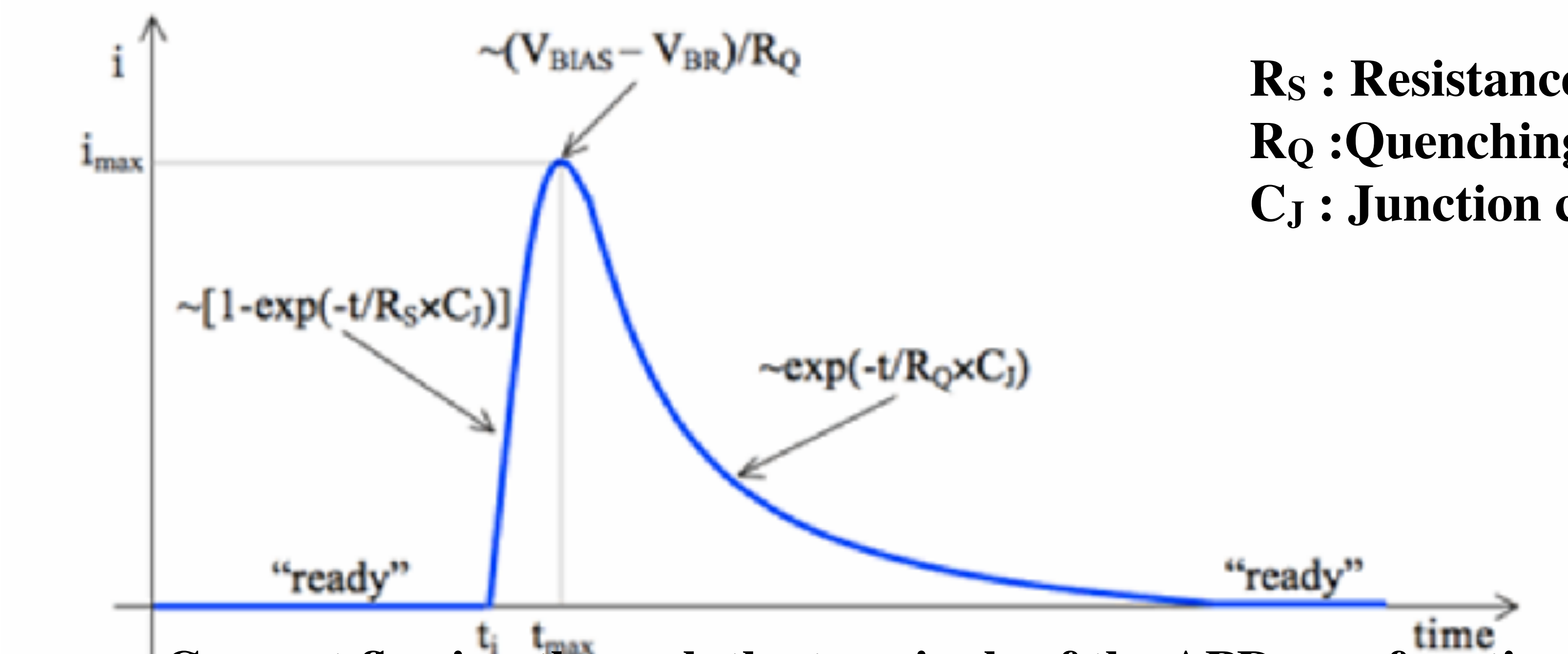
STUDY OF MULTI MPPC BIASING METHODS

Korea Univ.
Wooseung, Jung

MPPC OPERATION PRINCIPLE

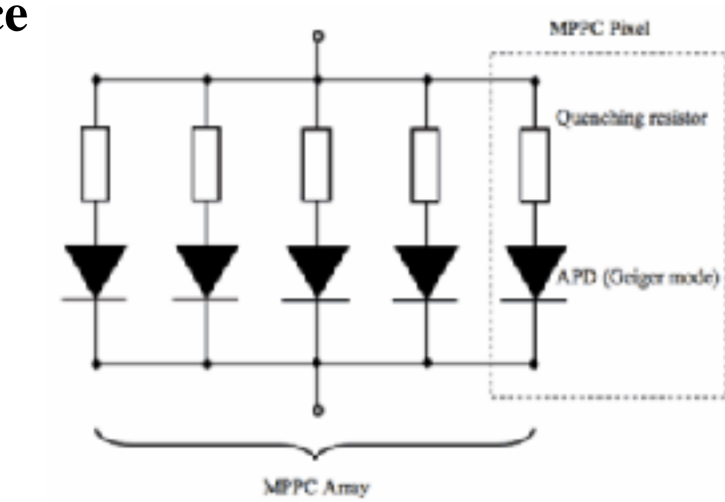


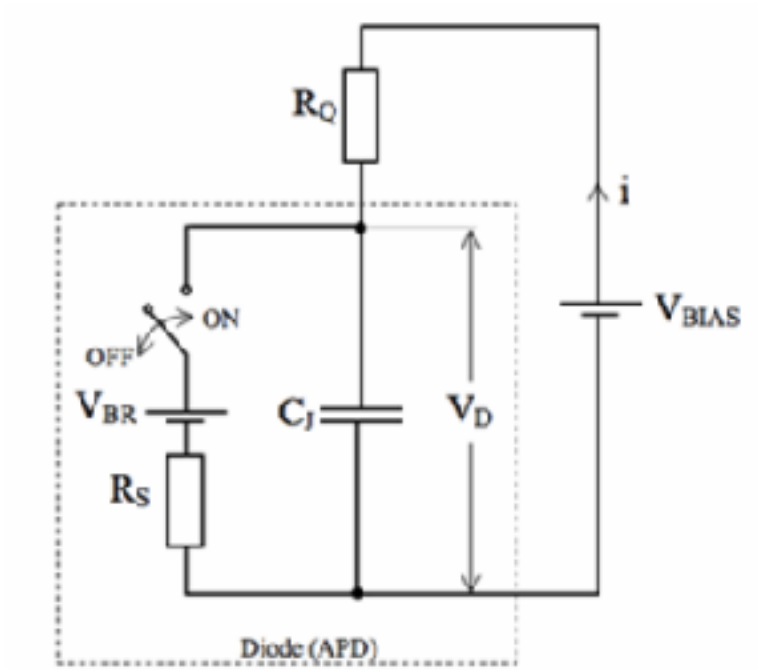
Current flowing through the terminals of the APD as a function

R_S : Resistance of the entire APD during a discharge

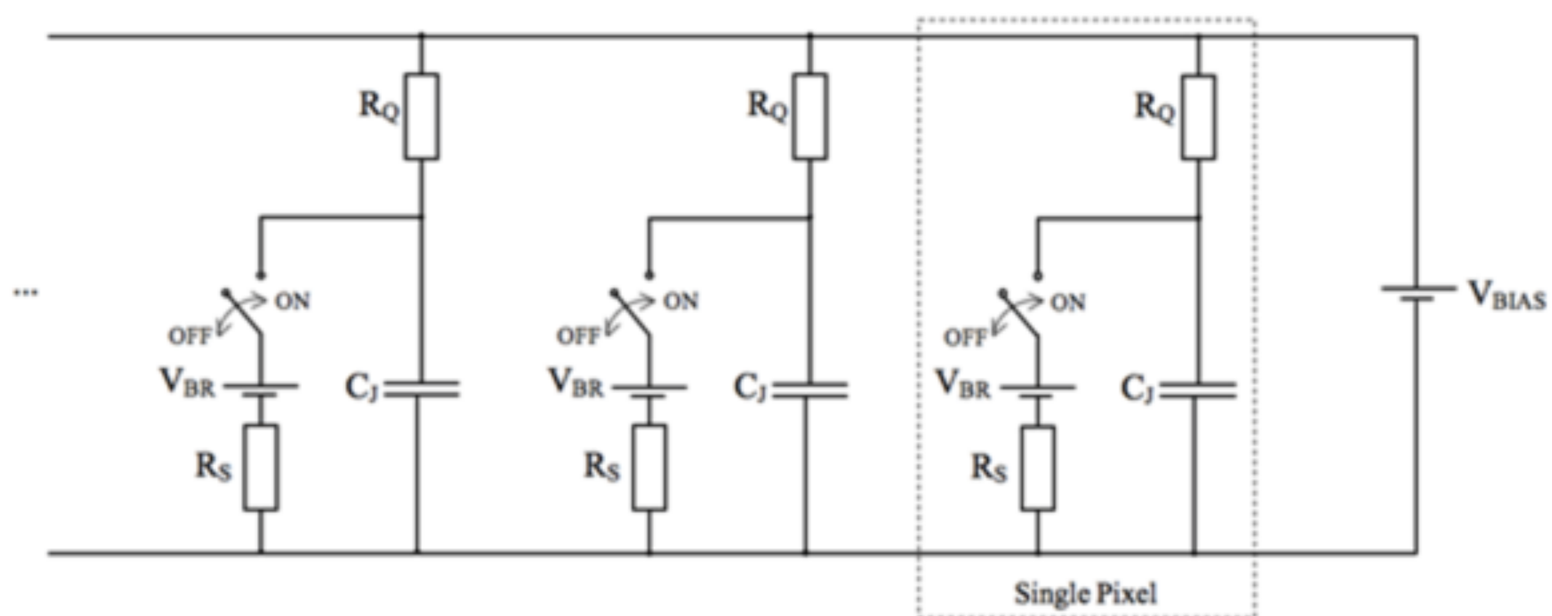
R_Q :Quenching resistor

C_J : Junction capacitance





Equivalent circuit of MPPC's single GAPD

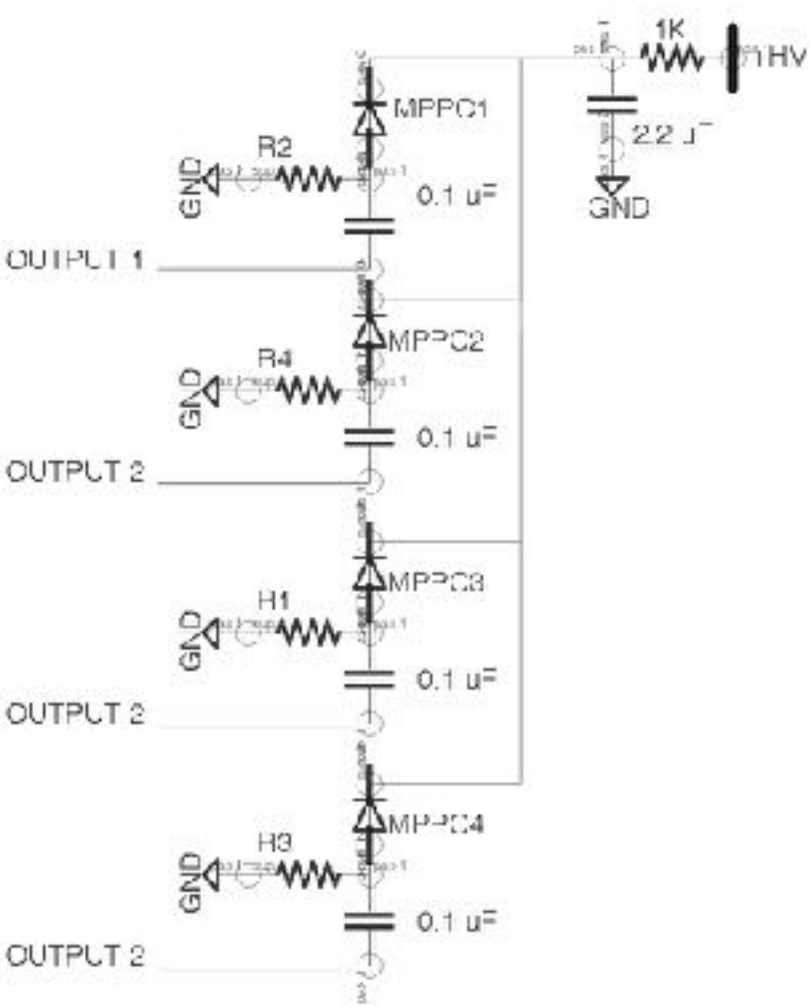


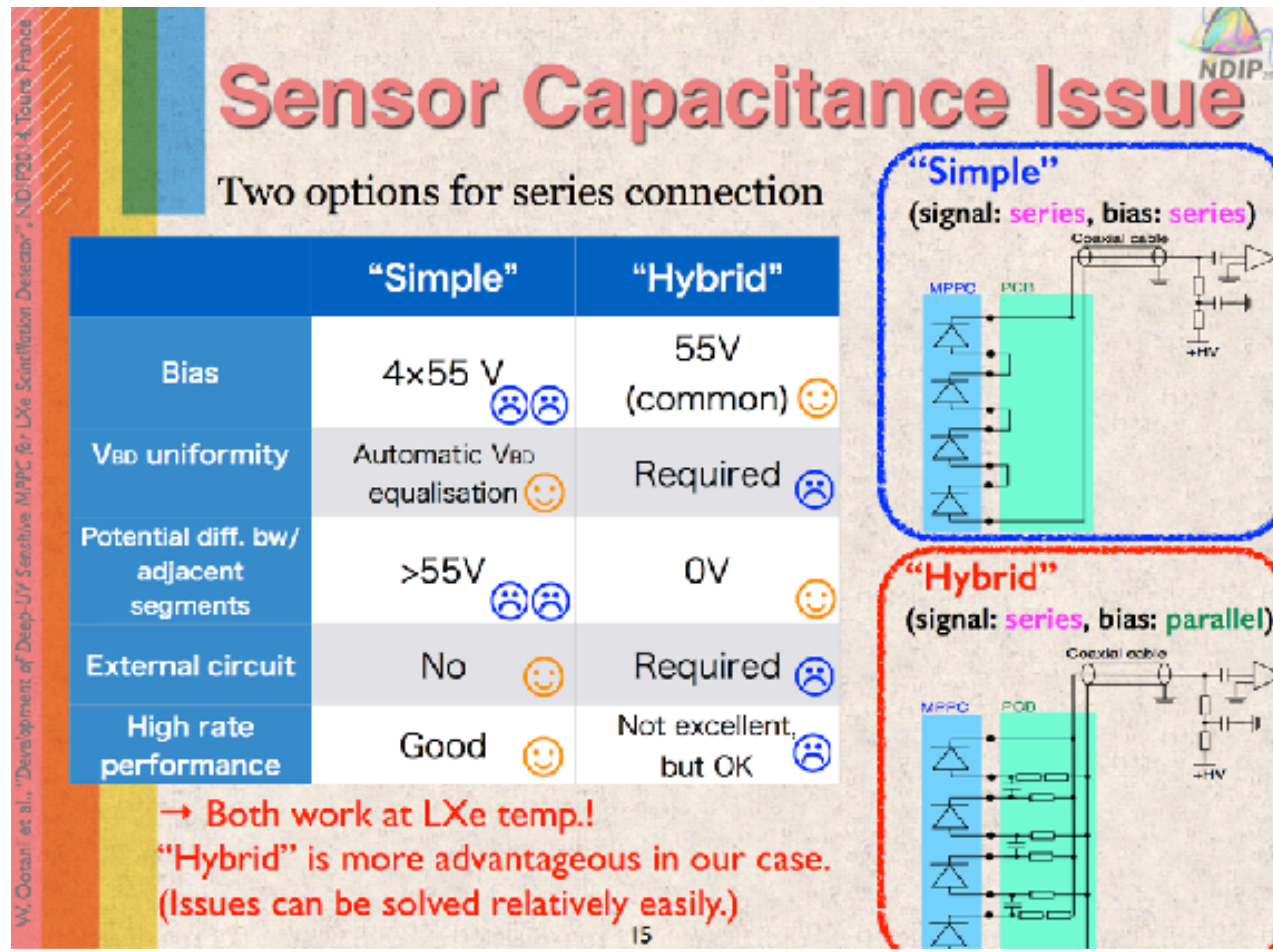
Equivalent circuit of MPPC

MPPC BIASING ISSUE

Many MPPCs connected together on the sides of hodoscope scintillator

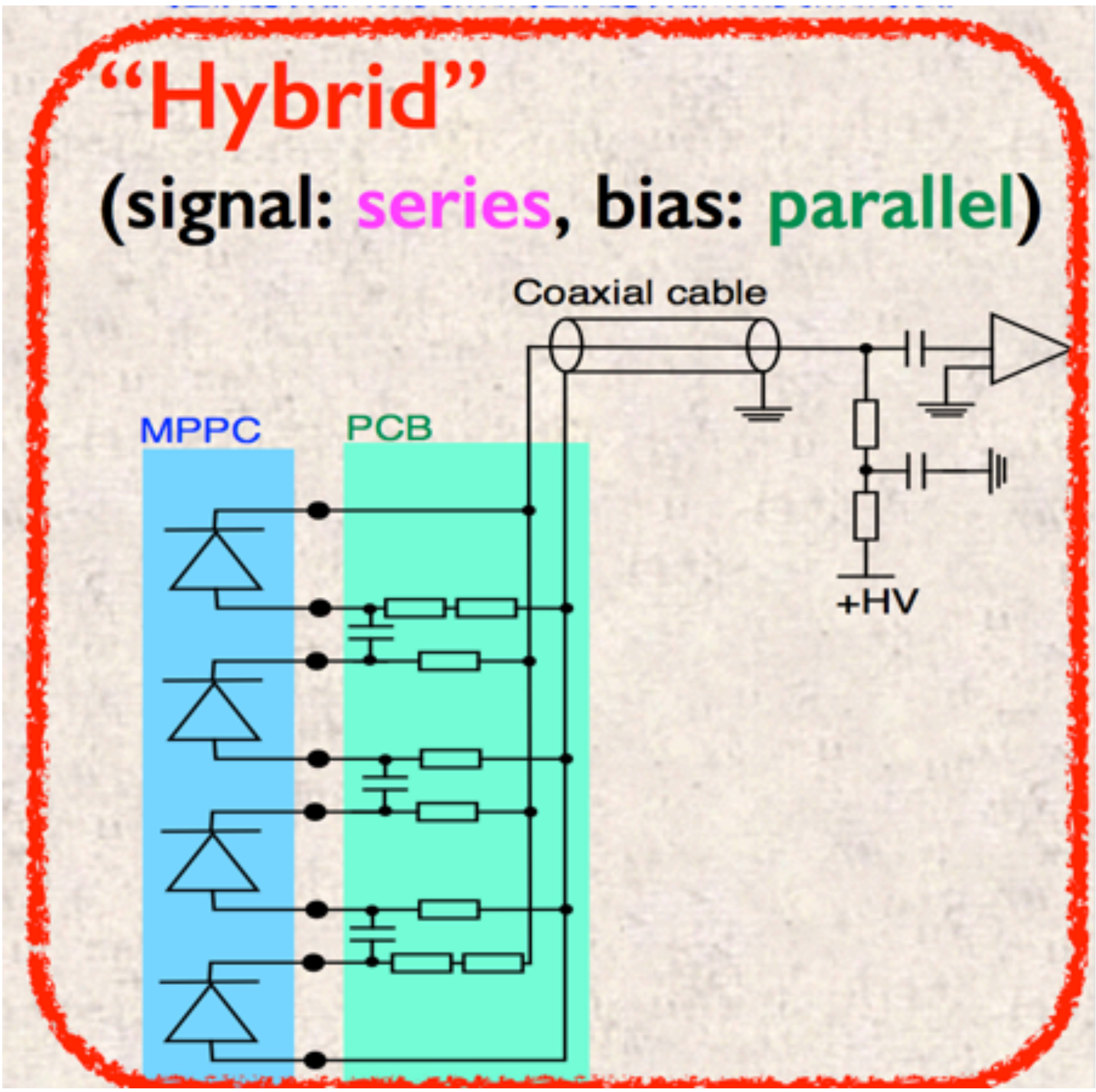
-> Should have to choose MPPC biasing method which is suitable in our system.





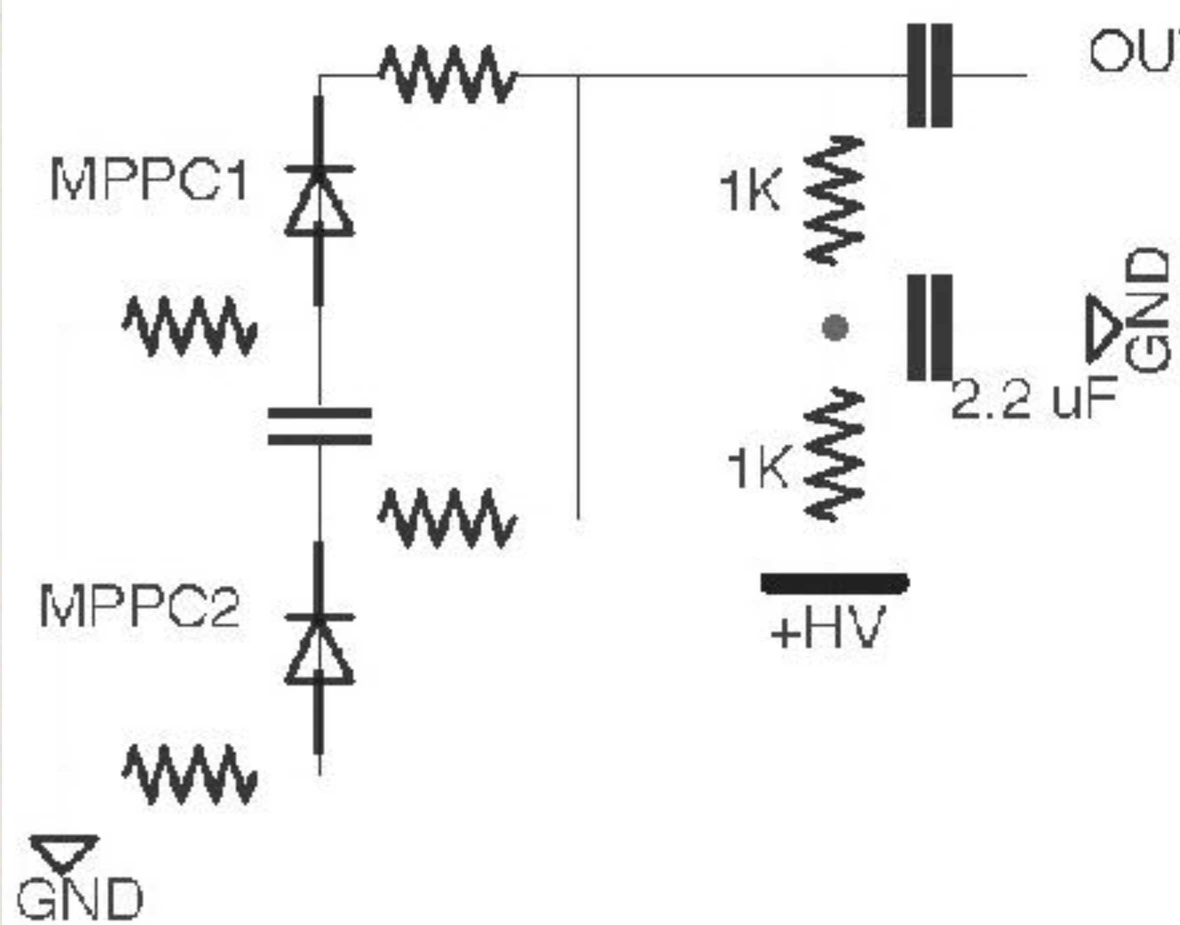
Parallel connection **Series connection**

HYBRID CONNECTION



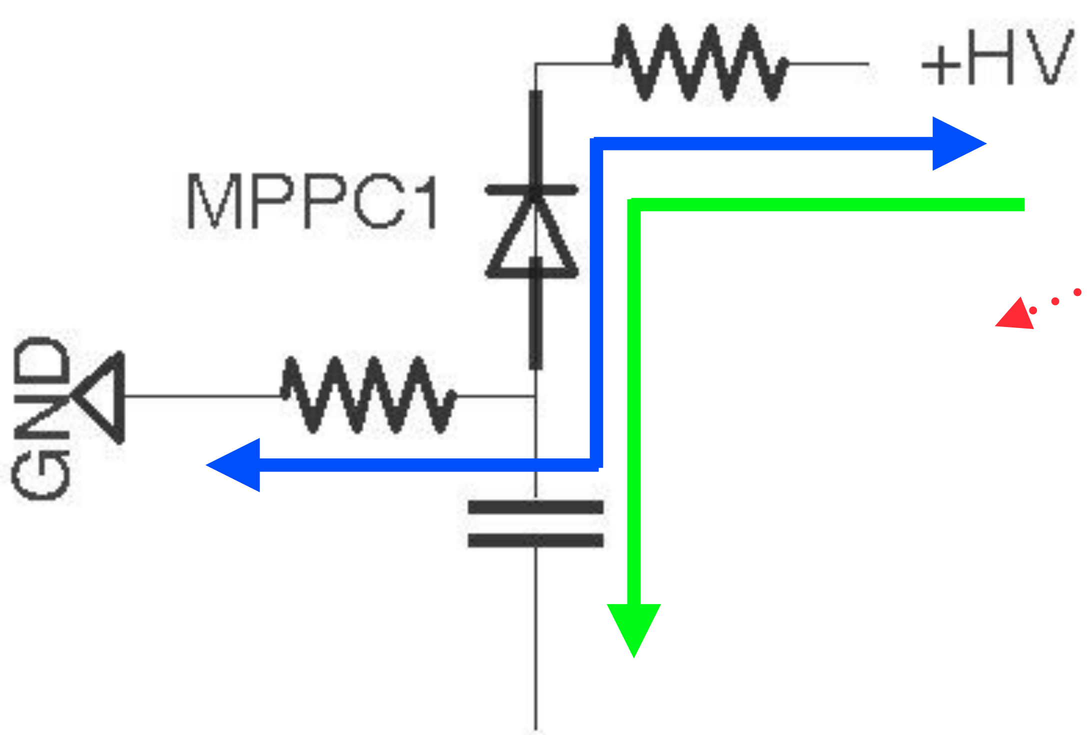
Hasegawa-san's suggestion

⊕ Additional Amplifier

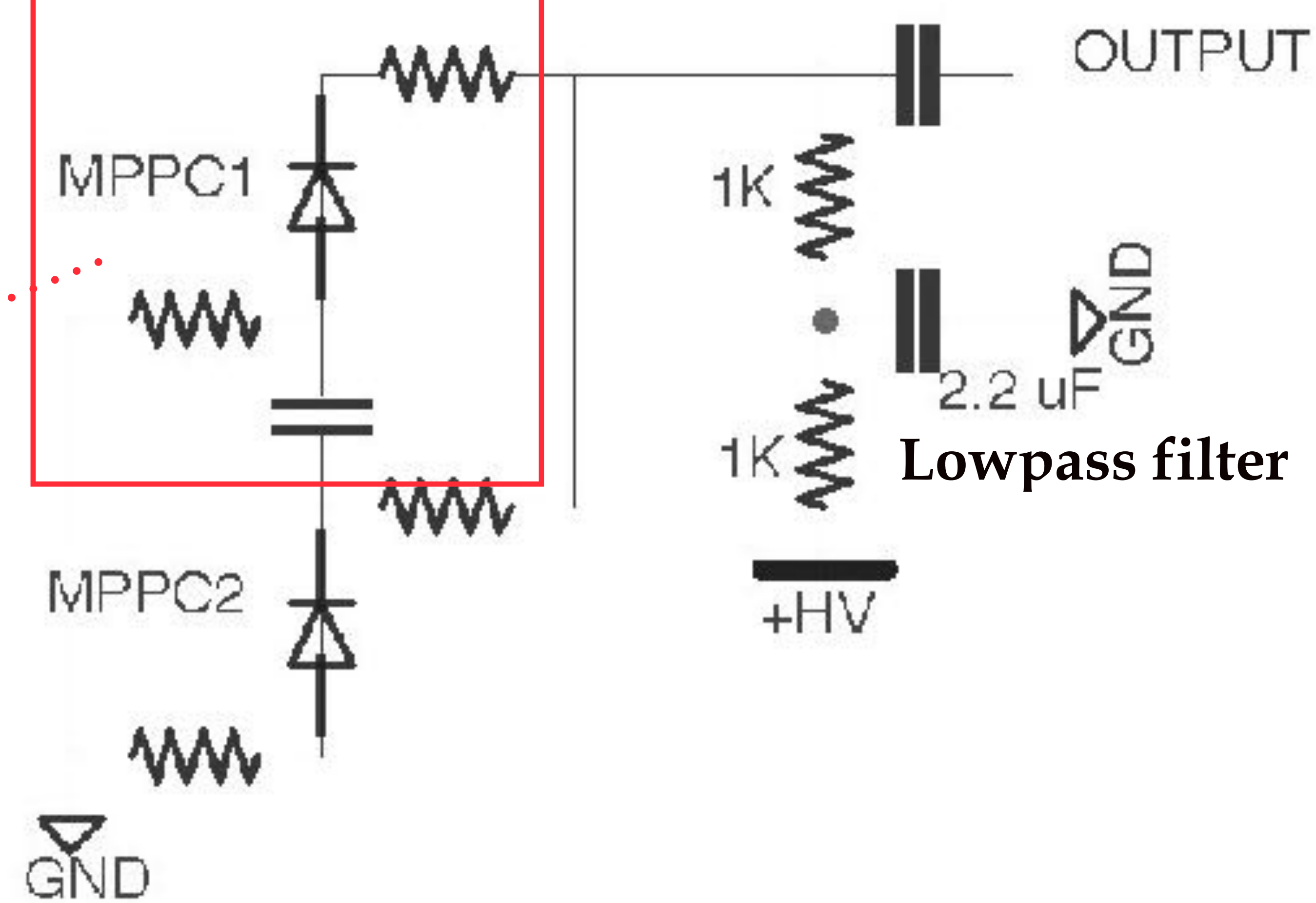


Equivalent circuit(for 2 MPPC ver.)
(Additional amplifier should be connected in serial)

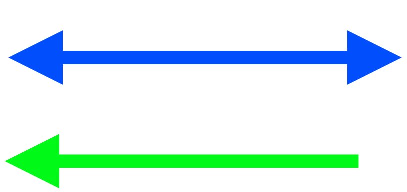
WORKING PRINCIPLE



Single-unit diagram



Lowpass filter

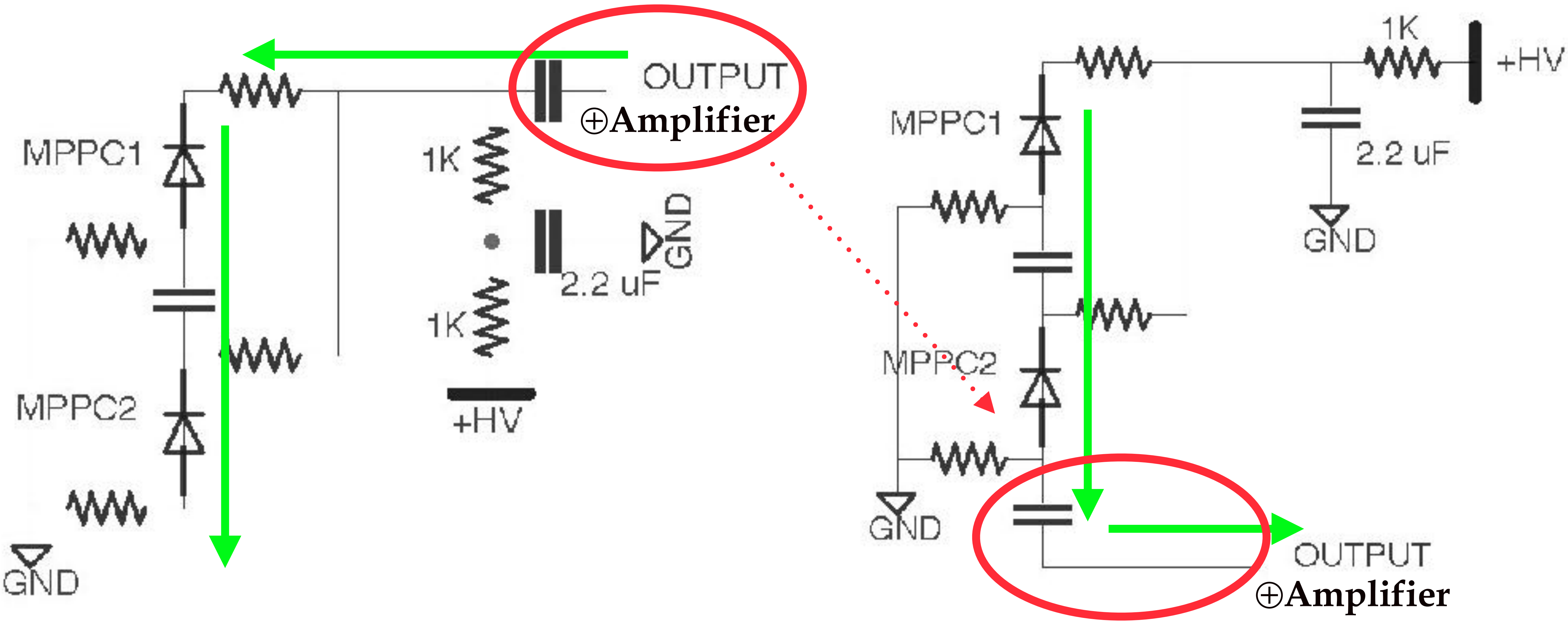


DC line(for HV biasing)

AC line(Way of MPPC photocurrent)

Equivalent circuit(for 2 MPPC ver.)

CIRCUIT MODIFICATION



In Hasegawa-san's suggestion, signal has a negative polarity.

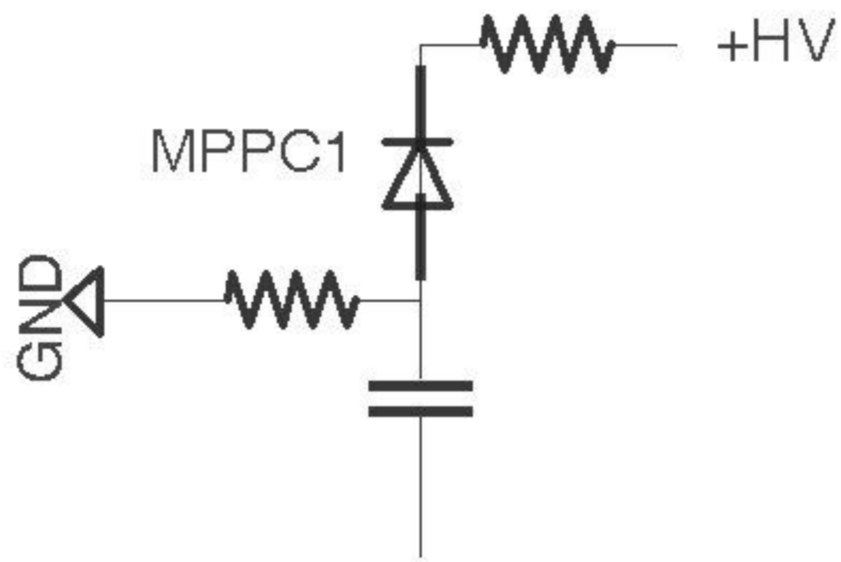
But, common amplifiers working as an inverter. So final output has a positive polarity.

=> Modified circuit to have a positive output.

TEST STEPS

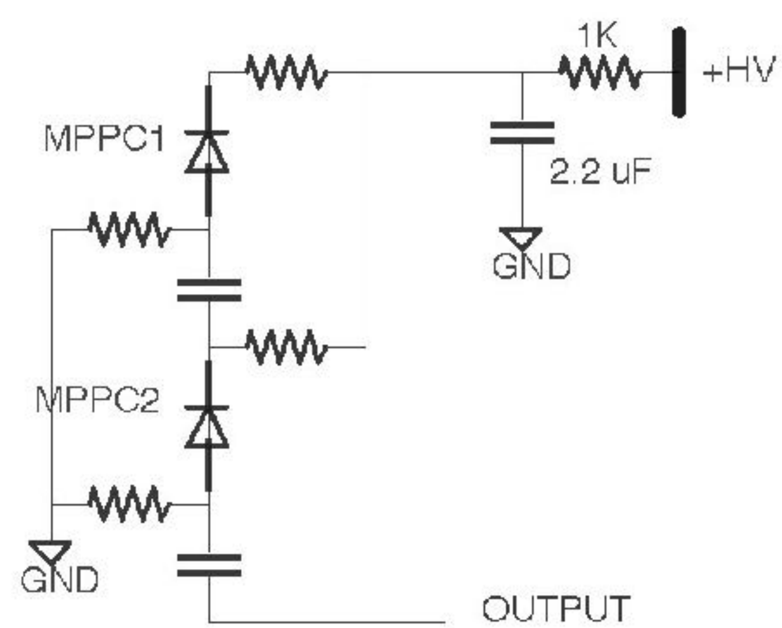
LED test for signal shape study

1. Single MPPC test



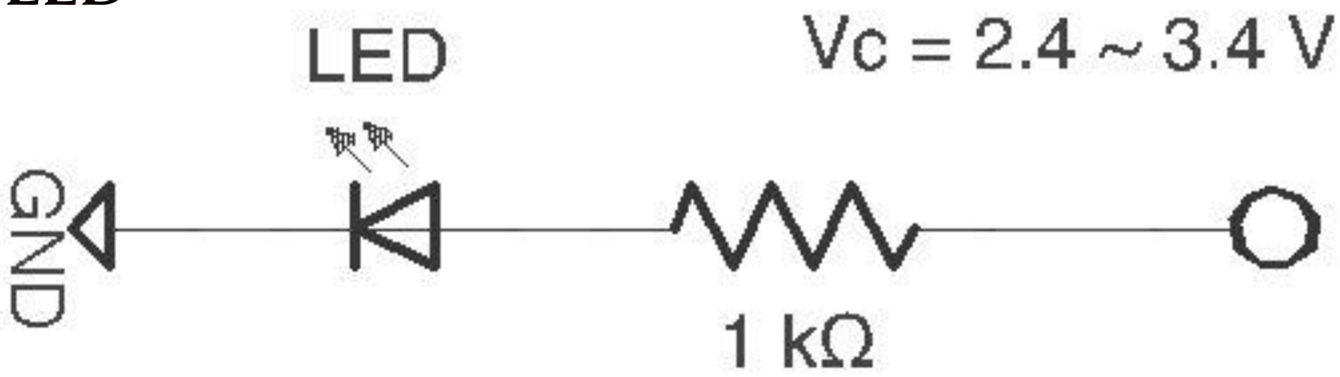
2. Hybrid connection test

- with 1 MPPC
- with 2 MPPCs



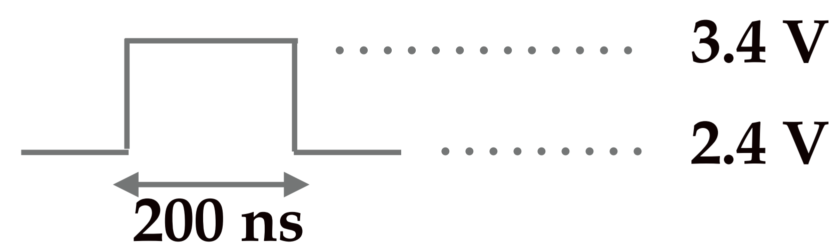
TEST MATERIALS AND CONDITIONS

LED



Function generator's output

(Repetition rate : 1 kHz)



MPPC(S13360-1350CS)

Type no.	Pixel pitch (μm)	Effective photosensitive area (mm)	Number of pixels	Package	Fill factor (%)
S13360-1350CS	50	1.3 × 1.3	667	Ceramic	74
S13360-1350PE				Surface mount type	
S13360-3050CS		3.0 × 3.0	3600	Ceramic	
S13360-3050PE				Surface mount type	
S13360-6050CS		6.0 × 6.0	14400	Ceramic	
S13360-6050PE				Surface mount type	

Type no.	Measurement conditions	Spectral response range λ (nm)	Peak sensitivity wavelength λp (nm)	Photon detection efficiency PDE[*1] λ=λp (%)	Dark count[*2] Typ. (kcps)	Dark count[*2] Max. (kcps)	Terminal capacitance Ct (pF)	Gain M	Breakdown voltage VBR (V)	Crosstalk probability (%)	Recommended operating voltage Vop (V)	Temperature coefficient at recommended operating voltage ΔTVop (mV/°C)
S13360-1350CS	Vover =3 V	270 to 900	450	40	90	270	60	1.7×10^6	53 ± 5	3	VBR + 3	54
S13360-1350PE		320 to 900										
S13360-3050CS		270 to 900			500	1500	320					
S13360-3050PE		320 to 900										
S13360-6050CS		270 to 900			2000	6000	1280					
S13360-6050PE		320 to 900										

MPPC's capacitance = 60 pF

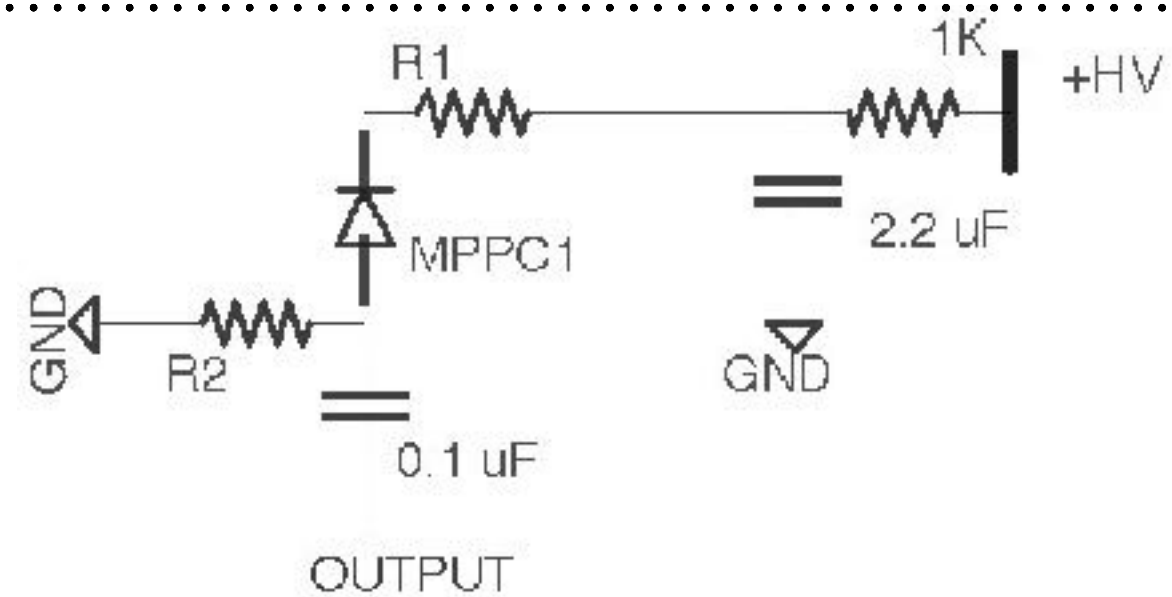
Test Condition

V_{MPPC} = 56 V

LED and MPPC adjoin each other

SINGLE MPPC TEST

Single MPPC's signal shape study



<u>Expectation</u>

- Rise time is strongly related to MPPC's own resistance and capacitance.

-> So, rise time will not become different.

- R1+R2 related to quenching.

-> if R1+R2 become bigger, signal tail become longer

SINGLE MPPC TEST

T_{rise} : signal's rise time

T_{sig} : signal full width

R1 : 0(jumper)

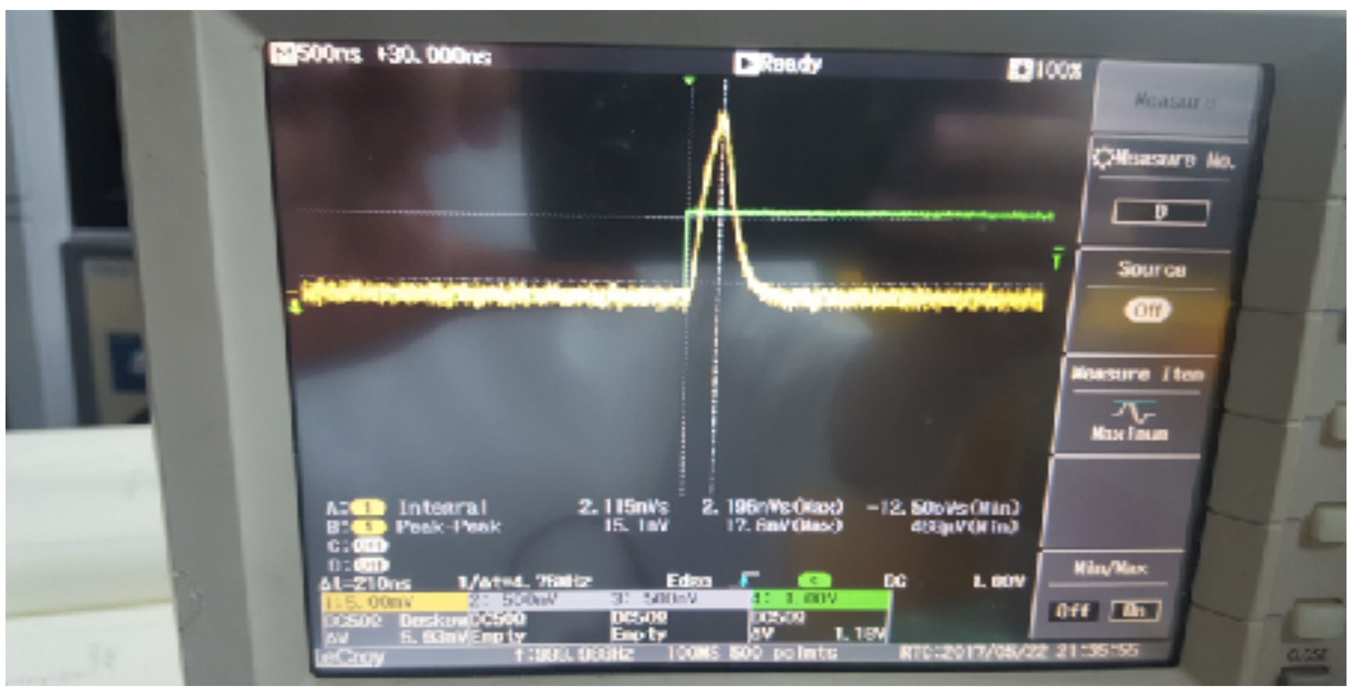
R2 : 10 kΩ

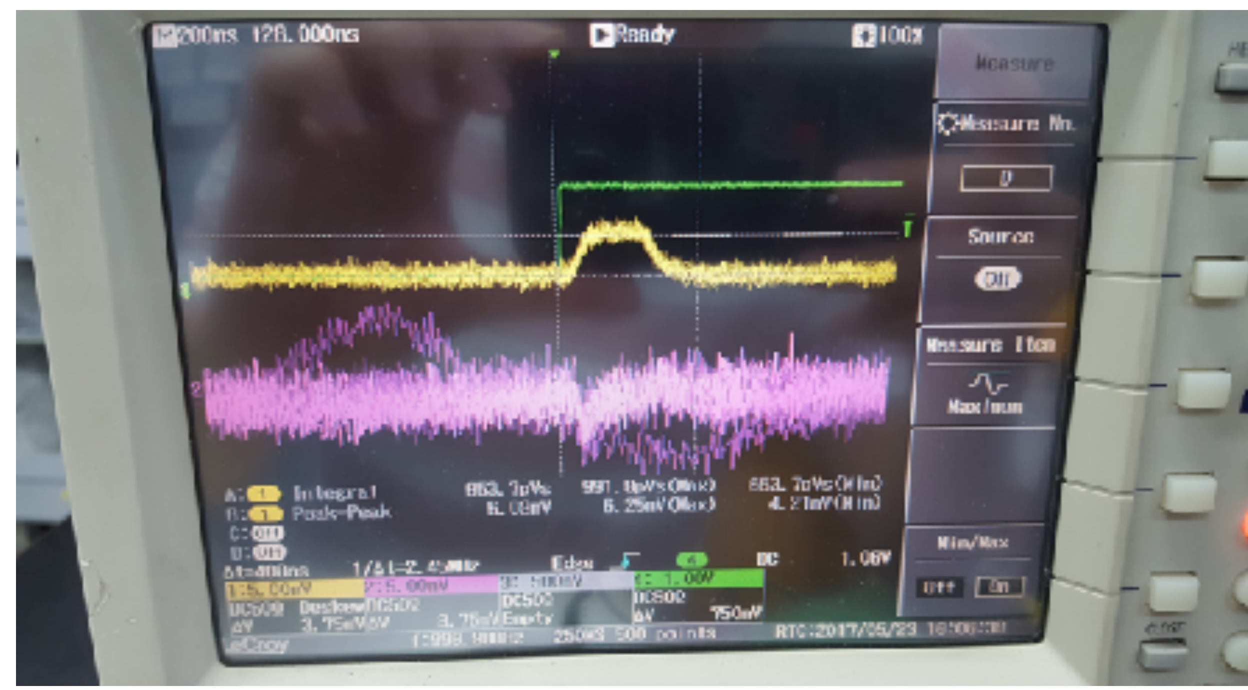
17.6 mV< $V_{p\text{-}p}$ < 20 mV

T_{rise} = 210 ns, T_{sig} ~ 500 ns

R2 : 100 Ω

4.21 mV< $V_{p\text{-}p}$ < 6.25 mV





Signal become smaller and there is a quenching problem.

SINGLE MPPC TEST

T_{rise} : signal's rise time

T_{sig} : signal full width

R1 : 0(jumper)

R2 : 10 kΩ

17.6 mV< $V_{p\text{-}p}$ < 20 mV

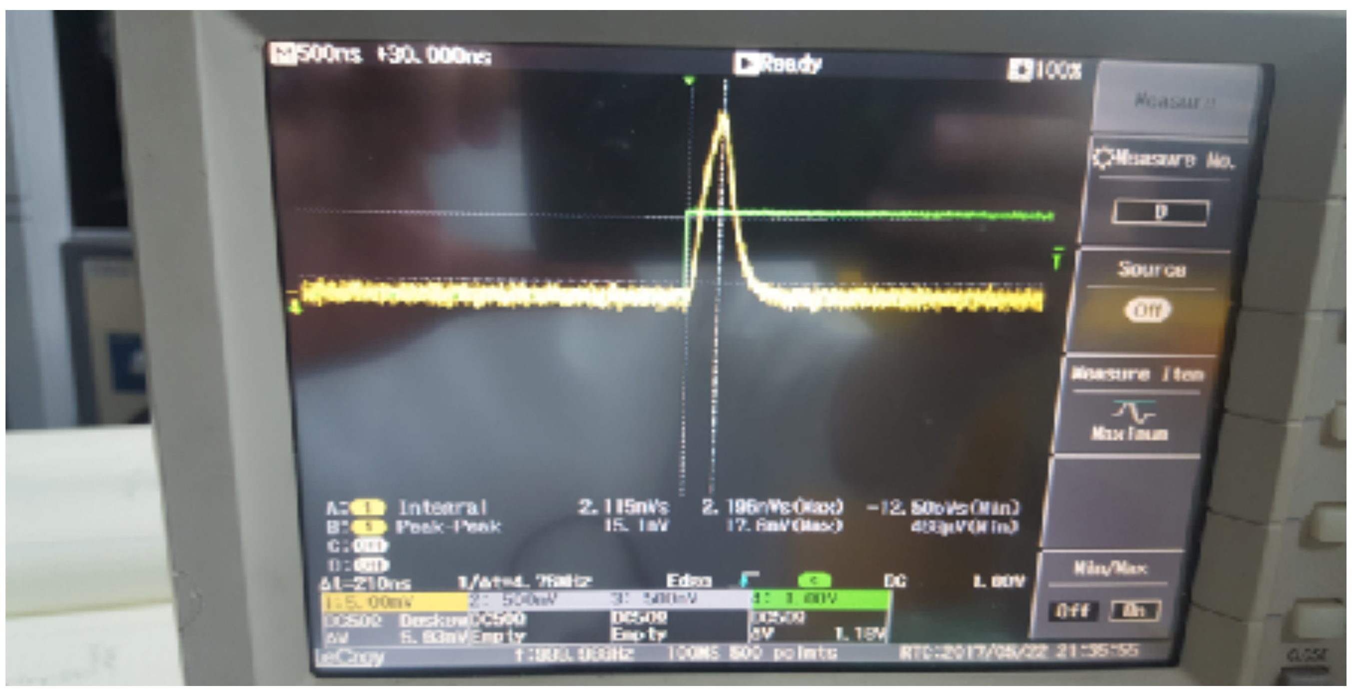
T_{rise} = 210 ns, T_{sig} ~ 500 ns

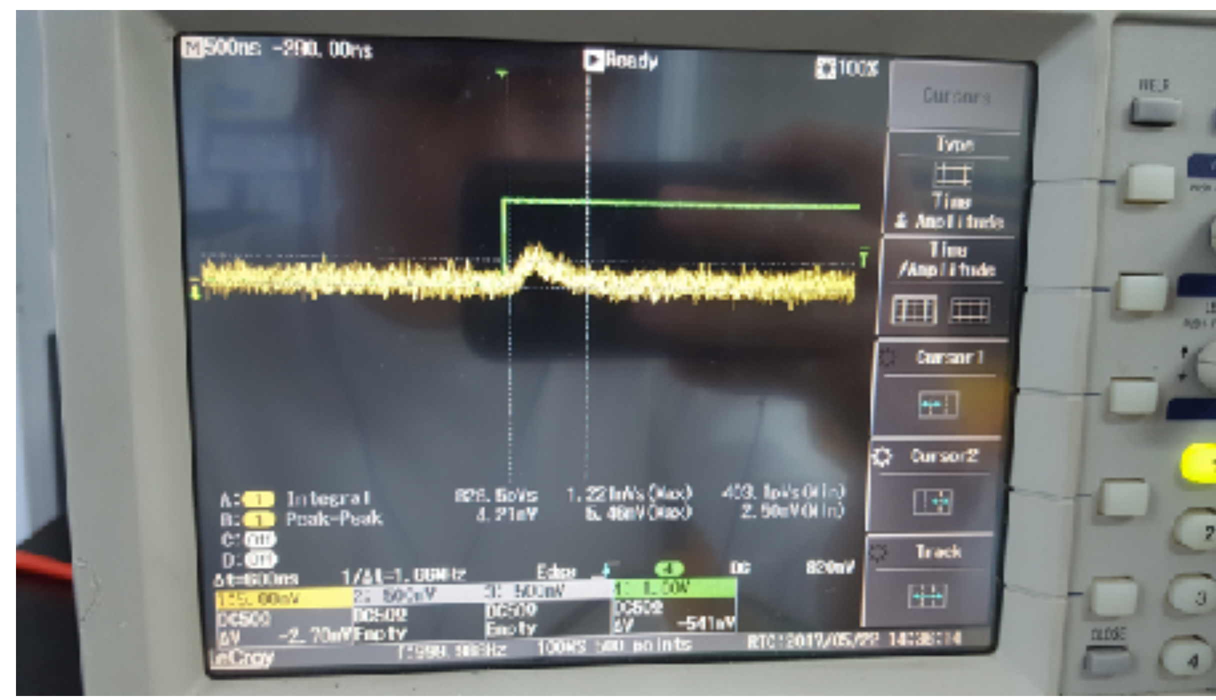
R1 : 10 kΩ

R2 : 10 kΩ

4.21 mV< $V_{p\text{-}p}$ < 6.25 mV

T_{rise} = 210 ns, T_{sig} ~ 600 ns

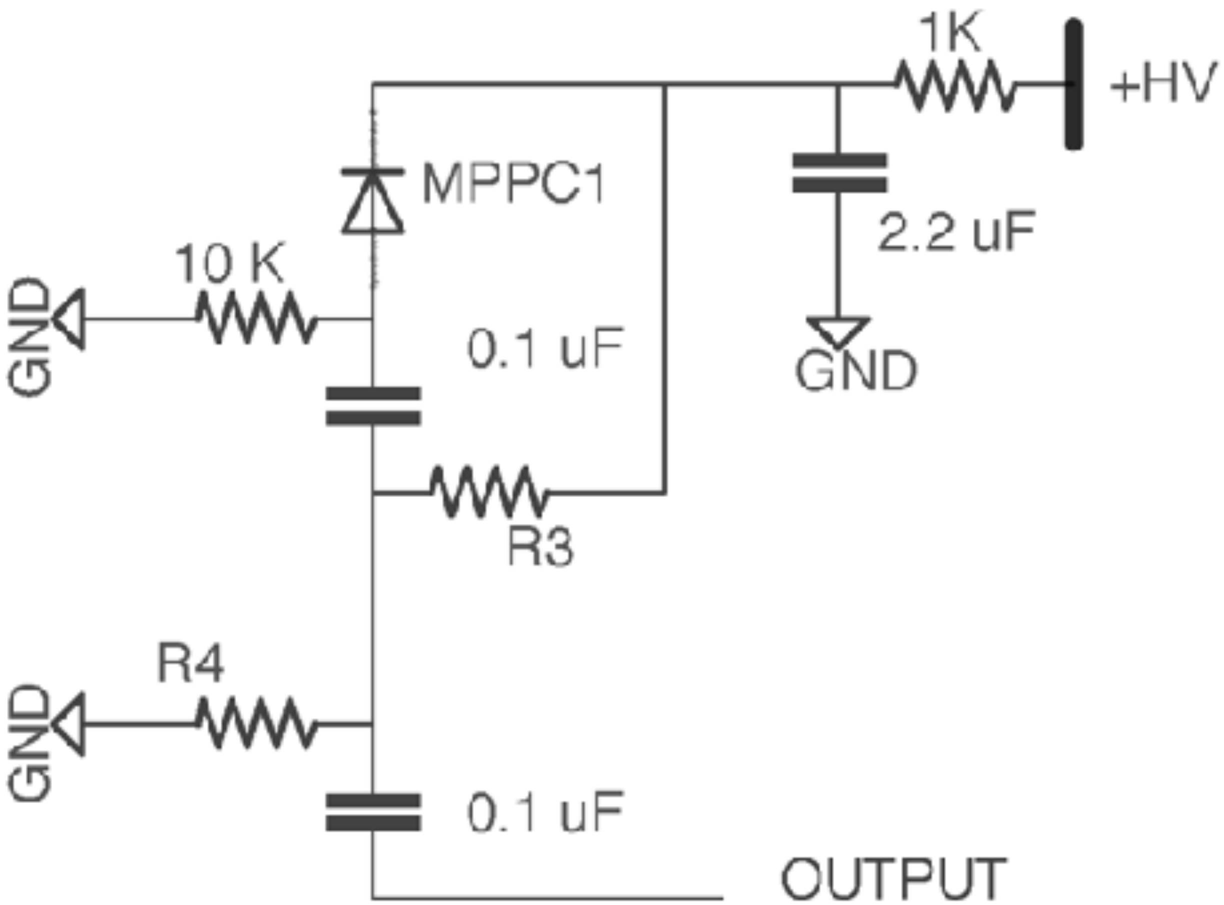




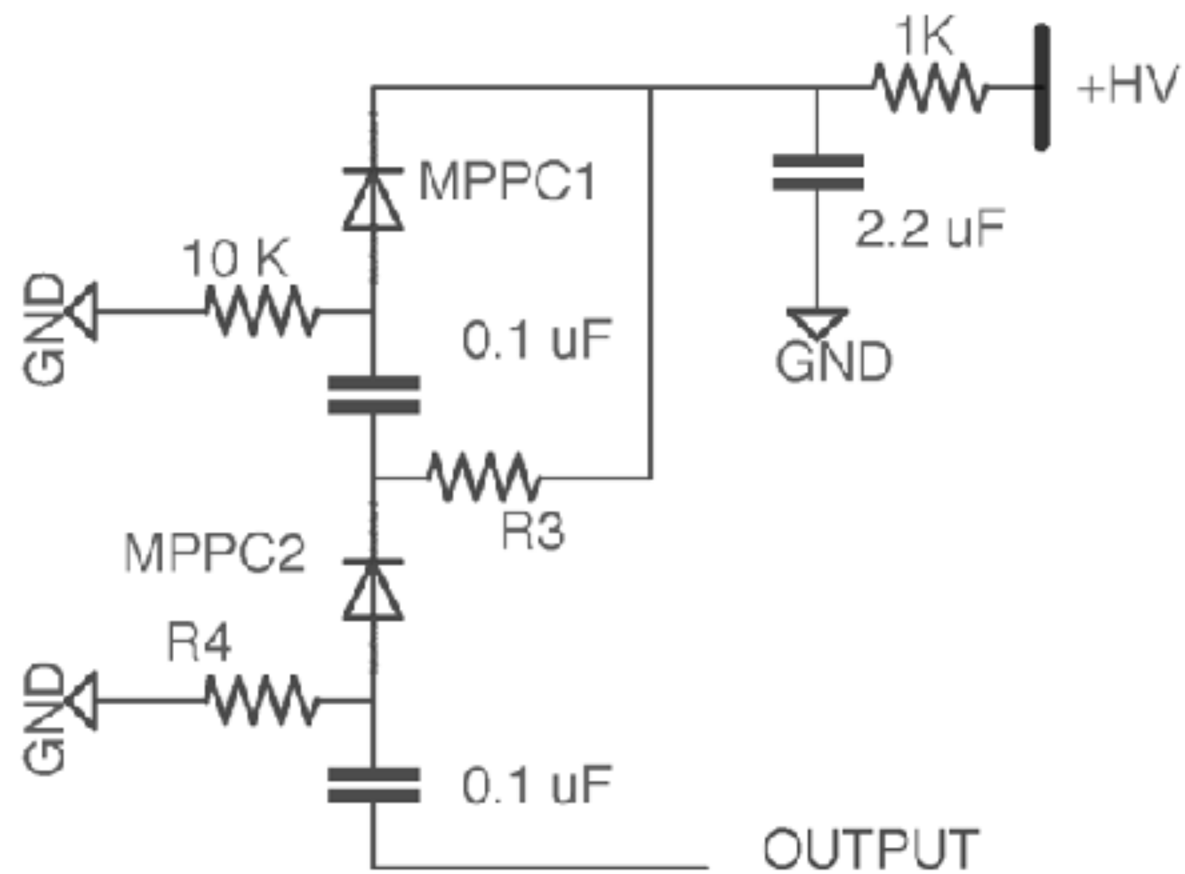
Signal become smaller and longer, but tail's length is not proportional to R1+R2.

HYBRID CONNECTION TEST

1. Checking MPPC signal shape's distortion through R3,R4 and coupling capacitor

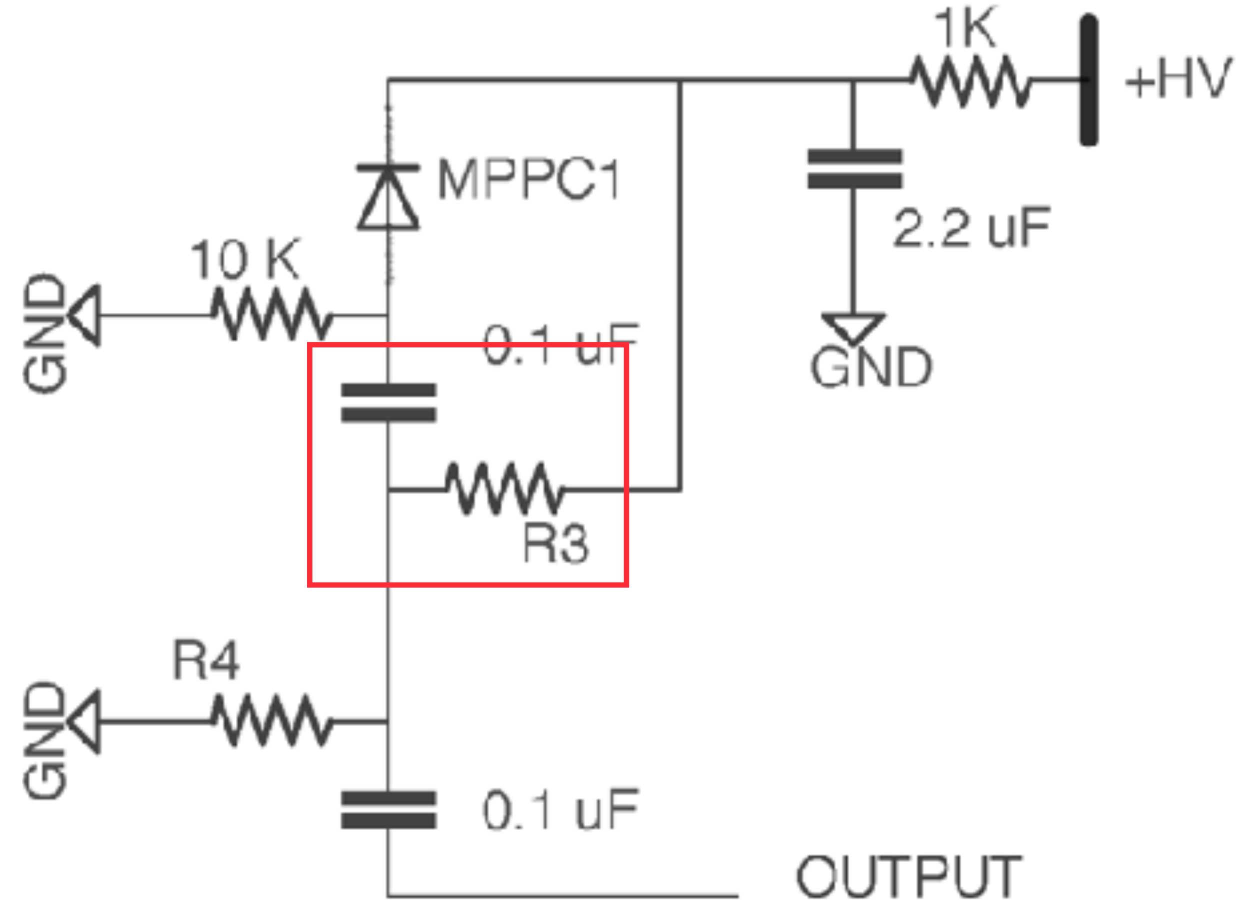


2. Checking MPPC signal shape's distortion not only through R3,R4 and coupling capacitor but also the other MPPC



HYBRID CONNECTION TEST

1. Checking MPPC signal shape's distortion through R3,R4 and coupling capacitor



Expectation

Coupling capacitor and R3 make high pass filter

(cutoff frequency = 1/2πRC)

HYBRID CONNECTION TEST

T_{rise} : signal's rise time

T_{sig} : signal full width

f_c : cutoff frequency

R3 : 10 kΩ

R4 : 10 kΩ

f_c ~ 159 hz

4.37 mV< $V_{p\text{-}p}$ < 5.78 mV

T_{rise} = 210 ns, T_{sig} ~ 600 ns

R3 : 10 kΩ

R4 : 50 kΩ

f_c ~ 32 hz

17.5 mV< $V_{p\text{-}p}$ < 19.0 mV

T_{rise} = 210 ns, T_{sig} ~ 600 ns

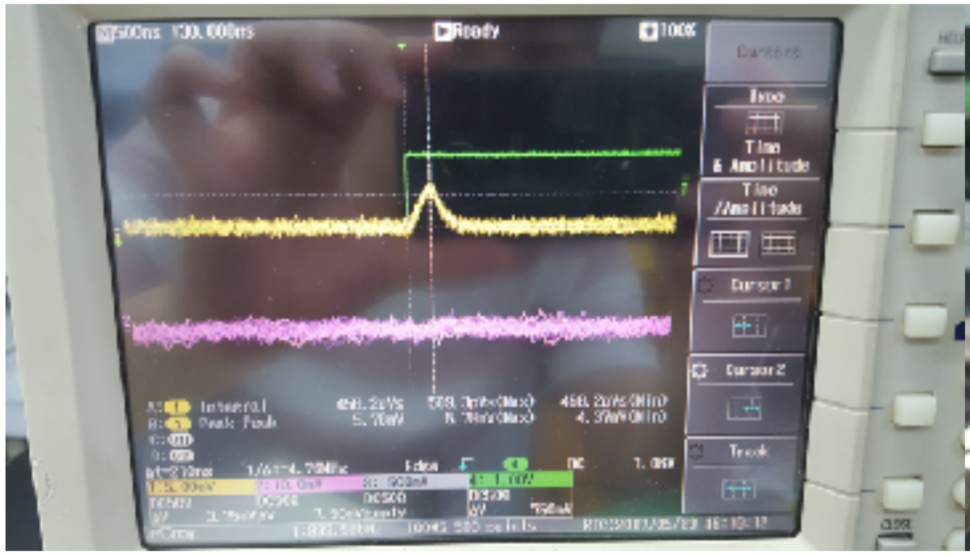
R3 : 10 kΩ

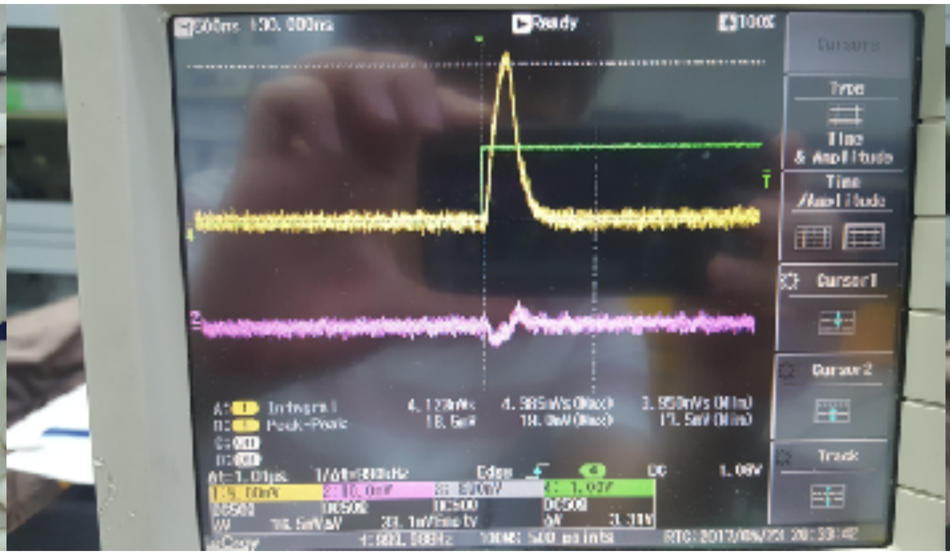
R4 : 1 MΩ

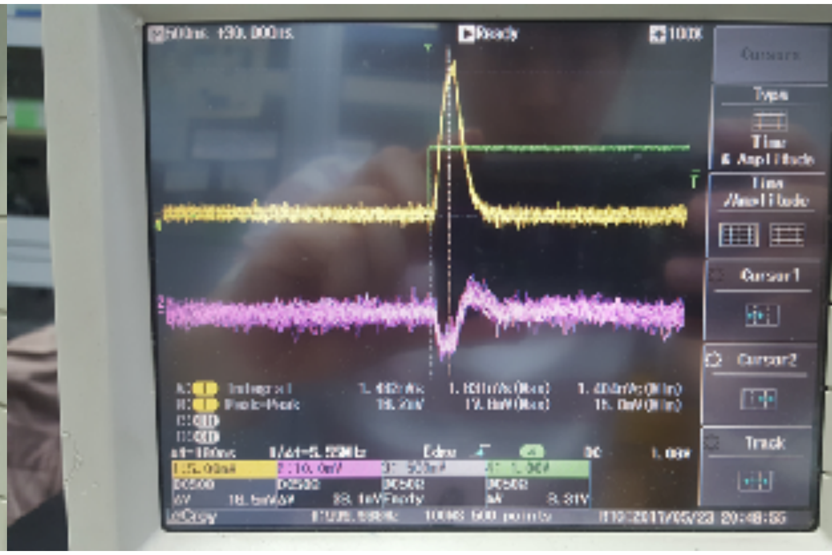
f_c ~ 2 hz

15.0 mV< $V_{p\text{-}p}$ < 17.6 mV

T_{rise} = 210 ns, T_{sig} ~ 600 ns



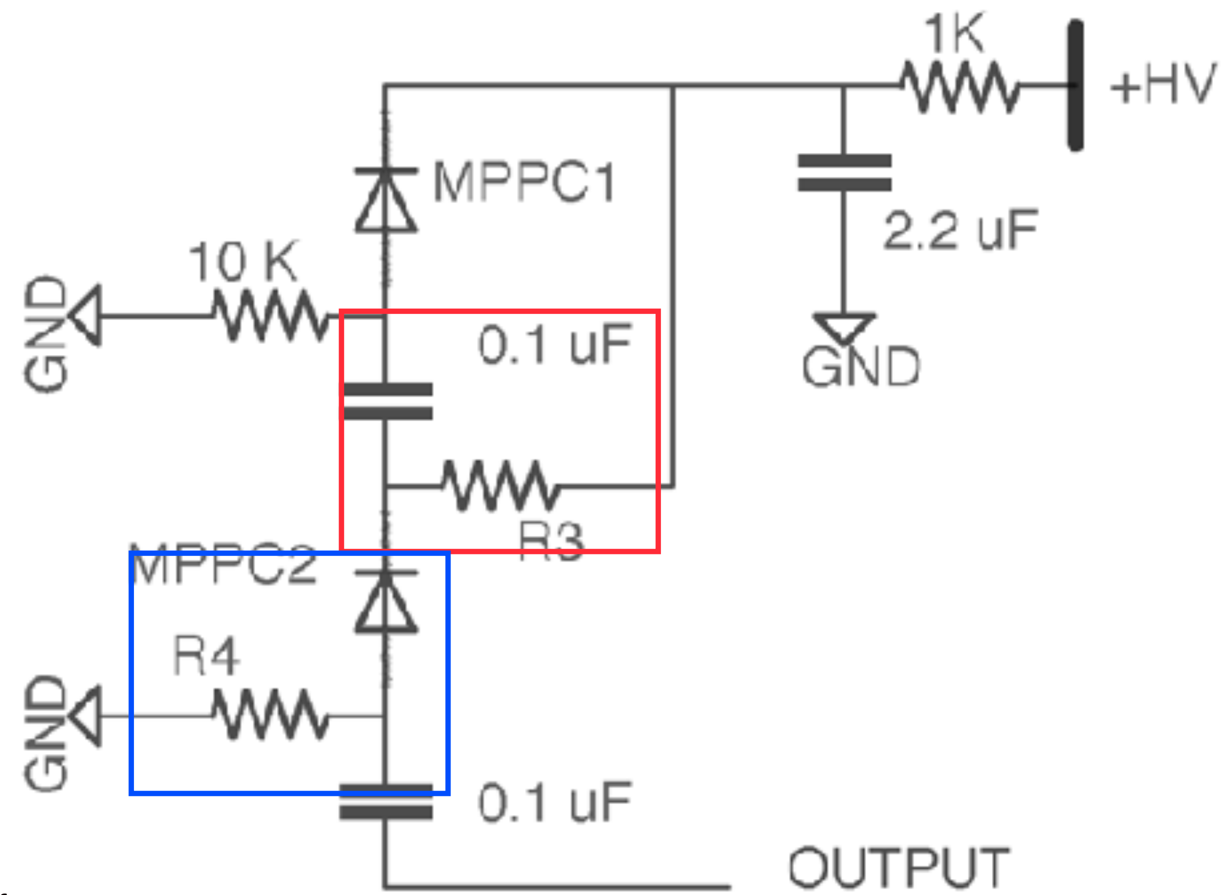




Condition of low cutoff frequency is needed.

HYBRID CONNECTION TEST

2. Checking MPPC signal shape's distortion not only through R3,R4 and coupling capacitor but also the other MPPC



<u>Expectation</u>

1. Coupling capacitor and R3 make high pass filter

(cutoff frequency = 1/2πRC)

2. Second MPPC and R4 also make high pass filter(=passive differentiator)

Because of small capacitance of MPPC(order of 10 pf), there is a signal distortion.

-> Under shoot!

HYBRID CONNECTION TEST

T_{rise} : signal's rise time

T_{sig} : signal full width

f_c : cutoff frequency

R3 : 10 kΩ

R4 : 1 MΩ

15.0 mV< $V_{p\text{-}p}$ < 17.6 mV

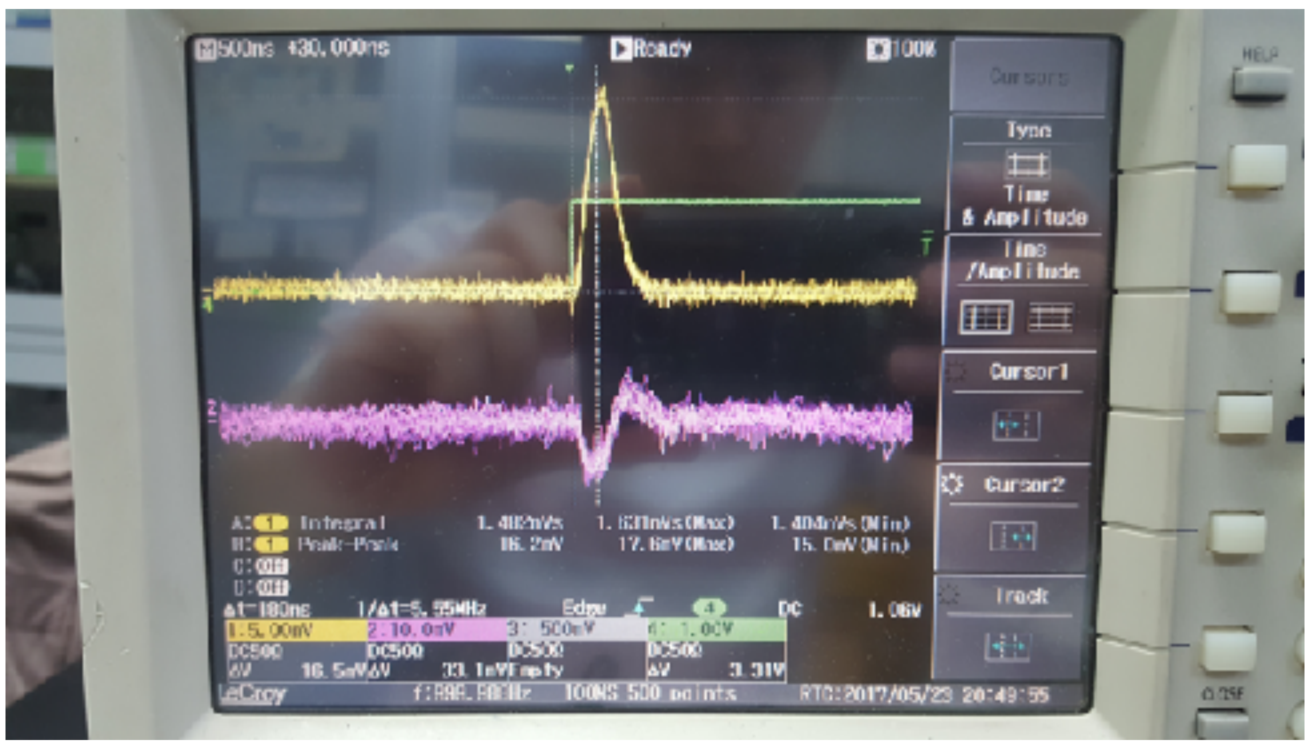
T_{rise} = 210 ns, T_{sig} ~ 600 ns

R3 : 10 kΩ

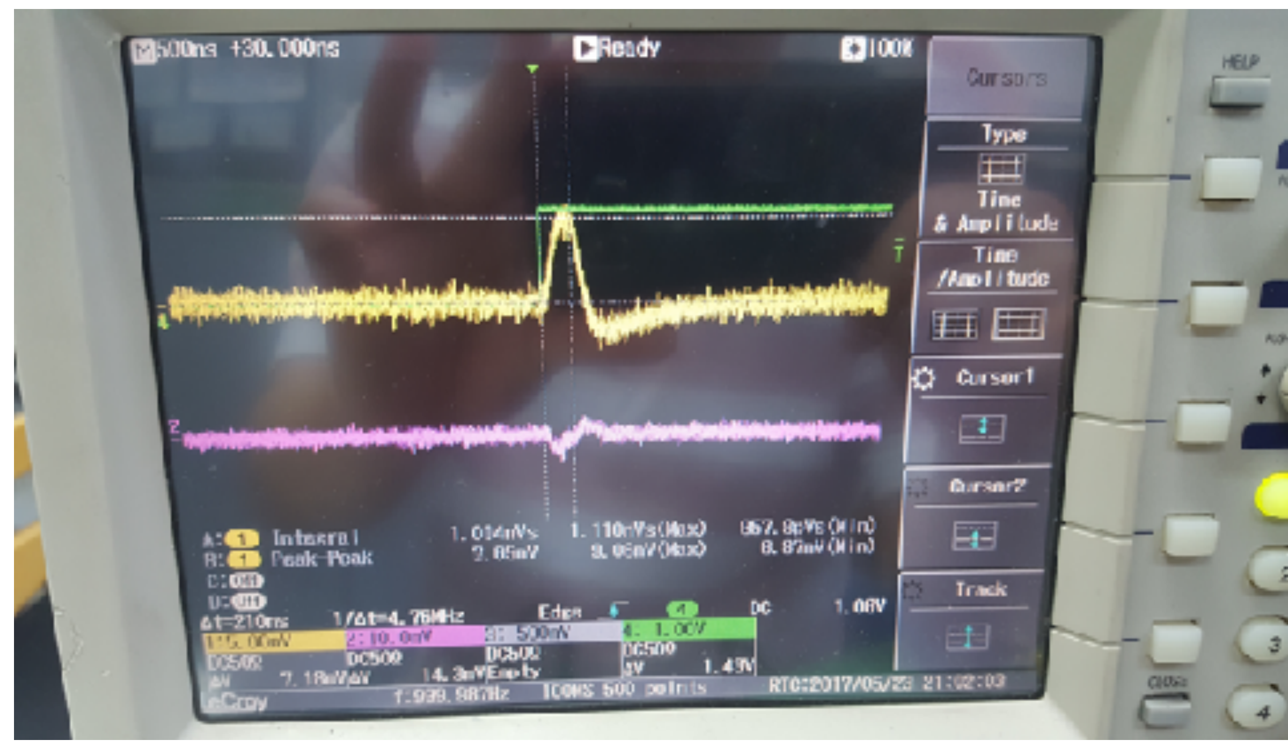
R4 : 1 MΩ

V_{pos} ~ 7.18 mV

T_{rise} < 210 ns, T_{sig} > 1 us



Without second MPPC



With second MPPC

Because of second MPPC, signal become bipolar and smaller.

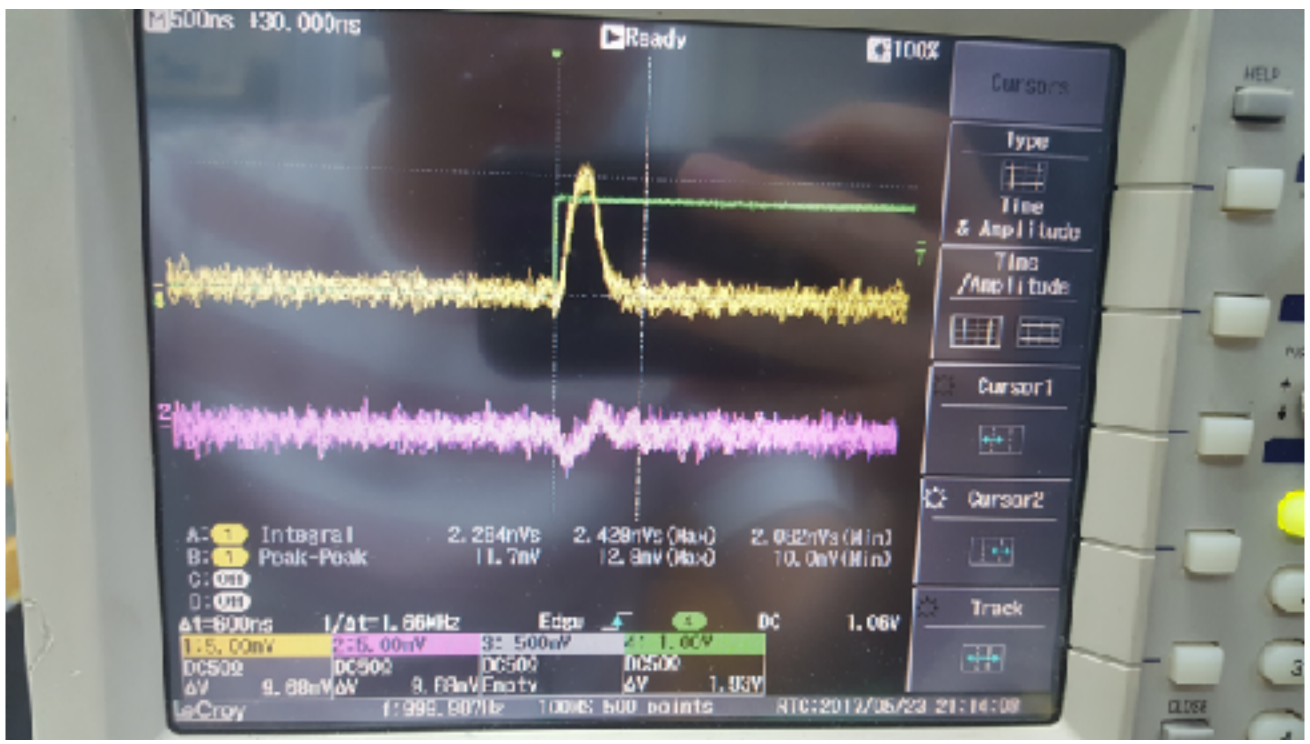
HYBRID CONNECTION TEST

T_{rise} : signal's rise time

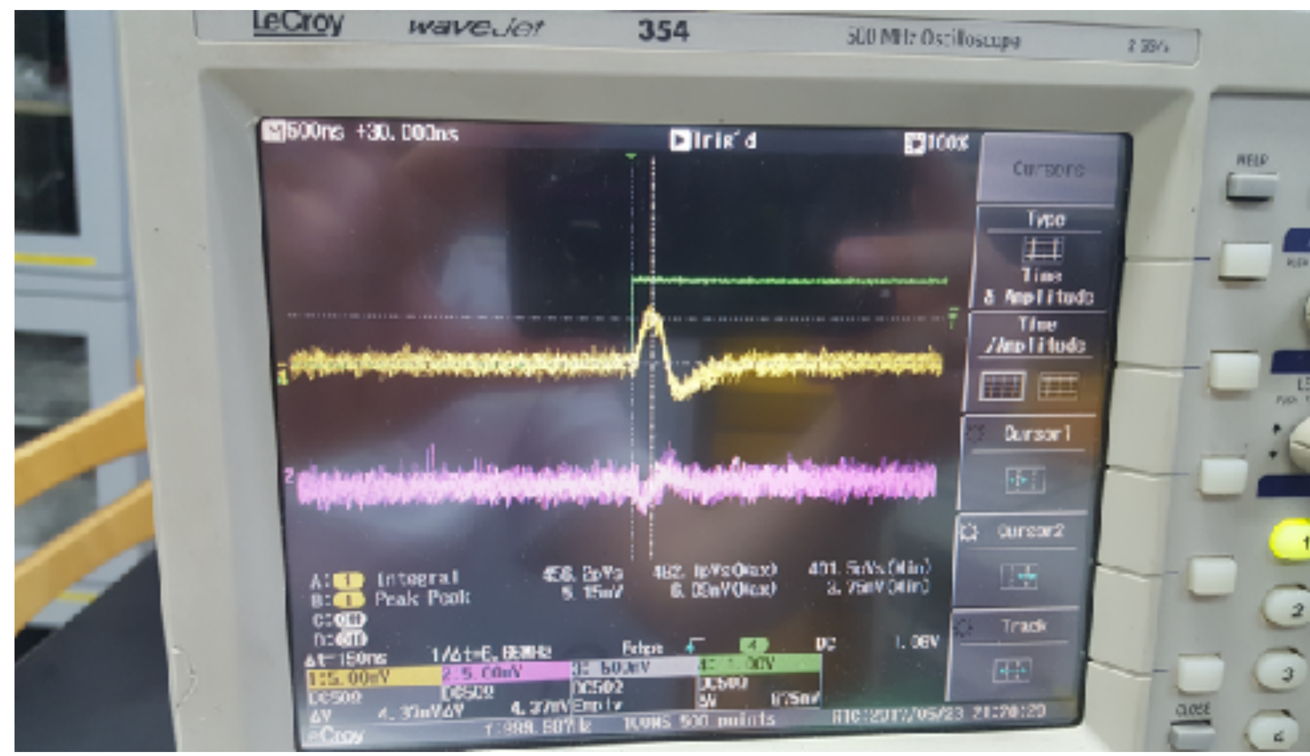
T_{sig} : signal full width

f_c : cutoff frequency

Without second MPPC	With second MPPC
R3 : 1 kΩ	R3 : 1 kΩ
R4 : 1 MΩ	R4 : 1 MΩ
10.0 mV< $V_{p\text{-}p}$ < 12.5 mV	V_{pos} ~ 4.37 mV
T_{rise} = 210 ns, T_{sig} ~ 600 ns	T_{rise} ~ 150 ns, T_{sig} > 1 us



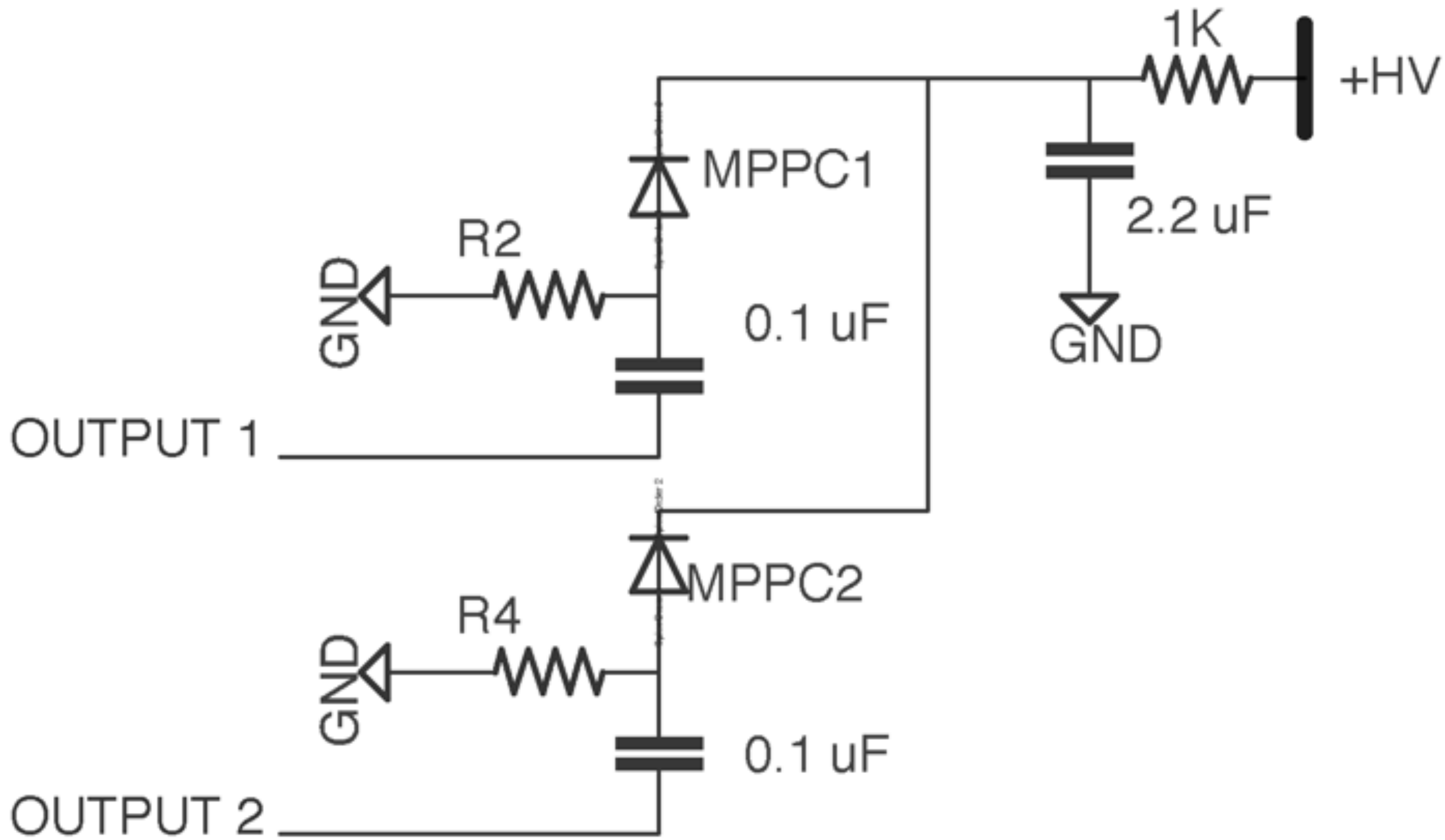
Without second MPPC



With second MPPC

To see the effect of additional MPPC clearly, chosen small value of R3

PARALLEL CONNECTION TEST

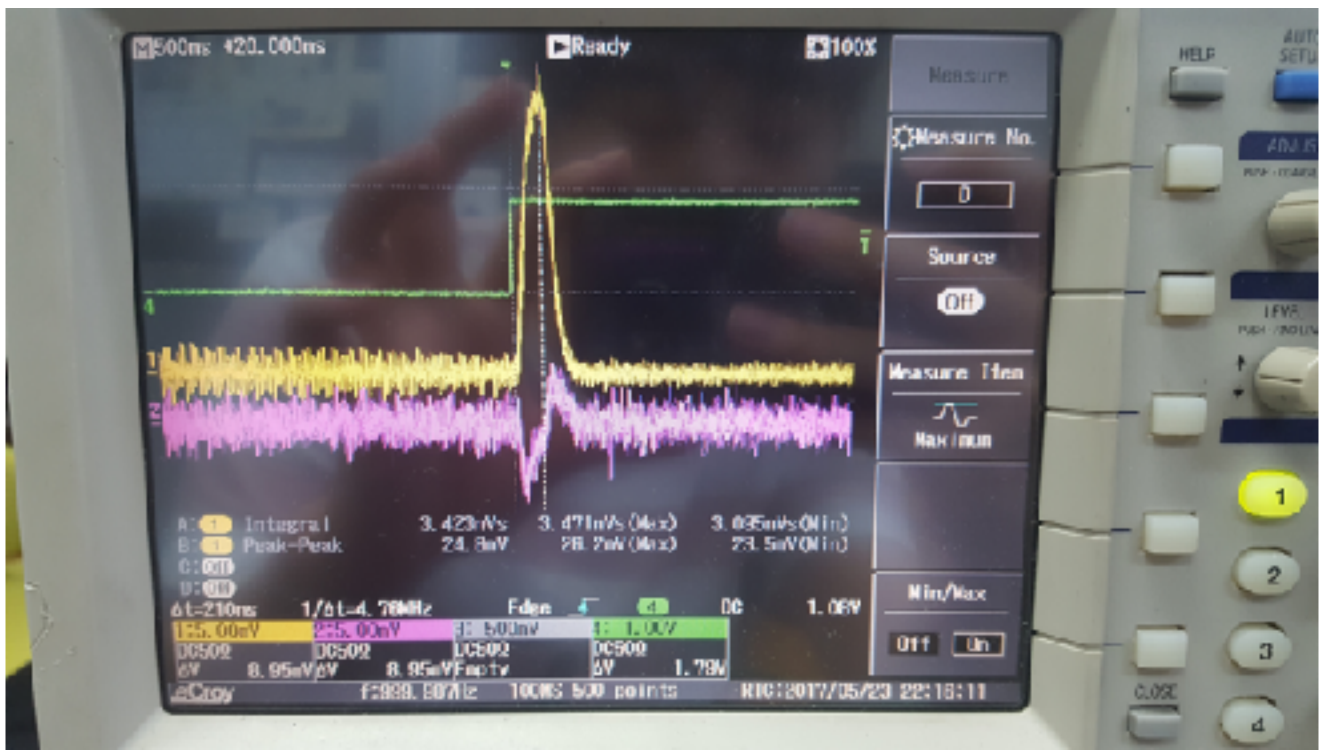


PARALLEL CONNECTION TEST

R2=R4=10 kΩ

23.5 mV< $V_{p\text{-}p}$ < 26.2 mV

T_{rise} = 210 ns, T_{sig} ~ 500 ns



In parallel connection, there is no worry about signal distortion through MPPCs

SUMMARY

1. In hybrid connection, coupling capacitors and resistors make high pass filter, also MPPC makes high pass filter(passive differentiator)
2. Because of high pass filter, low frequency signal distortion is occur.
3. Through passive differentiator chain which composed with MPPC, signal become bipolar(under shoot)
4. MPPC's capacitance has order of 10 ~100 pf, because of small capacitance of MPPC, it is hard to adjust RC value.
5. Hybrid connection has above problems, So Parallel connection can be one relatively good option.