString);
        sprintf(calibioTmpReportString," %02.2d %02.2d %02.2d %03.3d",
                actualTime->tm_hour,actualTime->tm_min,actualTime->tm_sec,
                (actualTimeInSecAnduSec.tv_usec/1000));
        strcat(calibioReportString,calibioTmpReportString);

// Add '\n' in the final cmd, ListenFromDevice will look for it!

        positionofbarran = strlen(calibioReportString);
        calibioReportString[positionofbarran] = '\n';
        calibioReportString[positionofbarran+1] = '\0'; //To finalize the string
```

```
//send 'em
        if(write(calibio_report_fd, calibioReportString,strlen(calibioReportString))
           != strlen(calibioReportString))
        {
            int myerrno=errno;
#ifdef ERROR
            cerr << GetTimeStamp() << " ERROR calibio_subsys_driver -> Fatal sending";
#endif
        }

        usleep(control_reaction_time);

    }

    return 0;
}
```

E Important Data Sheets

E.1 NSPB-310A Blue *Pulsed LED*