



# Superconductor magnets

# and quench detection

Site: SM-18

Leader: Turi Dániel

Horvát Zoltán Csatlós Botond

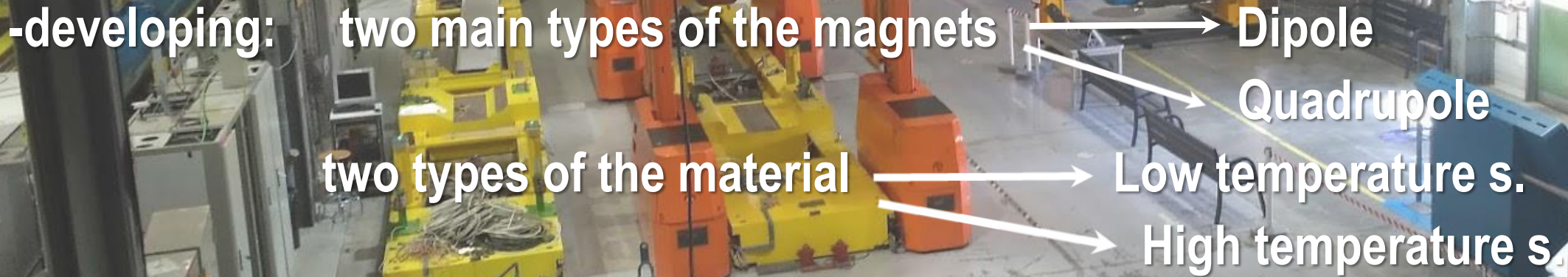
QCD outputs

RADIATION  
DANGER

CAUTION

# Where we were

- SM-18
- Magnet - testing:
  - resistance
  - isolation
  - quenches



- Research: e.g. YBCO cable



**The radiofrequency (RF) cavities**

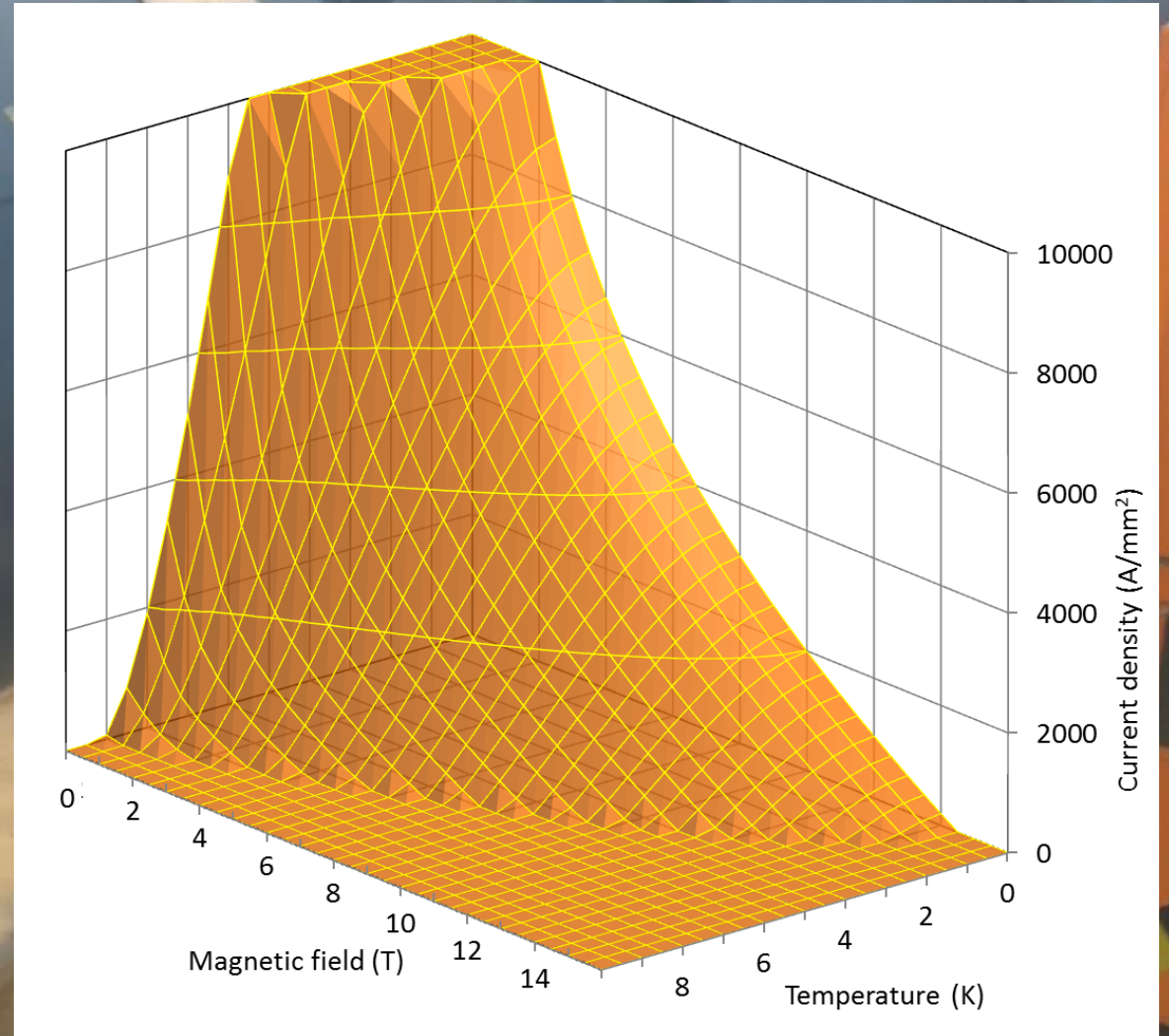
# Superconductivity

The material superconduct below the critical surface defined by

Critical temperature  $T_c$

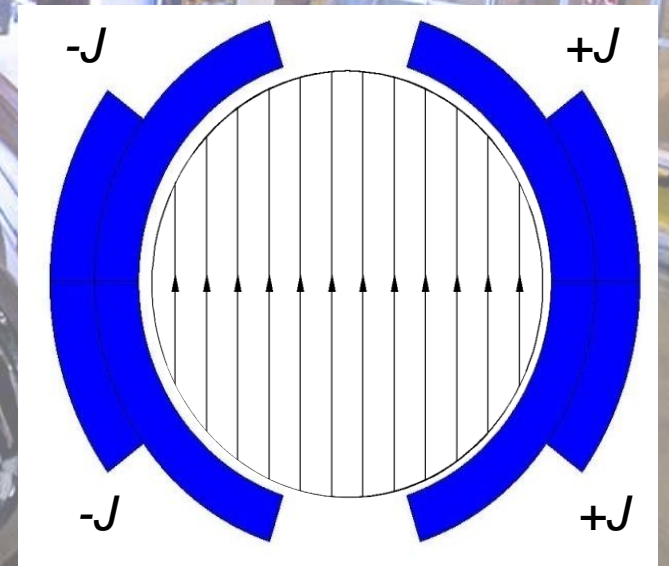
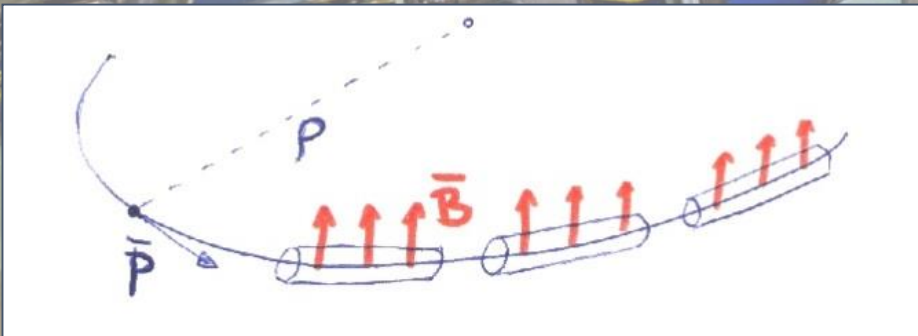
Upper critical magnetic field  $B_c$

Critical current density  $J_c$



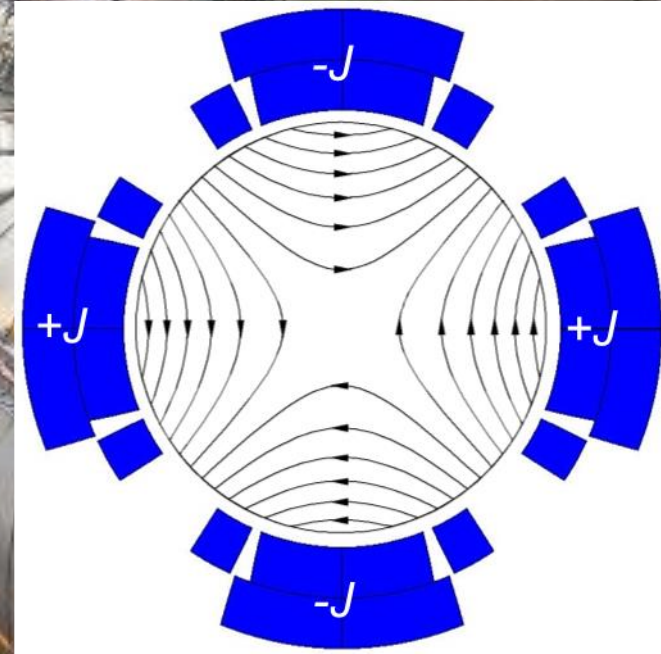
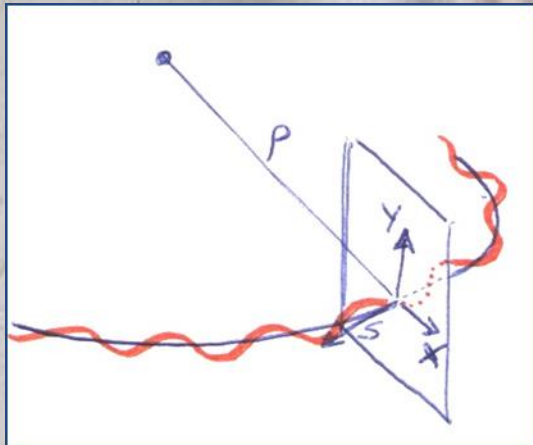
# Dipoles

- Electro-magnets: field produced by a current (or current density)
- Magnetic field bends the particles in a circular orbit



# Quadrupole magnets

- They act as a spring: focus the beam
- Prevent protons from falling to the bottom of the aperture due to the gravitational force



# Practical superconductors

Cu

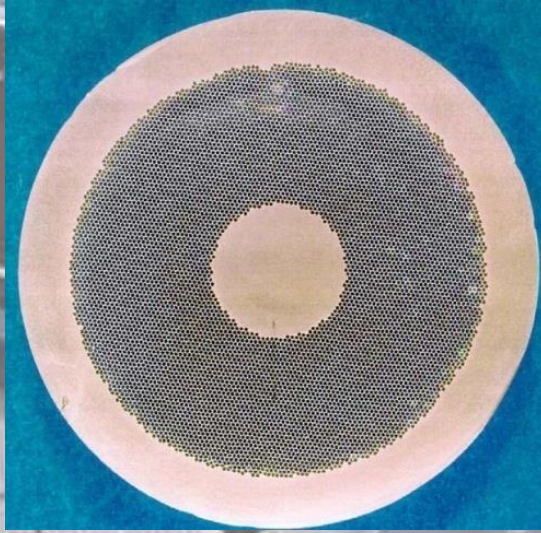


$$J_e \sim 5 \text{ A/mm}^2$$

$$I \sim 3 \text{ A}$$

$$B = 2 \text{ T}$$

Nb-Ti

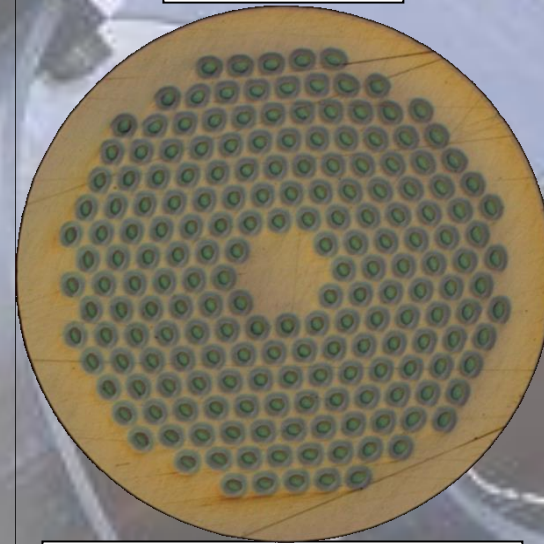


$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

$$I \sim 300\text{-}400 \text{ A}$$

$$B = 8\text{-}9 \text{ T}$$

Nb<sub>3</sub>Sn

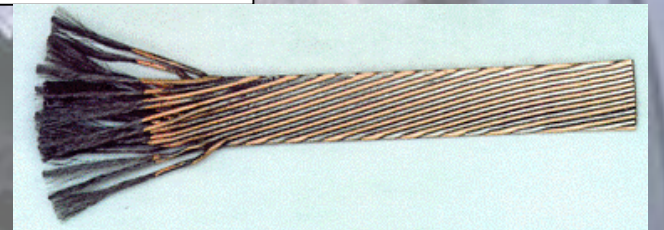


$$J_e \sim 600\text{-}700 \text{ A/mm}^2$$

$$I \sim 300\text{-}400 \text{ A}$$

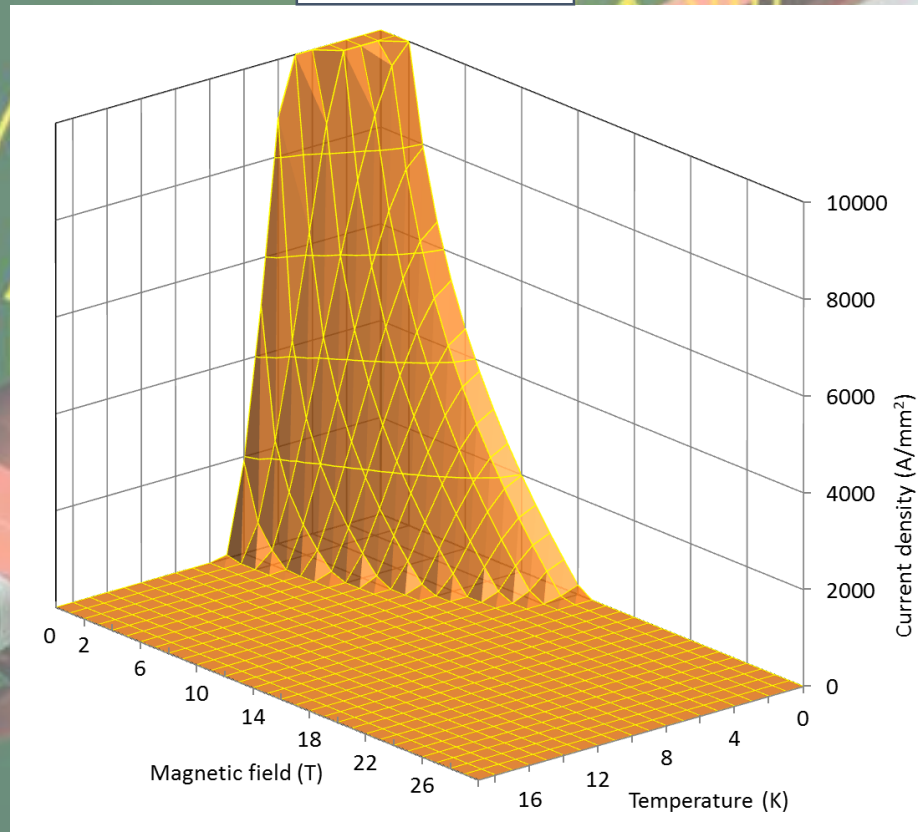
$$B = 12\text{-}13 \text{ T}$$

Rutherford cable

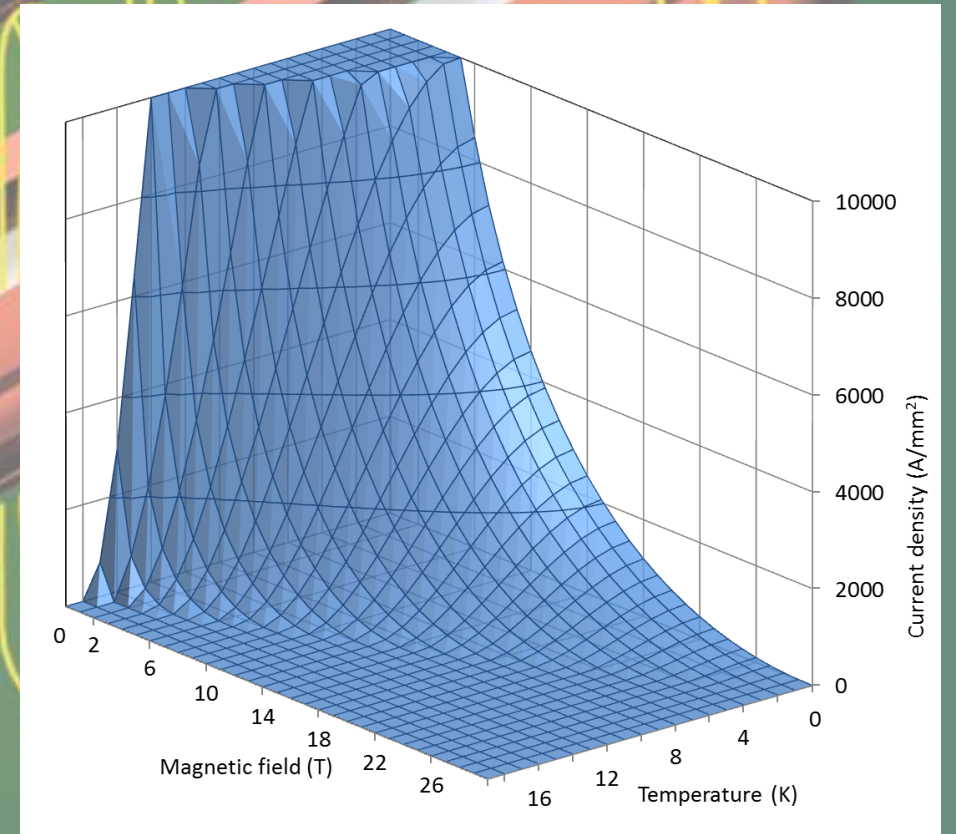


# Superconductivity Nb-Ti vs. Nb<sub>3</sub>Sn

Nb-Ti

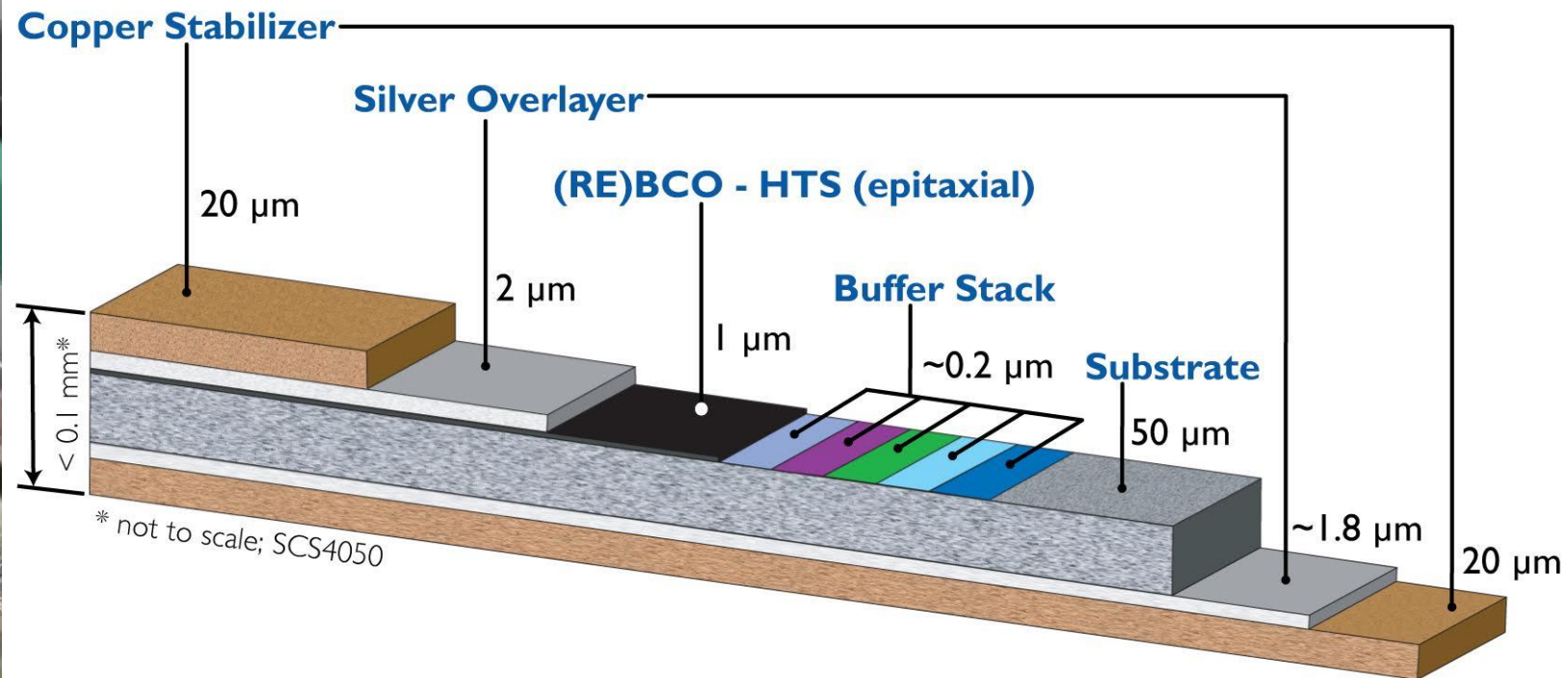


Nb<sub>3</sub>Sn





# Future Magnet with YBCO cable



# TESTING



The software interface is titled "HIGH VOLTAGE TEST v 2.0" and is running on a Windows desktop. The interface includes a menu bar (File, Mode, User name: vdesbol), a "Measurement" mode dropdown, and a "Bench Name" dropdown set to "ST-LONG". The "Magnet Name" is "MCBY\_39" and the "Sequence Type" is "MCBY".

On the left, there are three vertical gauges: "Ambient Temp. (K)" at 301, "Humidity (%)" at 30, and "Magnet Temp. (K)" at 1.90. Below these are buttons for "REMOTE CONTROL" (OFF), "RUN SEQUENCE", "RUN STEP", and "ABORT". A "COMMENTS" button is also present.

The central area shows a "Sequence" list with the following items:

- Insulation Strength measured at cold after power test
- Insulation Strength measured at cold before power test
- Insulation Strength measured at warm in cryostat after thermal
- Insulation Strength measured at warm in cryostat on air

The "Stack in sequence" shows "MCBY vs Ground". Below this is a table with the following data:

Number	Voltage HV+	Duration
1	200	02:01

The "Maximum Current (uA)" is set to 3.000. A "Switchbox Status" bar shows 16 slots, all of which are green. A "Show Details" button is located below the status bar.

On the right, there are three graphs showing "Resistance (Ohm)", "Current (A)", and "Voltage (V)" over a 15-second period. The "Resistance" graph shows a sharp peak at approximately 2 seconds. The "Current" graph shows a sharp peak at approximately 2 seconds. The "Voltage" graph shows a steady increase over time.

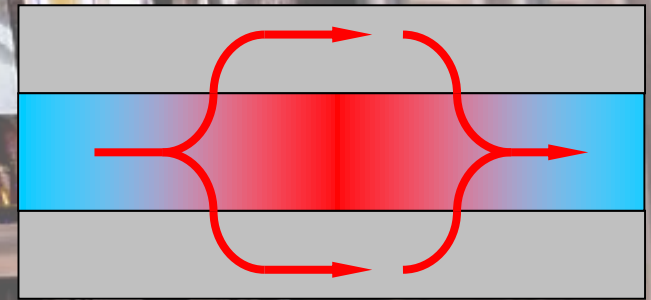
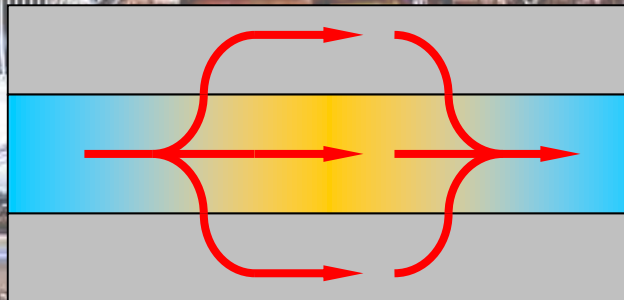
At the bottom, a "Messages" window displays the following log entries:

- [13/05/2017, 14:25:58] You can generate the report for this sequence of measurements.
- [13/05/2017, 14:25:51] Run Recovery is aborted!
- [13/05/2017, 14:25:51] Switchbox returns to safety position.

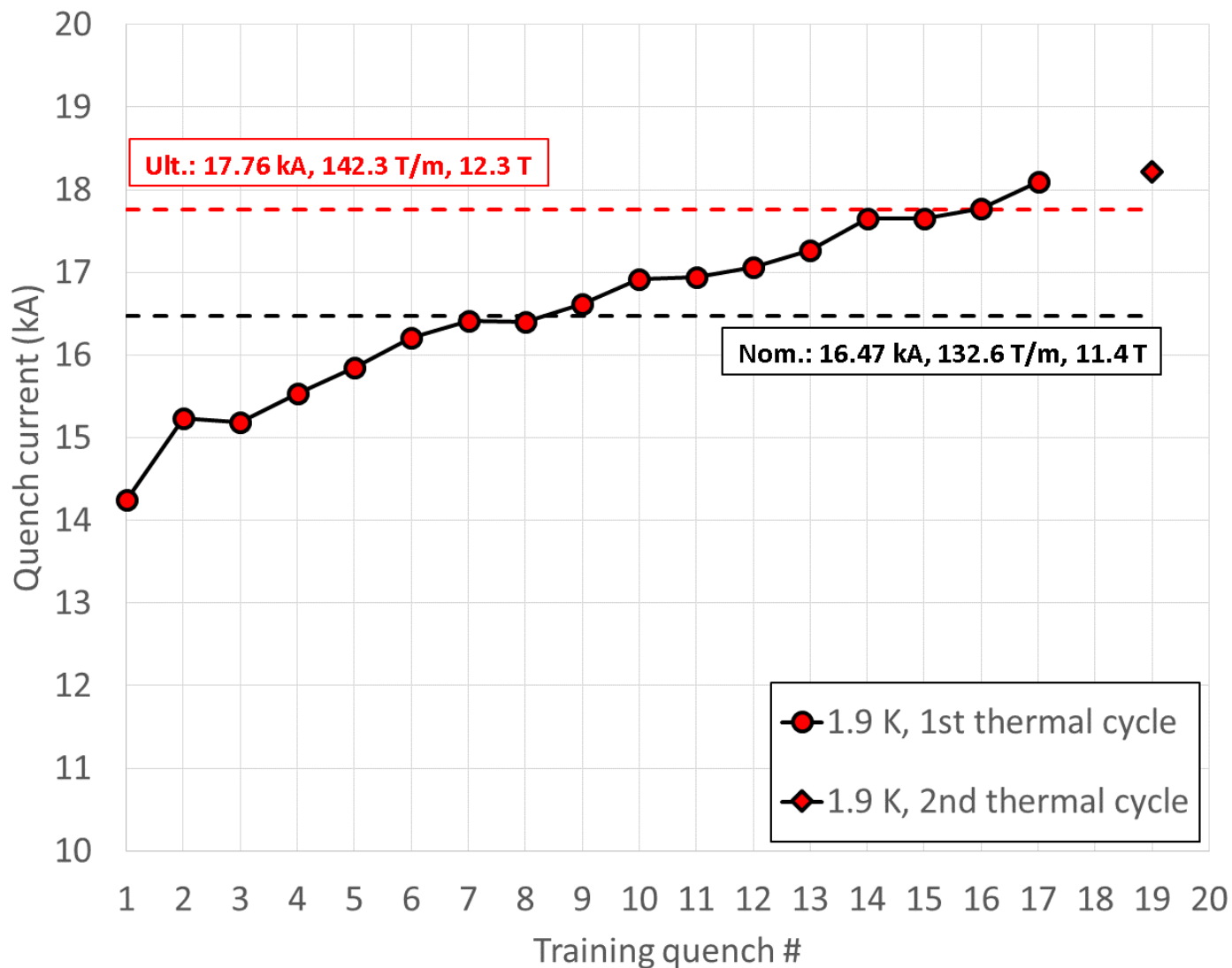


# Quenches

- Thermal energy released by
  - Mechanical events
  - Electromagnetic events
  - Thermal events
  - Nuclear events

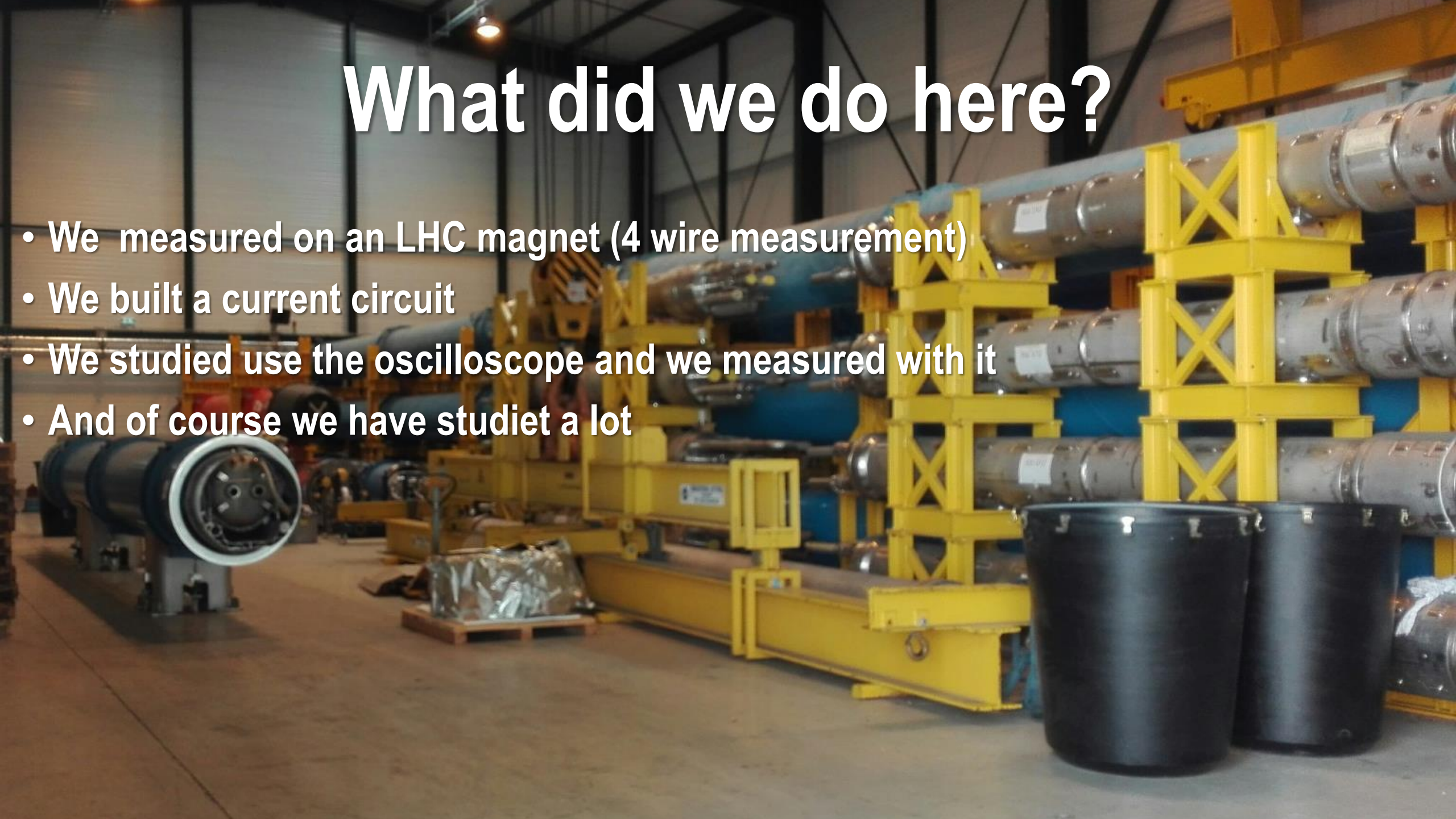


# Magnet training, quenches



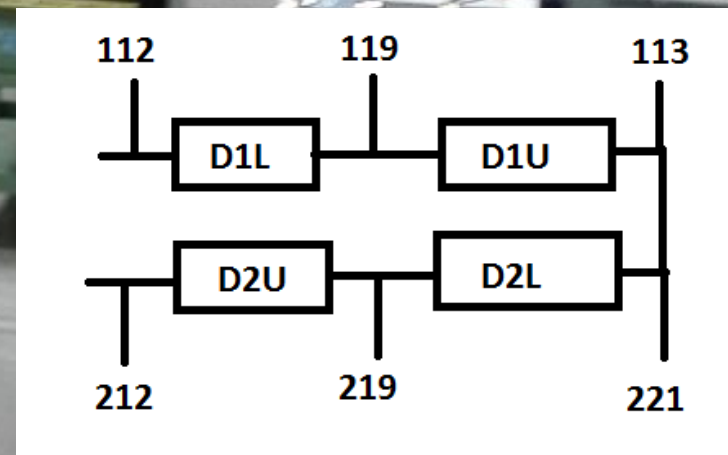
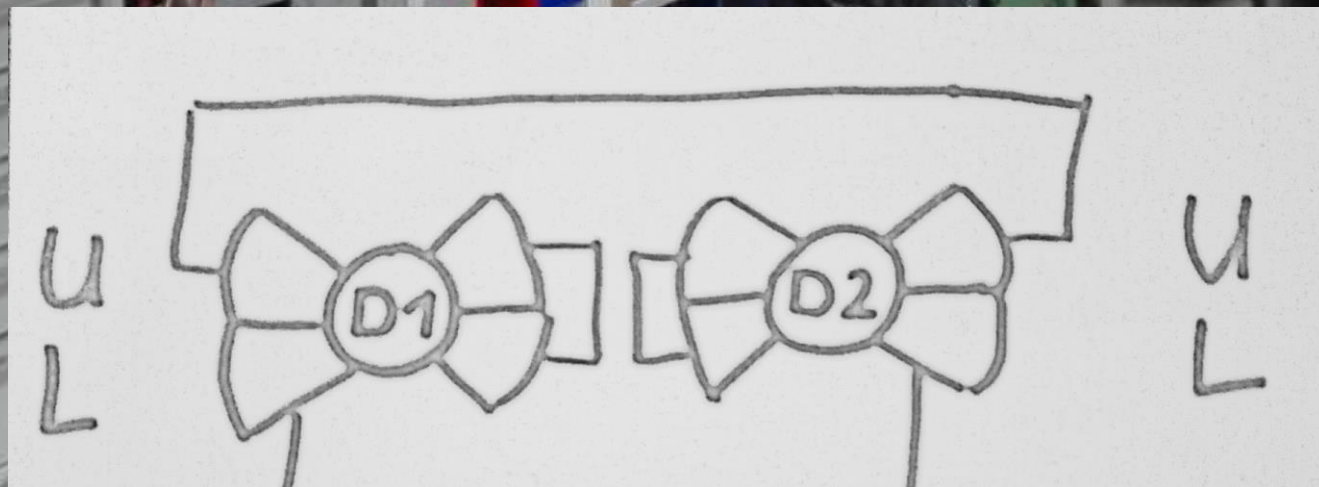
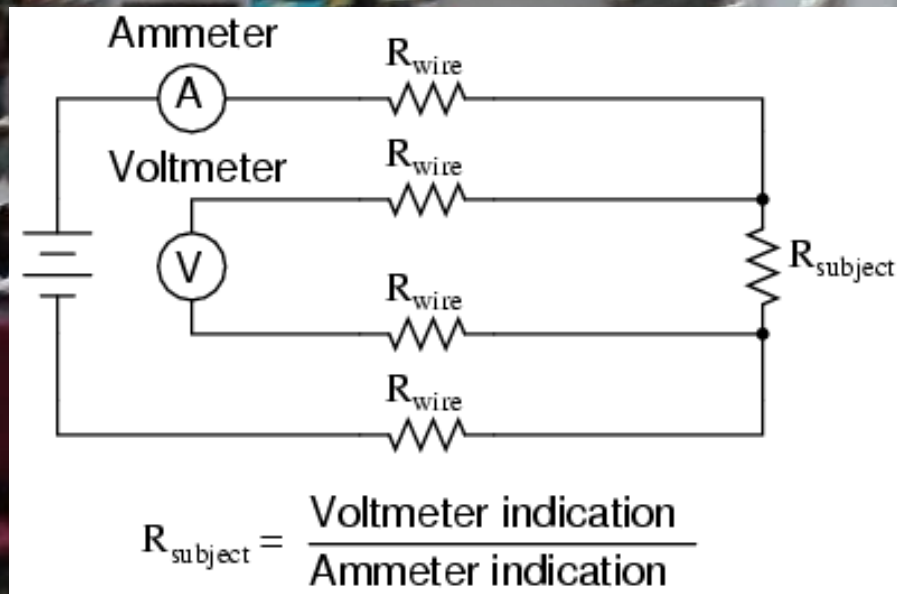
# What did we do here?

- We measured on an LHC magnet (4 wire measurement)
- We built a current circuit
- We studied use the oscilloscope and we measured with it
- And of course we have studied a lot

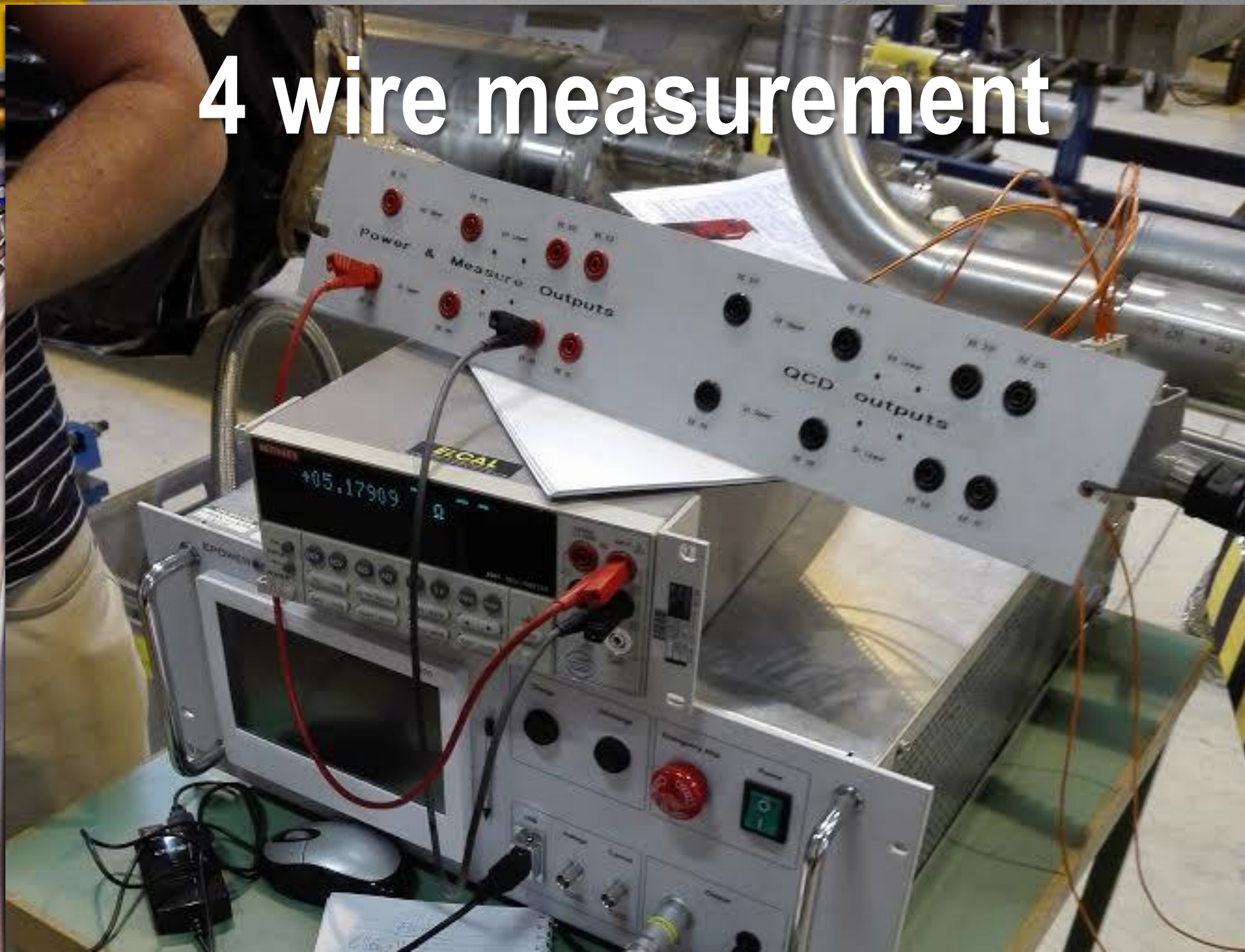


# 4 wire measurement

1st point	2nd point	Resistance [ $\Omega$ ]
112	119	3.43
113	119	3.36
112	113	5.18
1st point	2nd point	Resistance [ $\Omega$ ]
112	119	1.51
113	119	1.51
112	113	3.02



# 4 wire measurement



# Optical isolation amplifier

optocoupler

TL072x D, JG, P, PS and PW Package  
8-Pin SOIC, CDIP, PDIP, SO  
Top View

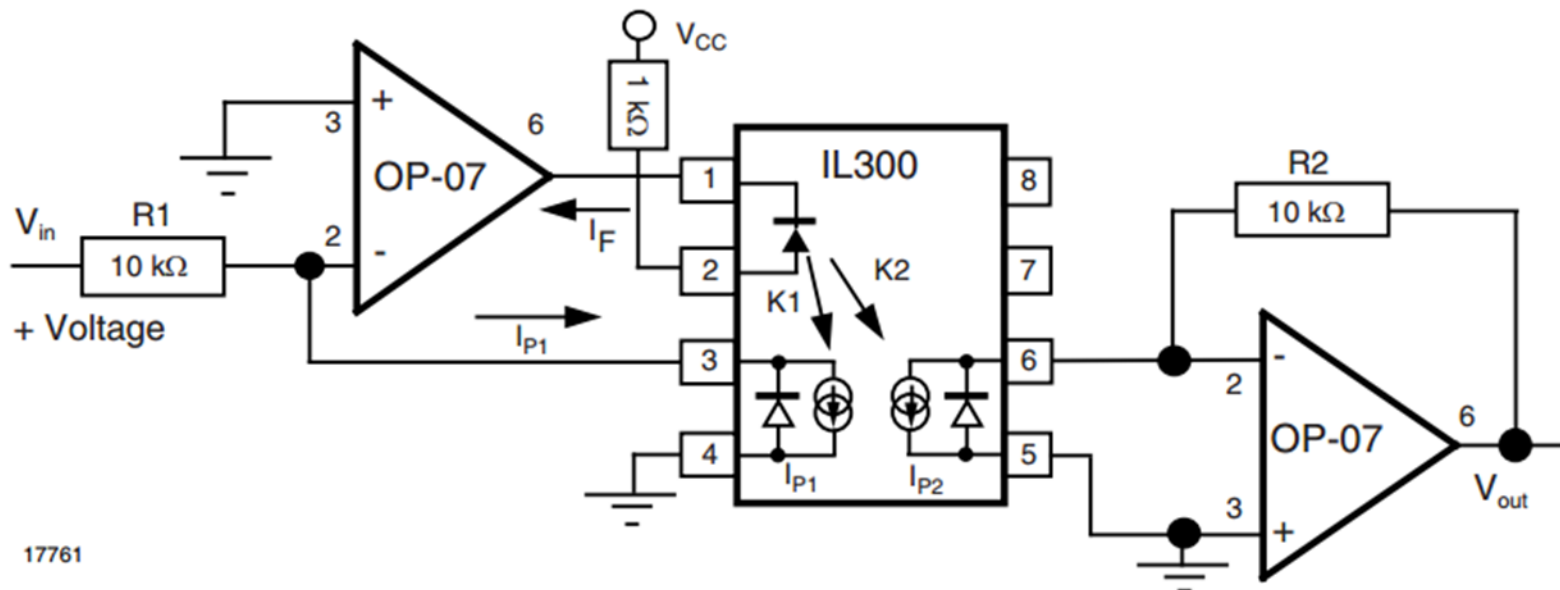
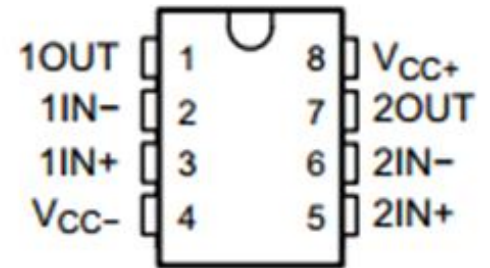
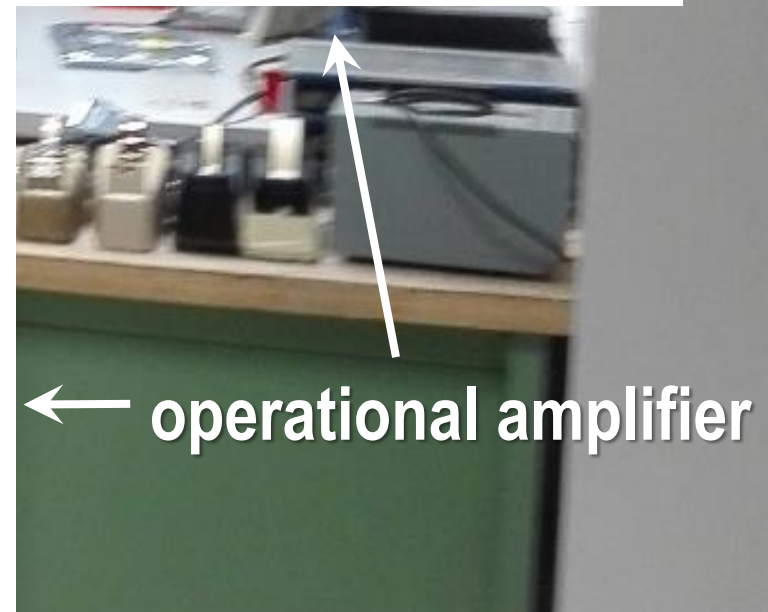


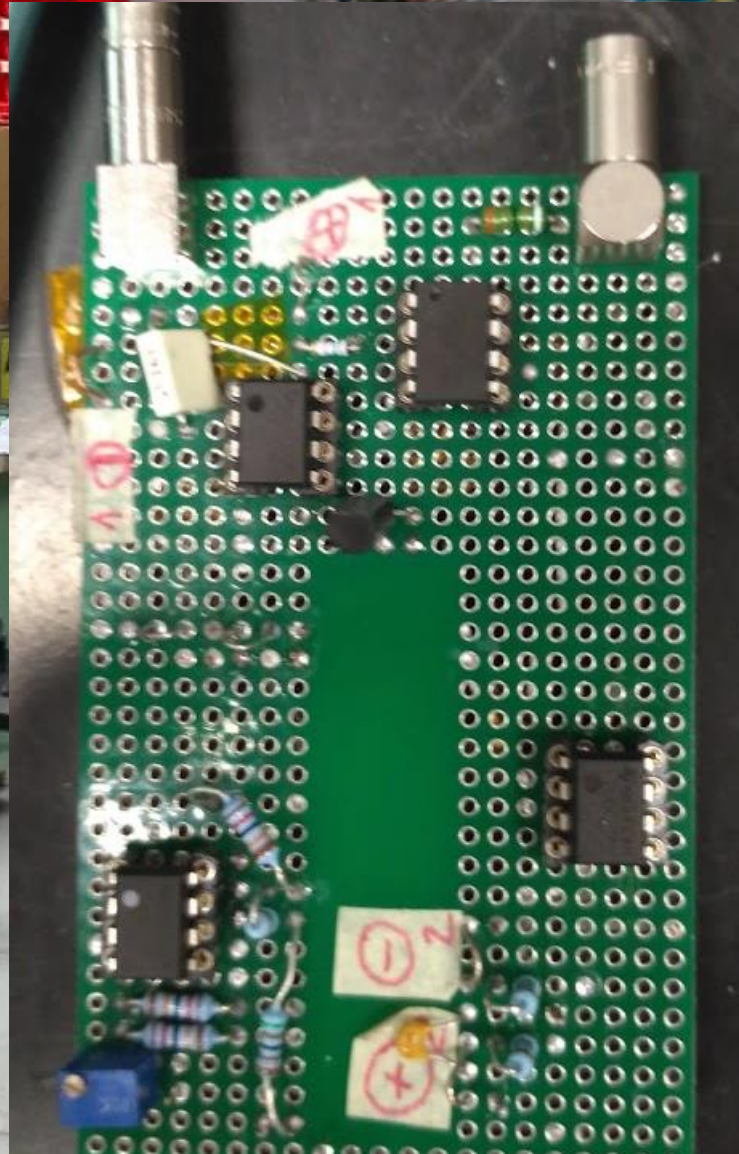
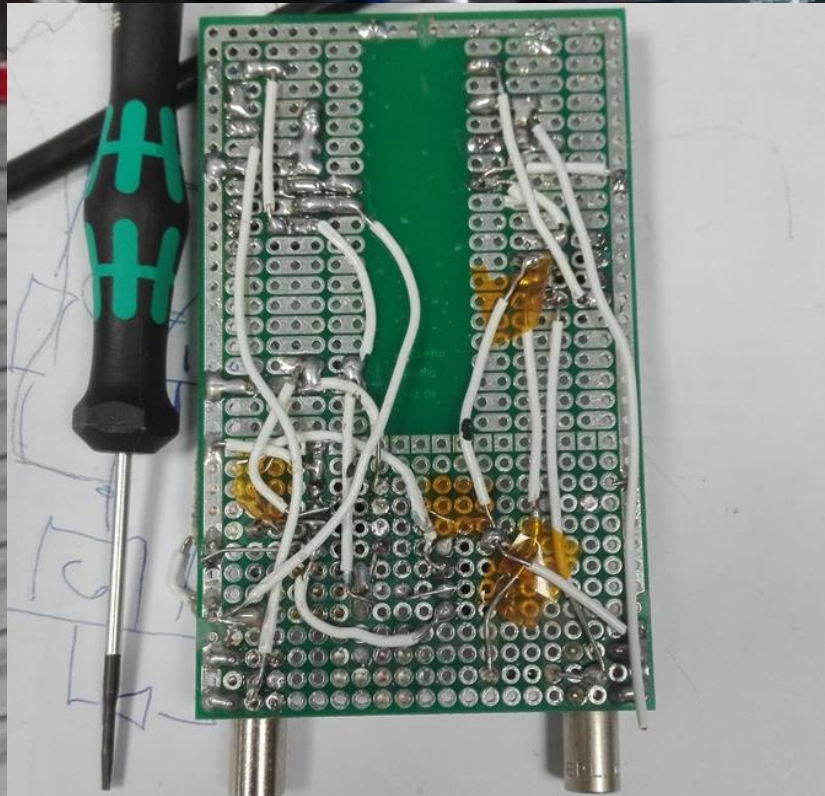
Fig. 10 - Positive Unipolar Photovoltaic Amplifier



← operational amplifier



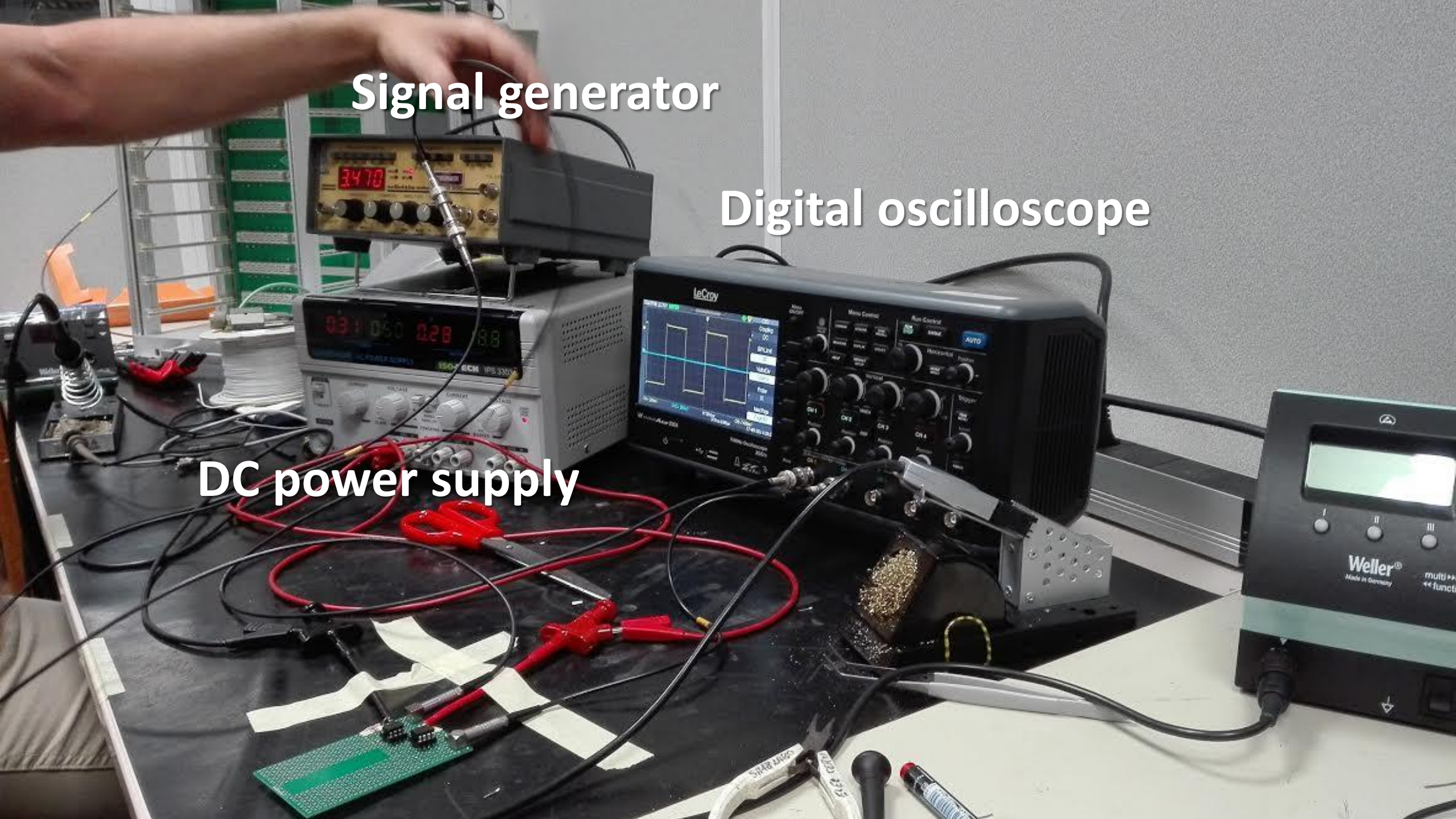
# Optical isolation amplifier



Signal generator

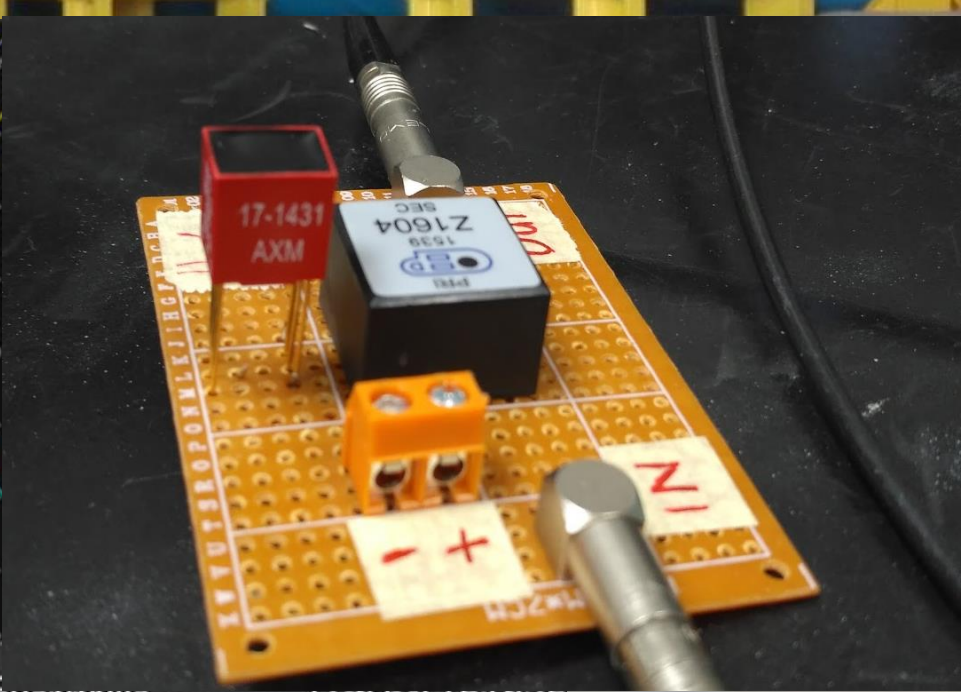
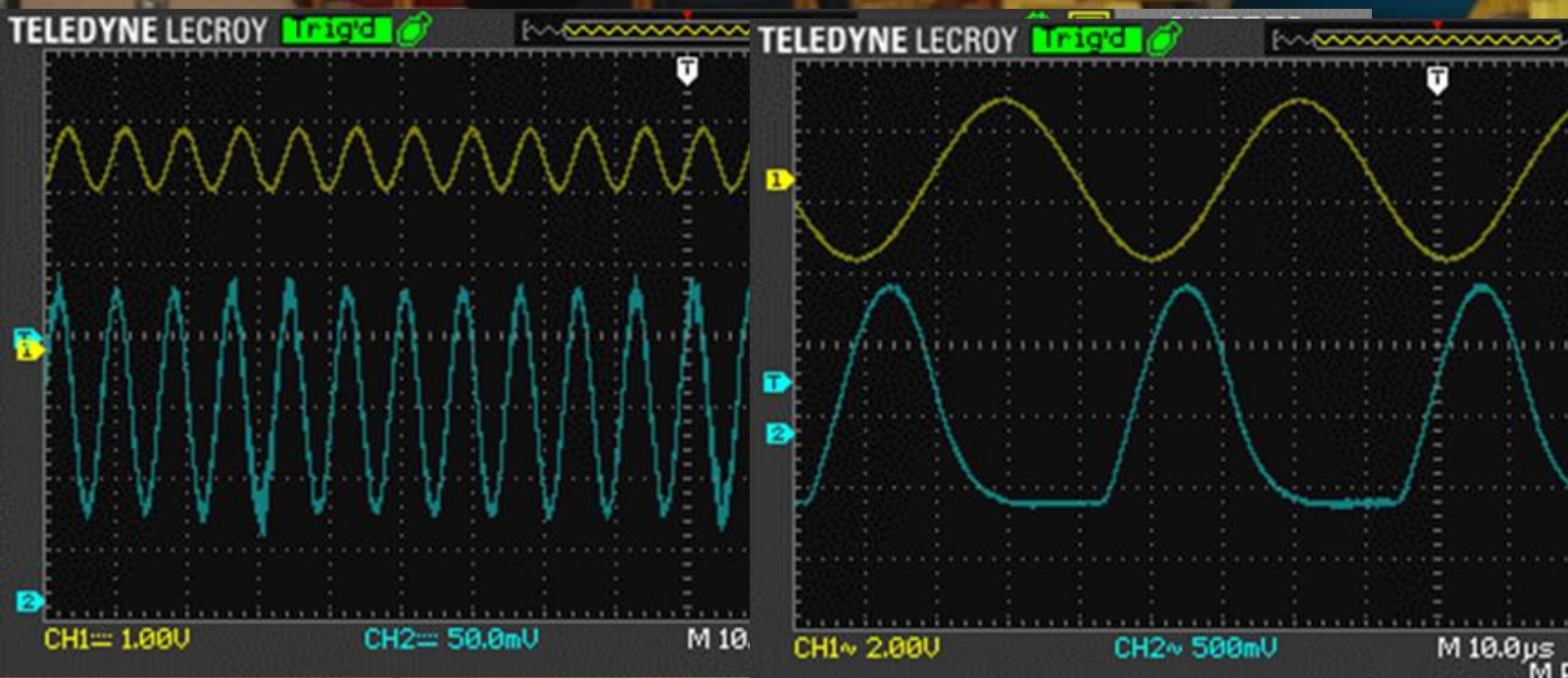
Digital oscilloscope

DC power supply



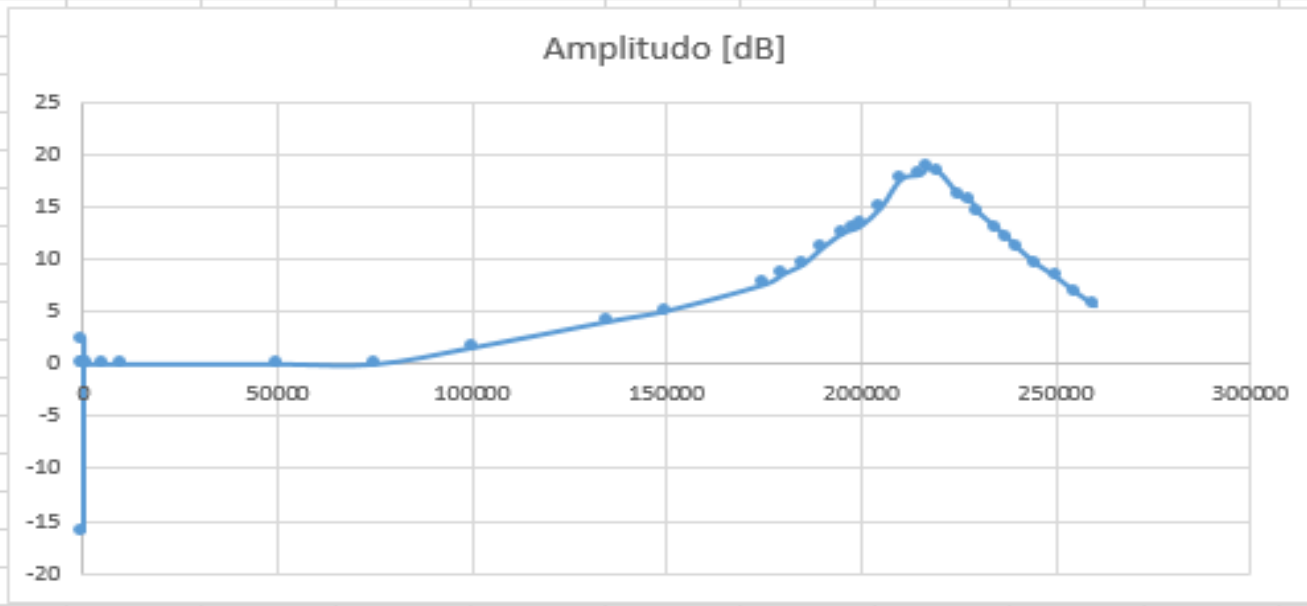
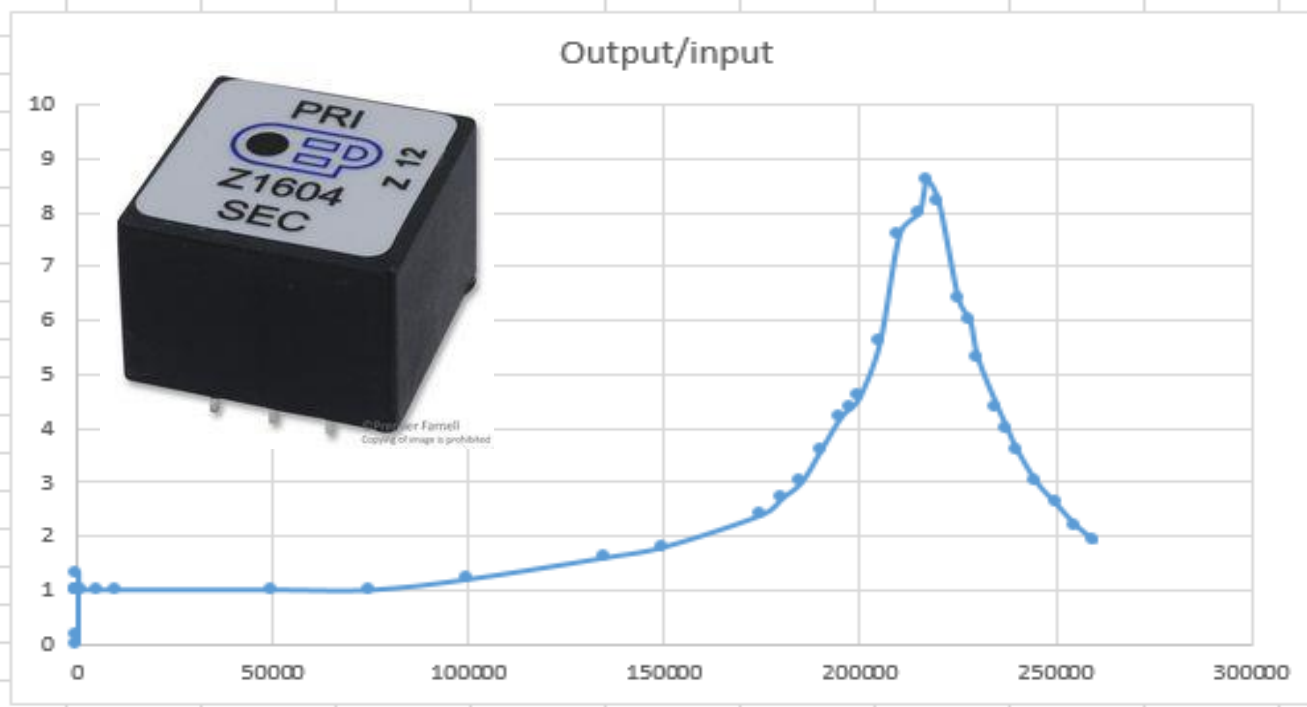
# The measurements

- We measured in different frequency sine waves to determine transfer characteristic
- we measured signal distortion to determine input voltage
- We compared the optocoupler to signal transformer circuits



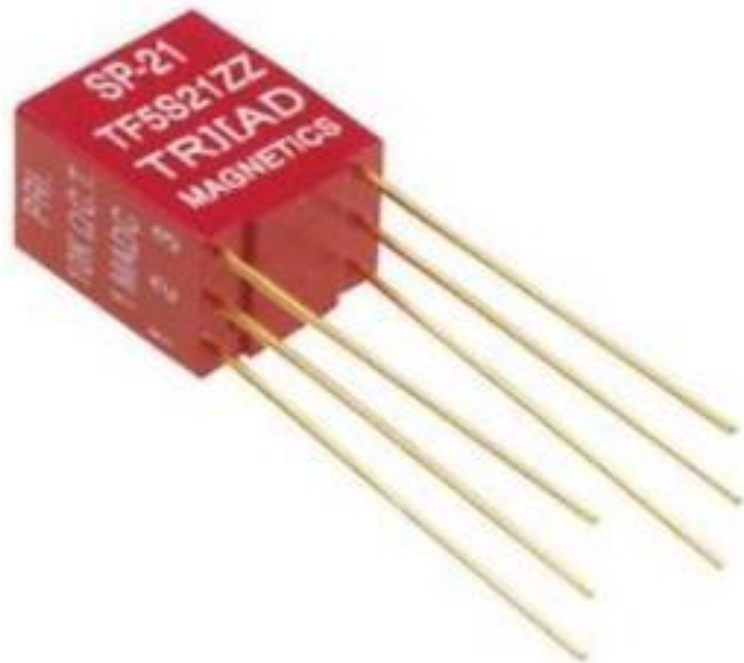
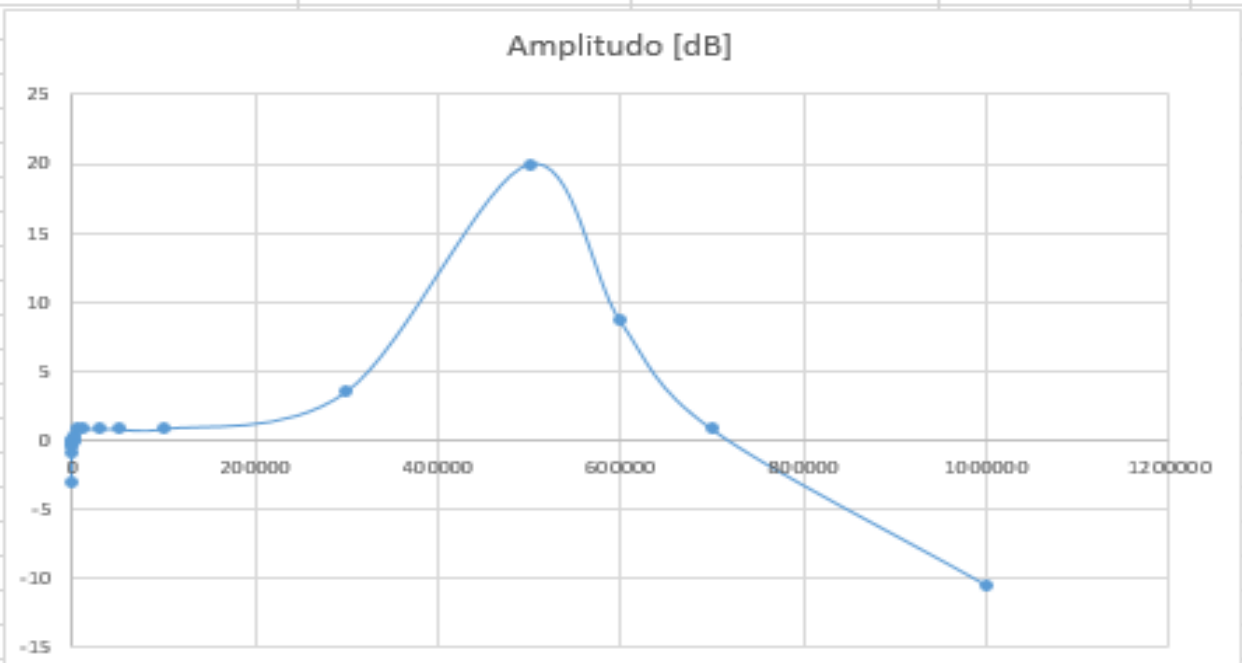
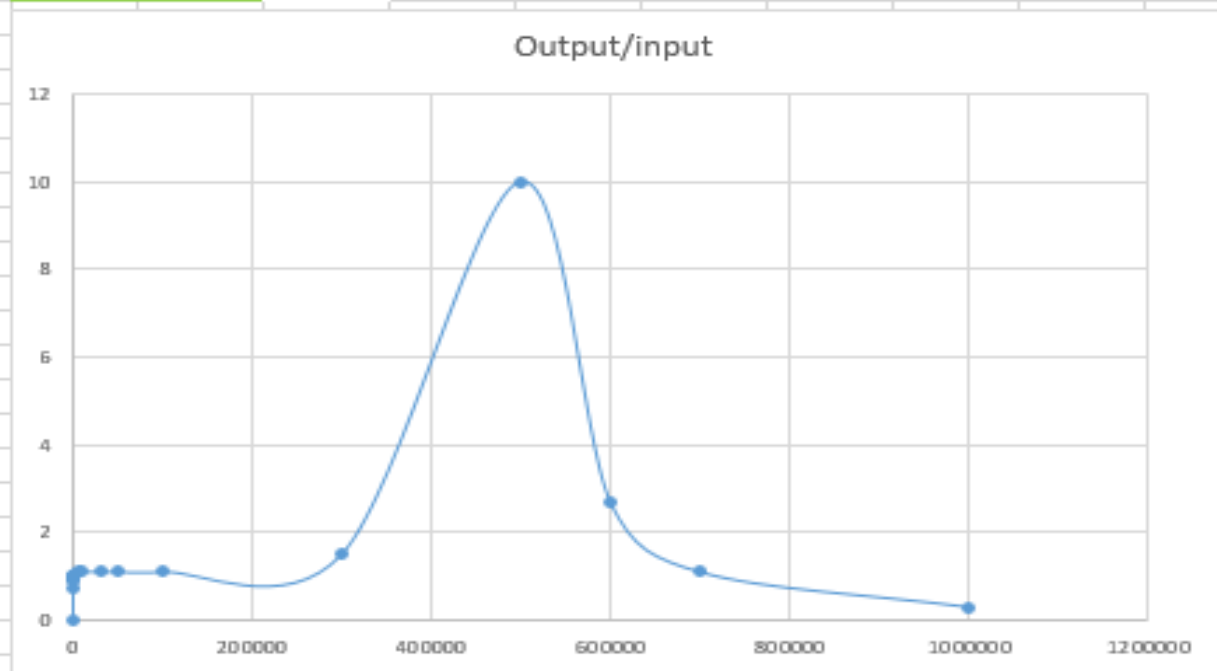
Frequency [Hz]	Output [mV]	Output/input	Amplitudo [dB]
0	0	0	#NUM!
10	16	0.16	-15.91760035
50	130	1.3	2.278867046
100	100	1	0
150	100	1	0
200	100	1	0
500	100	1	0
1000	100	1	0
5000	100	1	0
10000	100	1	0
50000	100	1	0
75000	100	1	0
100000	120	1.2	1.583624921
135000	160	1.6	4.082399653
150000	180	1.8	5.105450102
175000	240	2.4	7.604224834
180000	270	2.7	8.627275283
185000	300	3	9.542425094
190000	360	3.6	11.12605002
195000	420	4.2	12.46498581
198000	440	4.4	12.86905353
200000	460	4.6	13.25515663
205000	560	5.6	14.96376054
210000	760	7.6	17.61627185
215000	800	8	18.06179974
217000	860	8.6	18.68996902
220000	820	8.2	18.27627705
225000	640	6.4	16.12359948
228000	600	6	15.56302501
230000	530	5.3	14.48551739
235000	440	4.4	12.86905353
237500	400	4	12.04119983
240000	360	3.6	11.12605002
245000	300	3	9.542425094
250000	260	2.6	8.299466959
255000	220	2.2	6.848453616
260000	190	1.9	5.575072019

Input: 100 mV



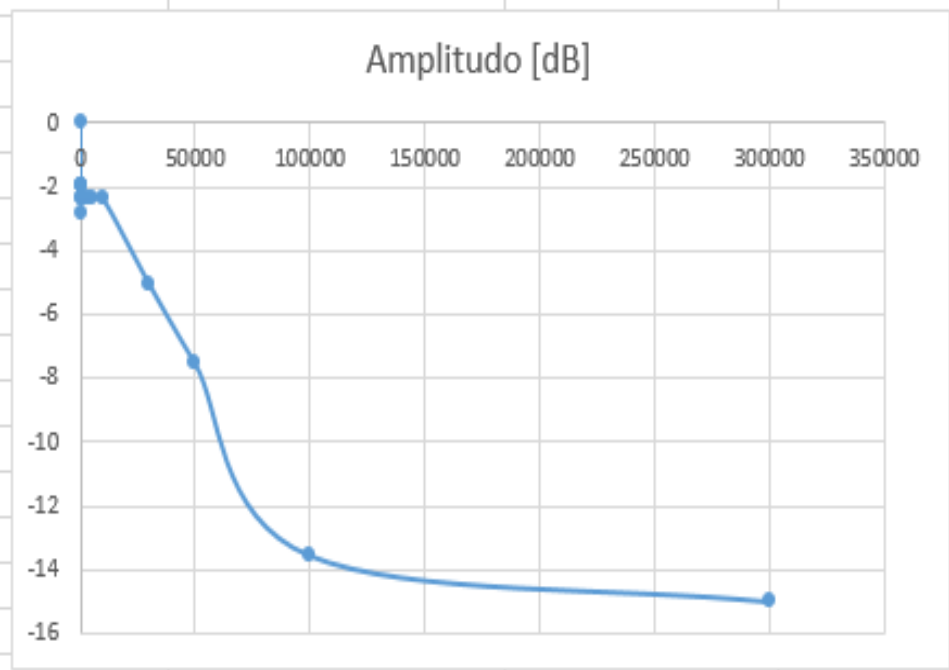
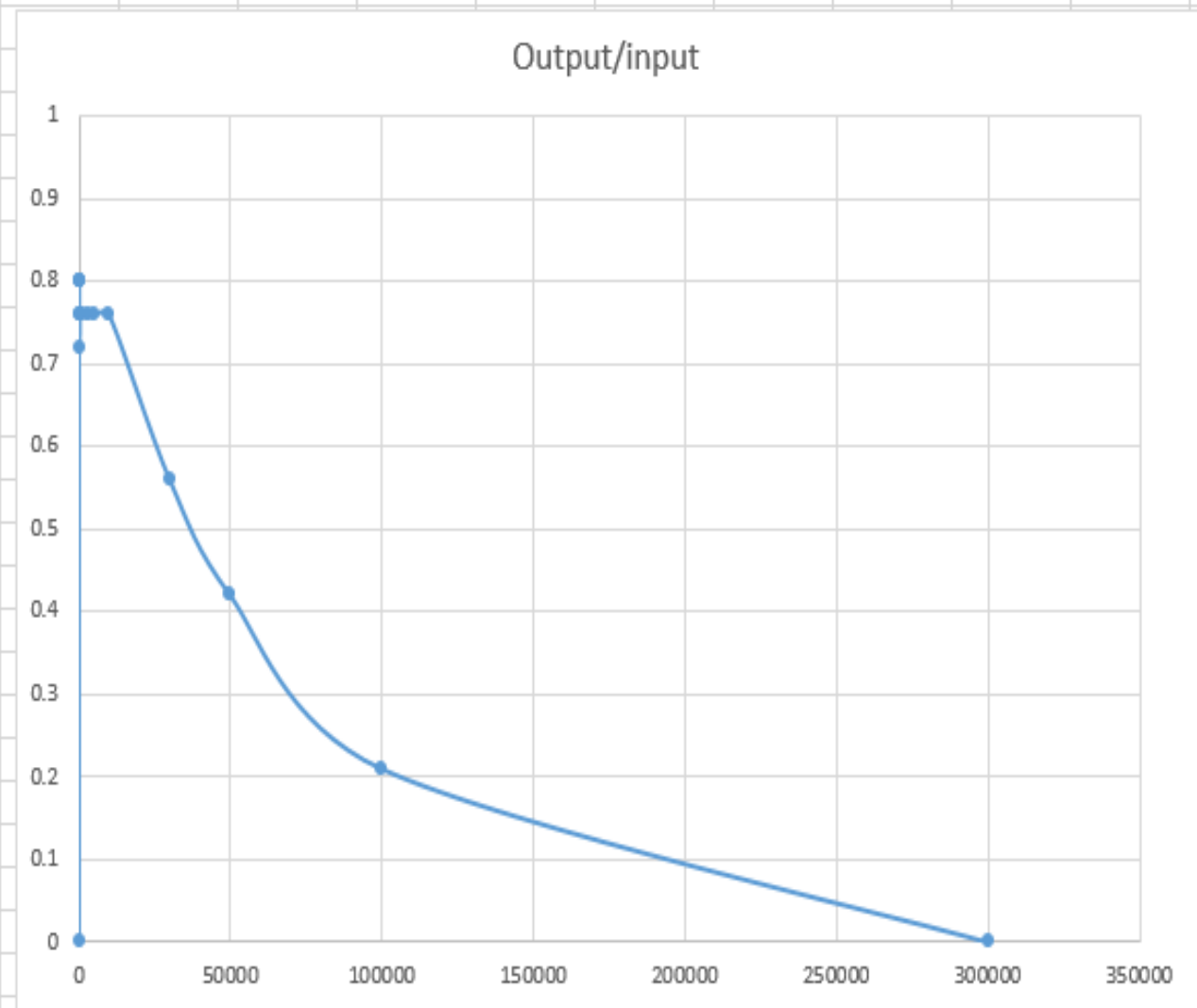
Frequency [Hz]	Output [mV]	Output	Amplitudo [dB]
0	0	0	#NUM!
10	70	0.7	-3.0980392
30	90	0.9	-0.915149811
50	95	0.95	-0.445527894
100	95	0.95	-0.445527894
300	100	1	0
500	100	1	0
1000	100	1	0
3000	105	1.05	0.423785981
5000	110	1.1	0.827853703
10000	110	1.1	0.827853703
30000	110	1.1	0.827853703
50000	110	1.1	0.827853703
100000	110	1.1	0.827853703
300000	150	1.5	3.521825181
500000	1000	10	20
600000	270	2.7	8.627275283
700000	110	1.1	0.827853703
1000000	30	0.3	-10.45757491

Input: 100 mV



Frequency [Hz]	Output [mV]	Output/input	Amplitudo [dB]
0	0	0	0
10	800	0.8	-1.93820026
30	800	0.8	-1.93820026
50	800	0.8	-1.93820026
100	720	0.72	-2.853350071
300	760	0.76	-2.383728154
500	760	0.76	-2.383728154
1000	760	0.76	-2.383728154
3000	760	0.76	-2.383728154
5000	760	0.76	-2.383728154
10000	760	0.76	-2.383728154
30000	560	0.56	-5.03623946
50000	420	0.42	-7.535014192
100000	210	0.21	-13.55561411
300000	0	0	-15

Input: 1 V





Thank you for the attention