Test pulse circuit for amplifier of charged particle detector in KOTO experiment

2022/12/22_Year-end Presentation Yuto Kawata, Yamanaka Lab.

Outline

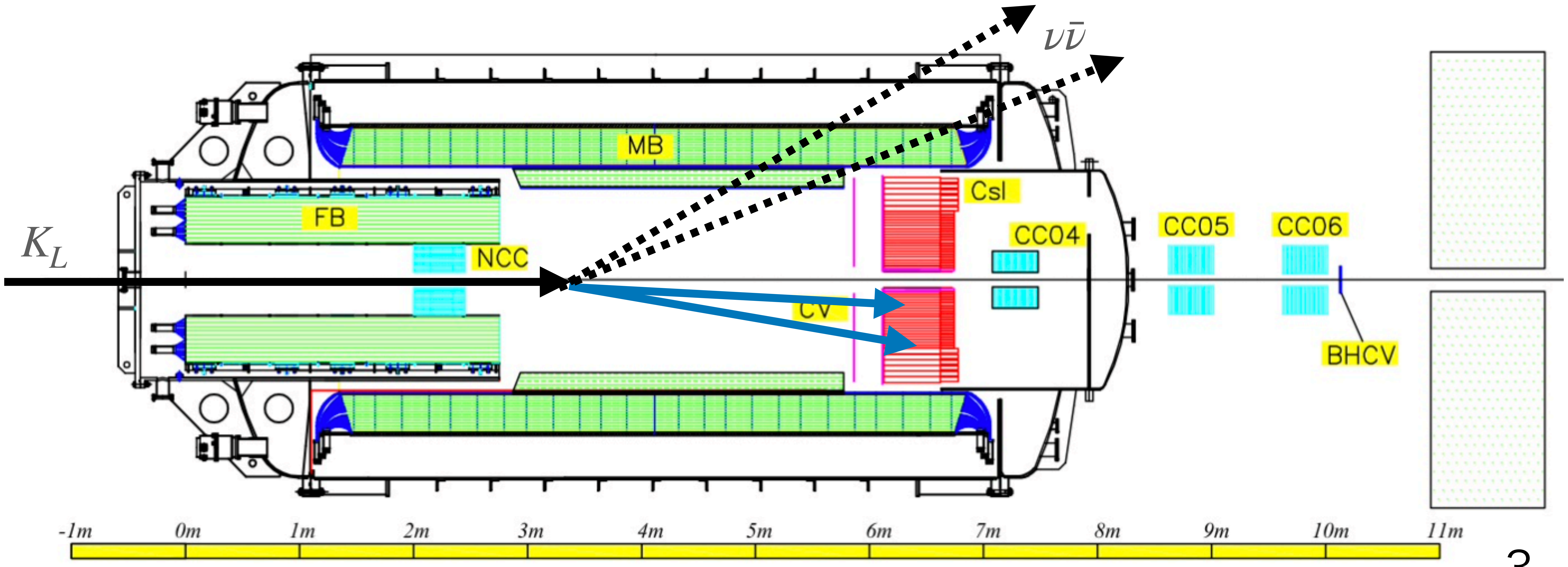
- KOTO experiment
- UCV for KOTO
- UCV Amplifier
- Test pulse circuit (TP)
- Design
- Operation check
- Conclusion

KOTO experiment

- KOTO: search for the CP violating decay $K_L \to \pi^0 \nu \bar{\nu}$
- $BR(K_L \to \pi^0 \nu \bar{\nu})_{SM} = 3 \times 10^{-11}$
- Small theoretical uncertainty(~2%)->easy to find the effect of New Physics

2γ + Nothing

(CsI) (Veto)



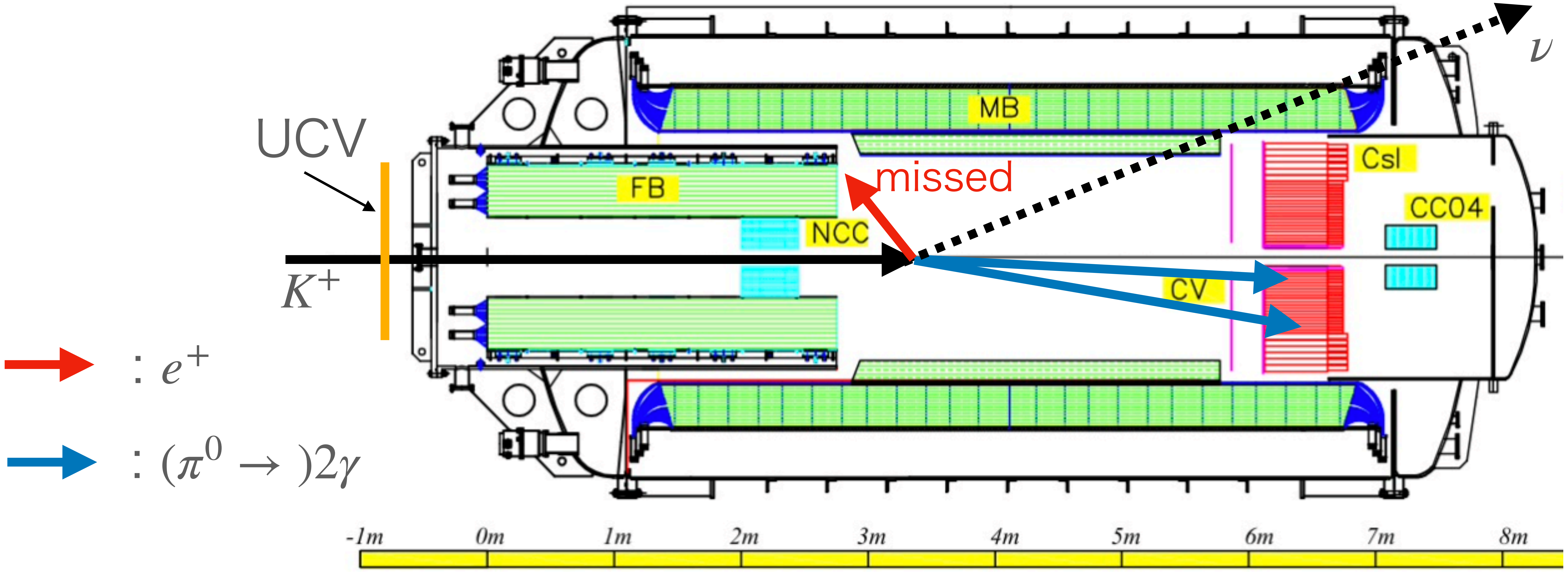
: $(\pi^0 \to)2\gamma$

Ref: https://koto.kek.jp/exp/detector/index.html

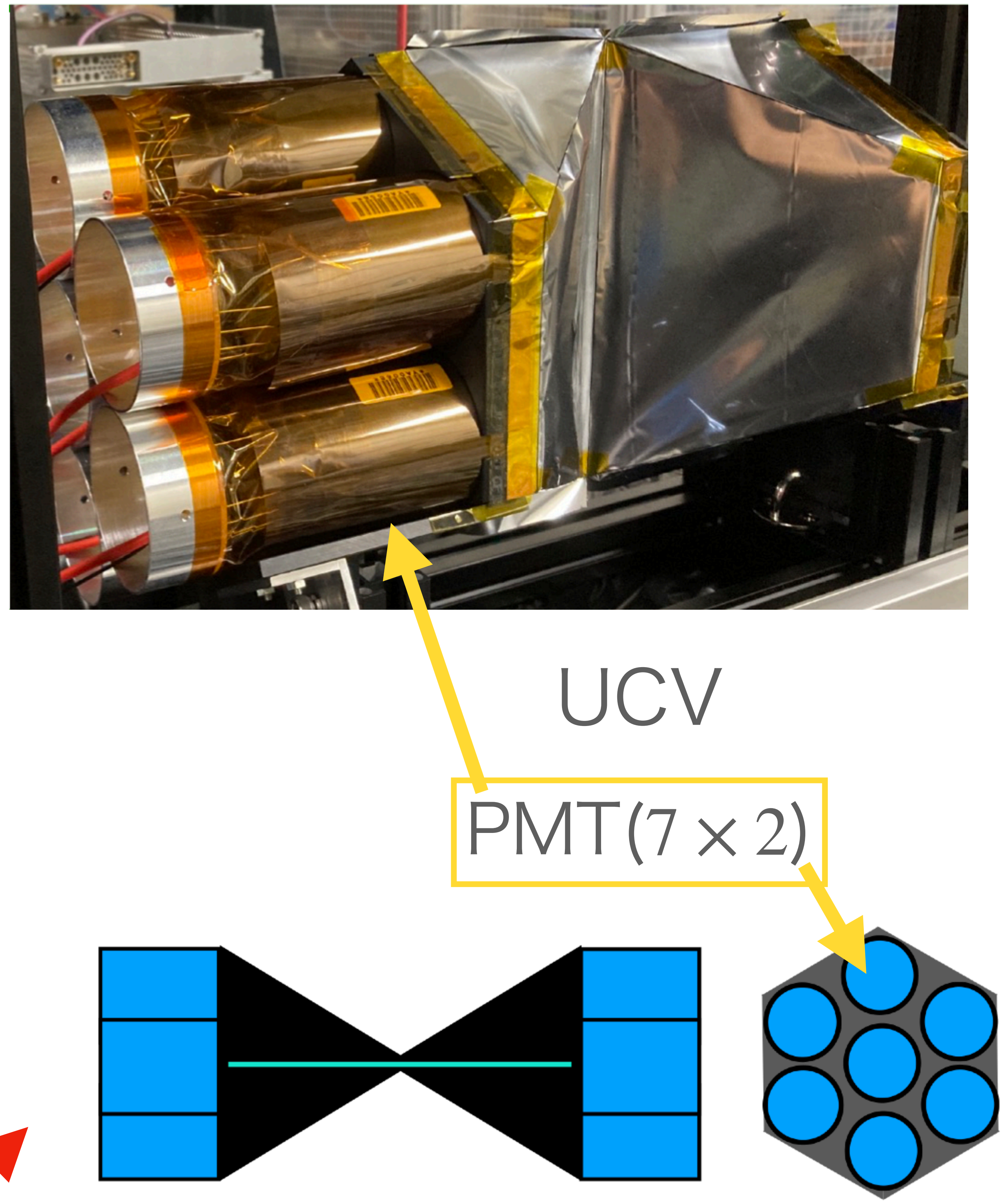
Upstream Charged Veto(UCV) for KOTO

- Small K^+ contamination in K_L beam is a source of a major background

  $(K^+ \rightarrow \pi^0 e^+ \nu)$



Ref: https://koto.kek.jp/exp/detector/index.html

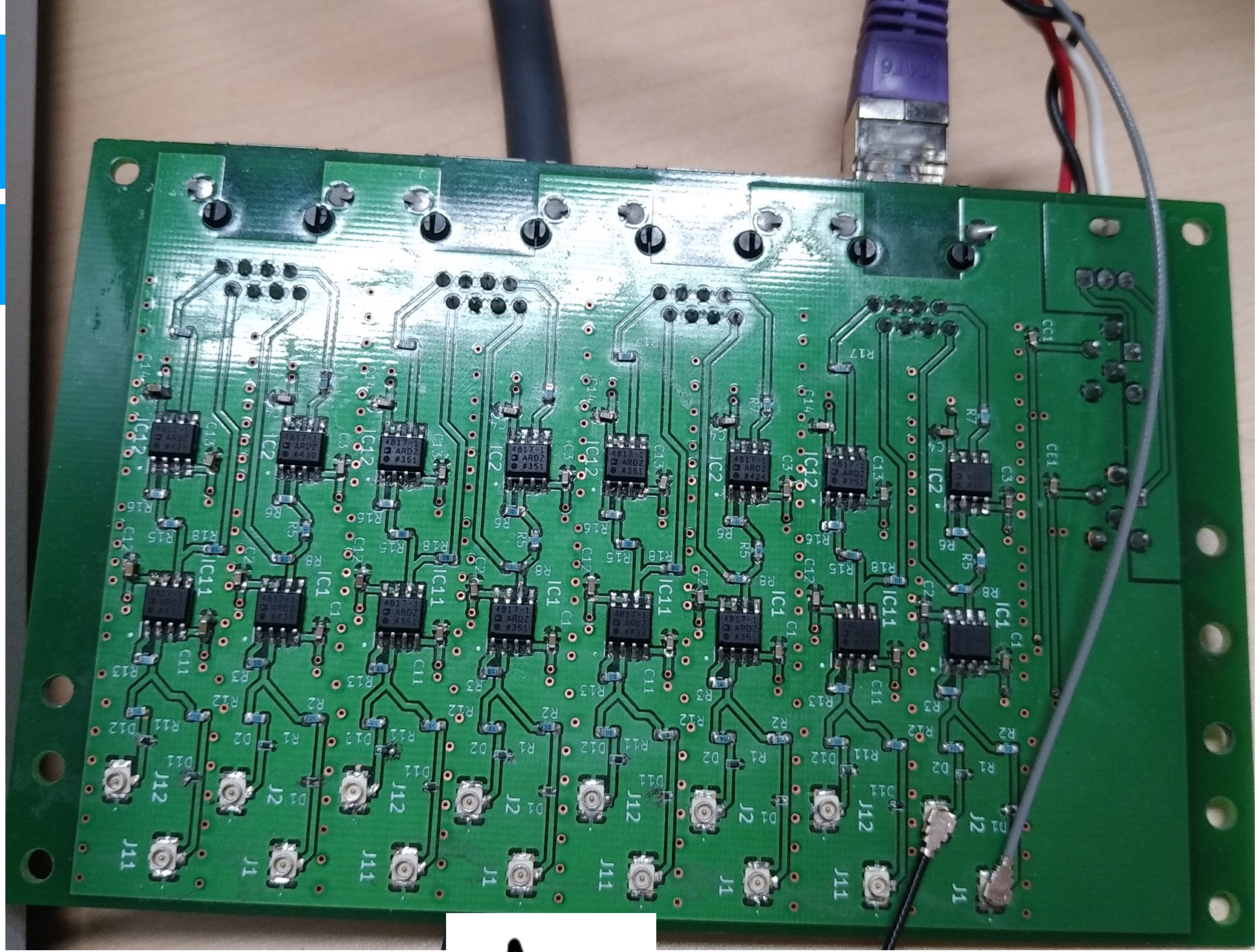


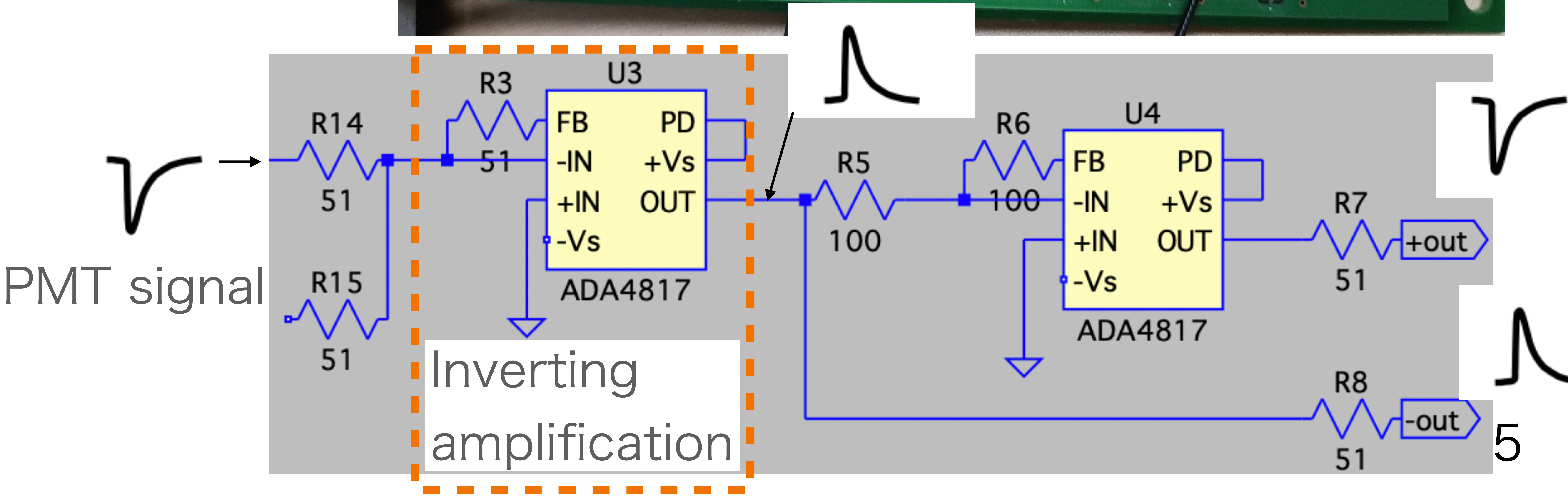
- To veto K^+, we are developing charged particle detector (UCV)

UCV Amplifier

Roles

- Sum up two PMT channels (14 PMT outputs -> 7 ADC channels)
- Differential output to cancel common-mode noise picked up in the signal transmission
- Gain : 1

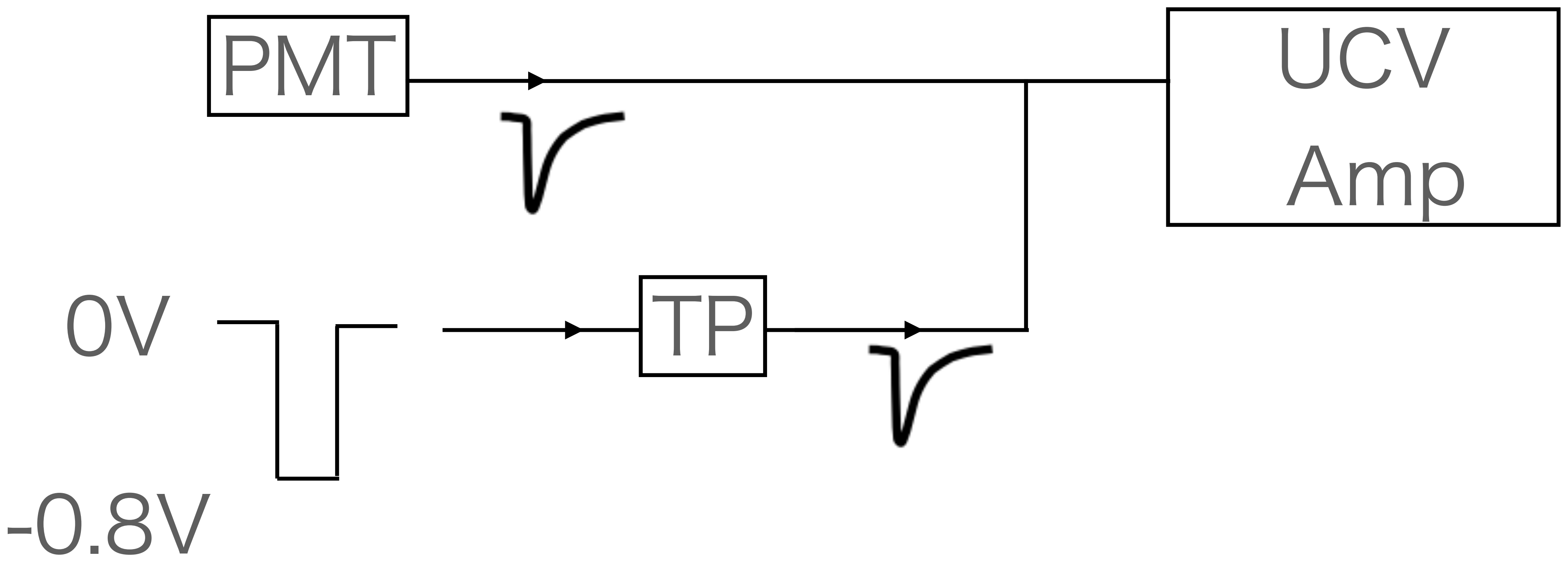




Test Pulse (TP) circuit

Roles

- Amplifies the signal, shapes it into a PMT-like waveform, and sends it to the UCV amplifier
  - To check that the UCV amplifiers are working
  - To check the timing variations between amplifier channels



	Current	Voltage(50Ω)
1 (Yes)	-16mA	-0.8V
0(No)	0mA	0V

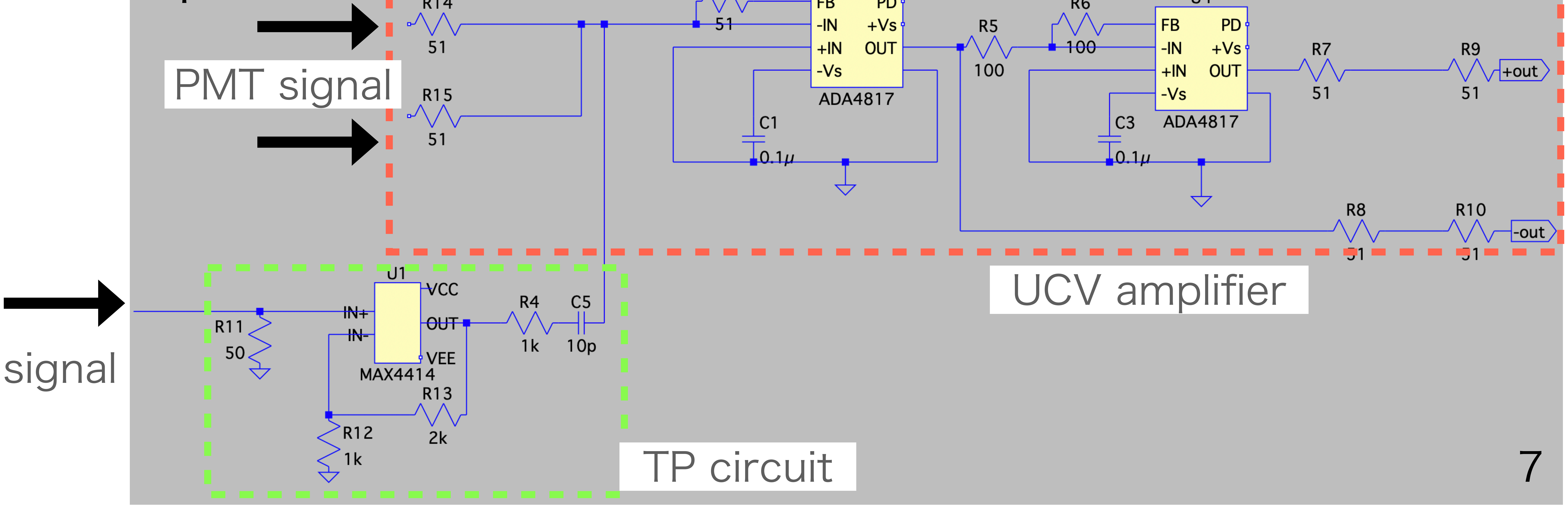
NIM standard

Test Pulse (TP) circuit

Motivation of my study

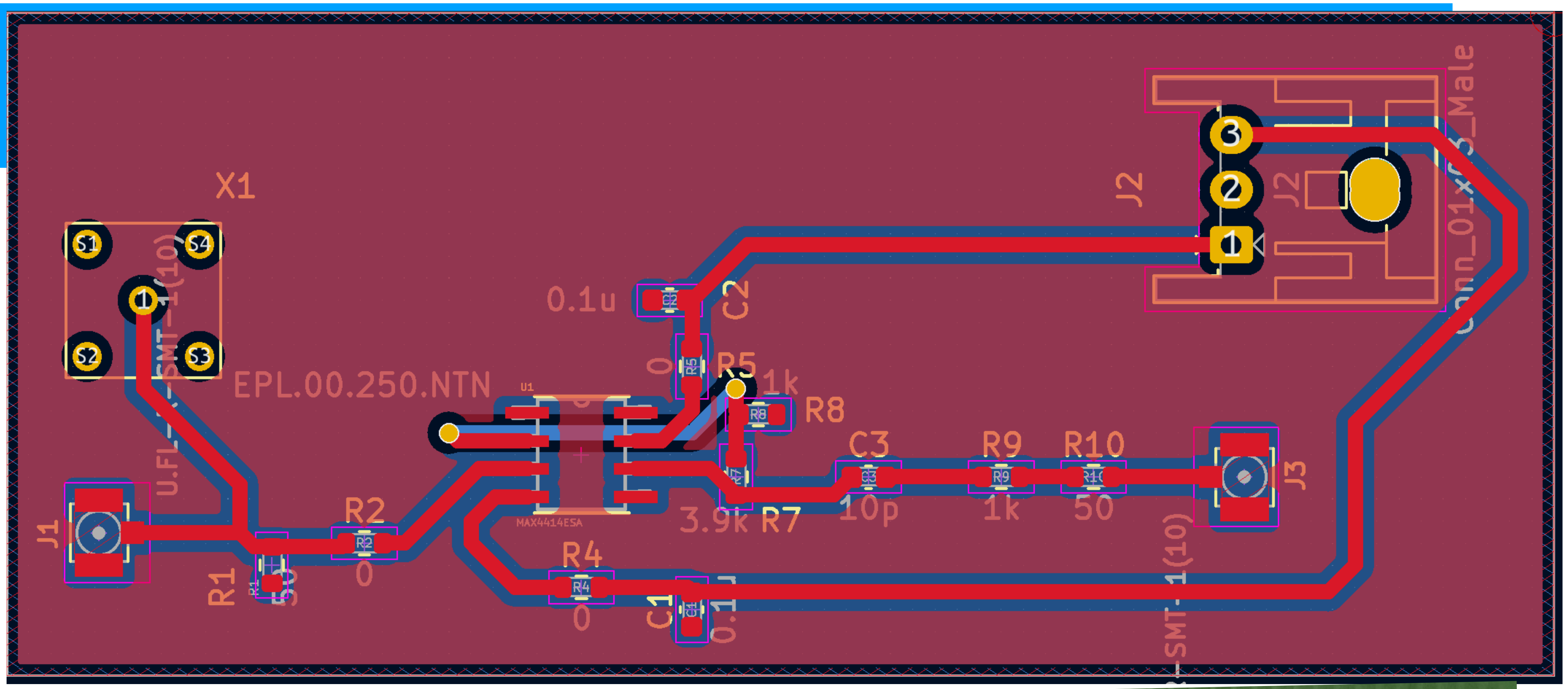
I did two checks to meet the demands for the TP circuit

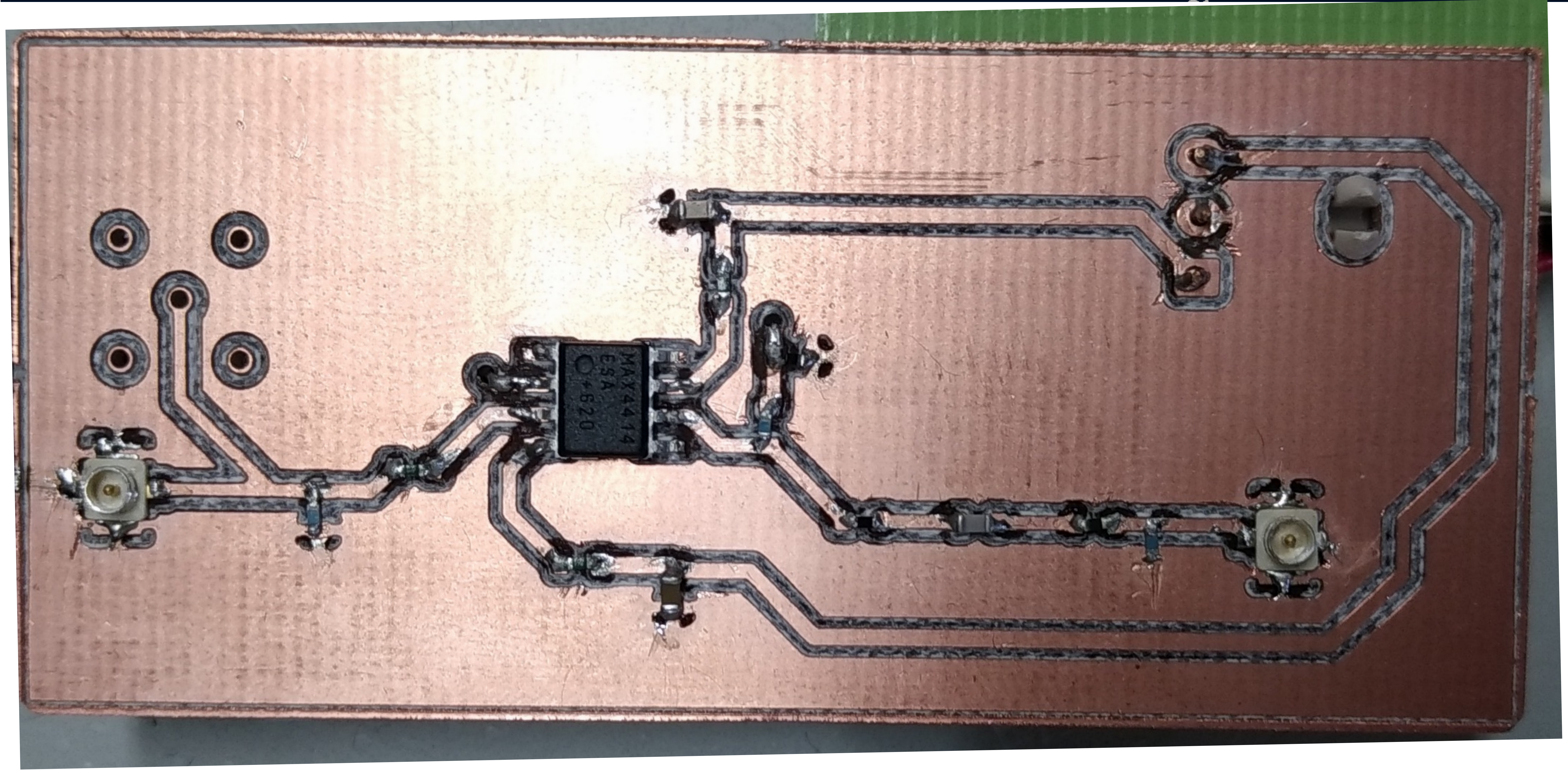
- Check 1: Can we see test signal from TP at Amplifier output?
- Check 2: Is there any effect on signal from PMT when we add TPI to UCV amplifier?

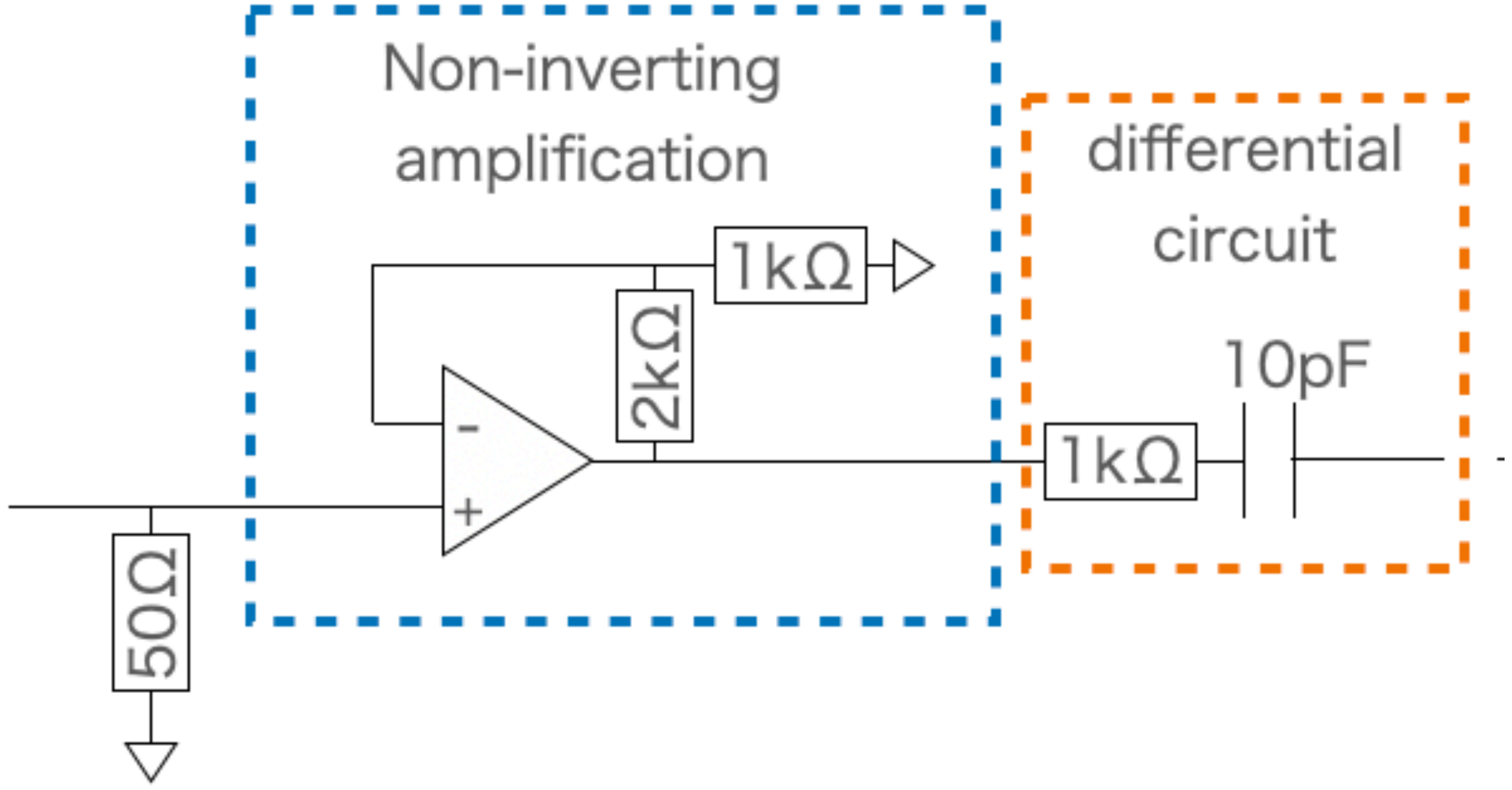


Design

- Used KiCad, and made the circuit board pattern

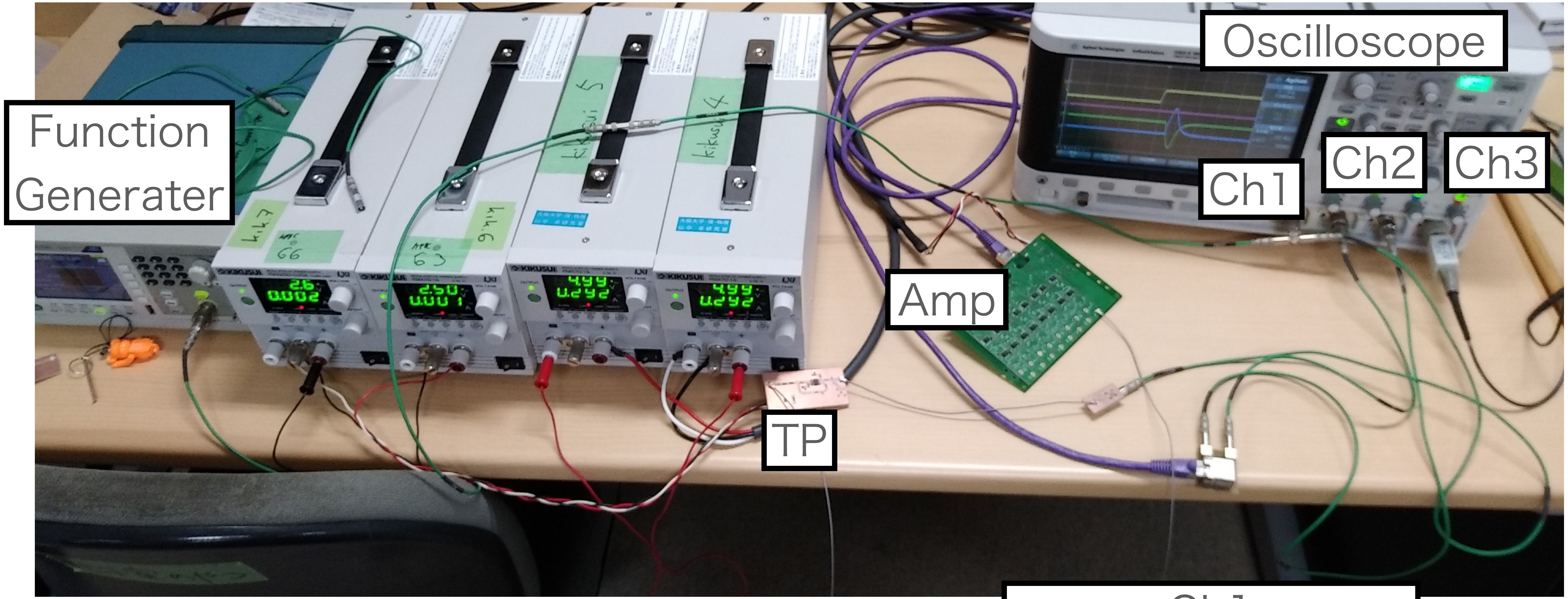


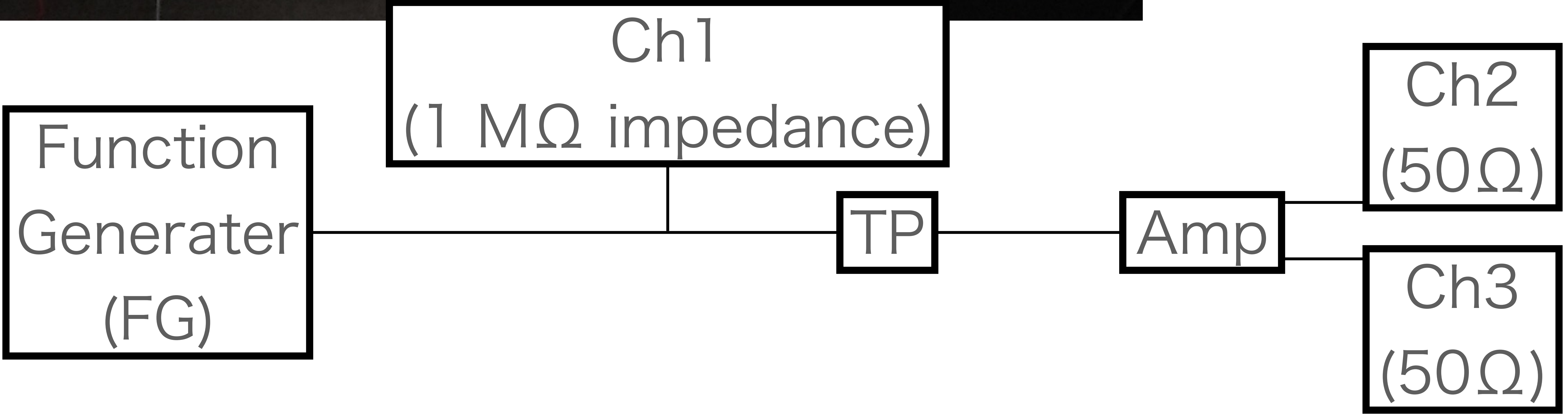




Operation check

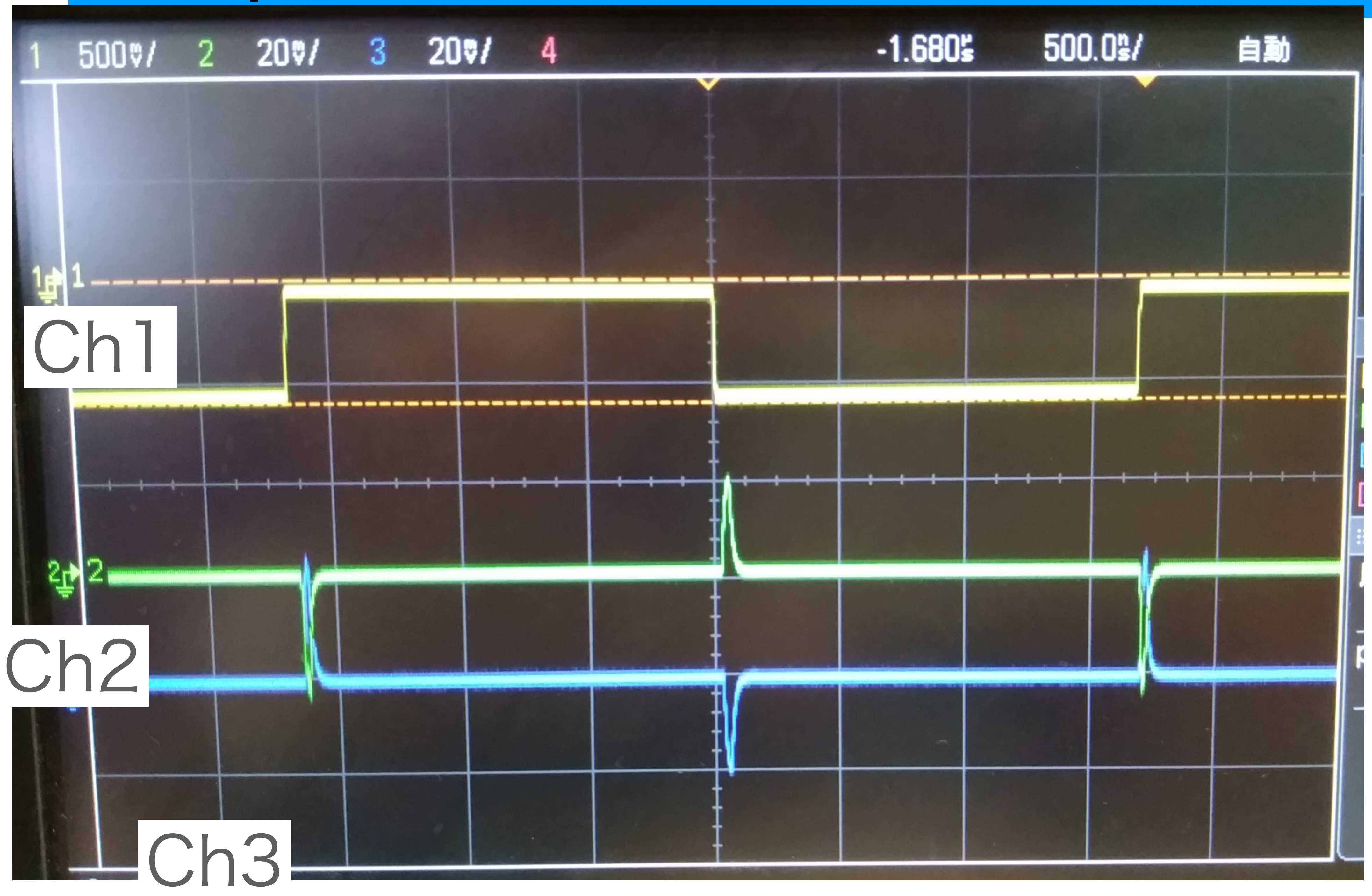
Set up of check 1: Can we see test signal from TP at Amplifier output?

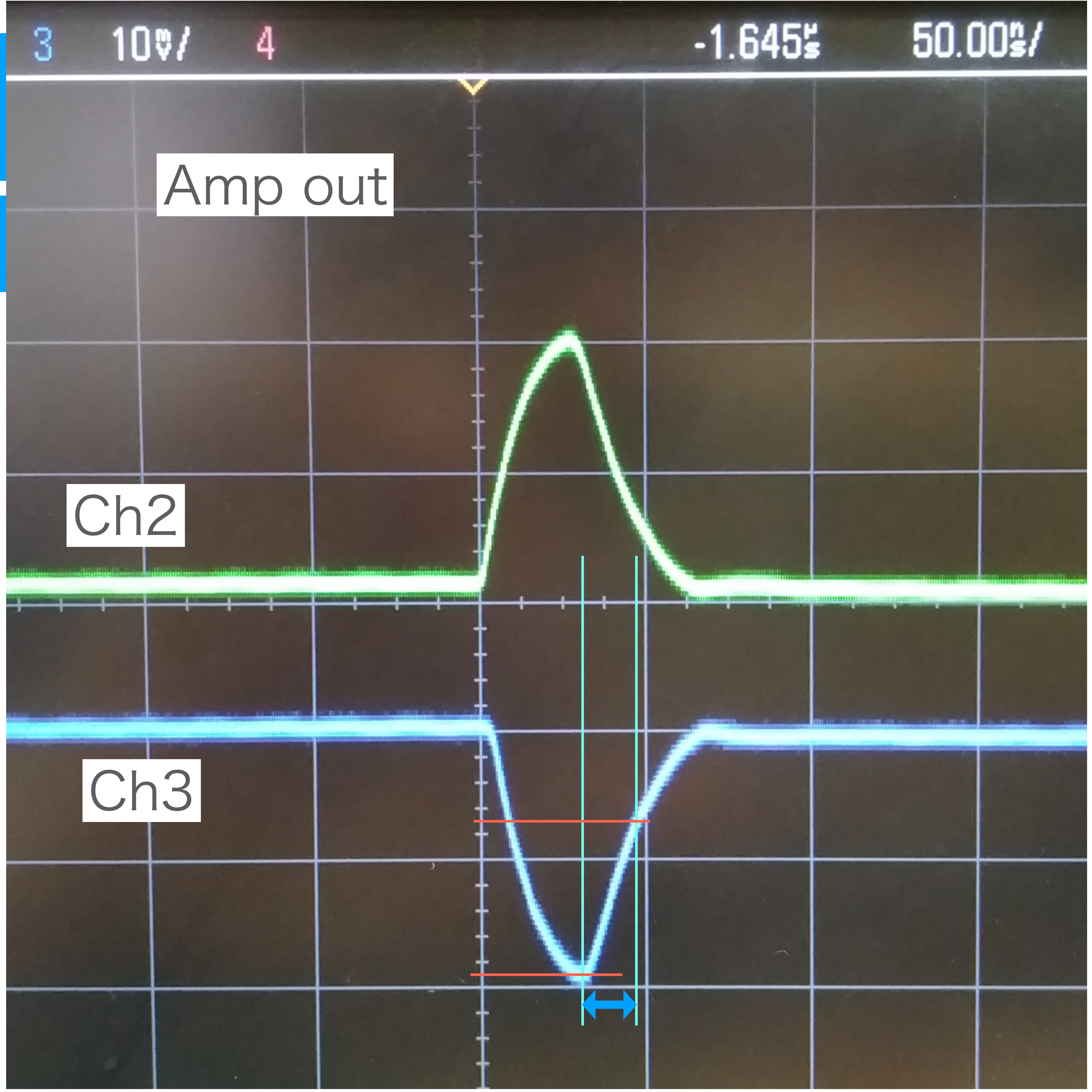


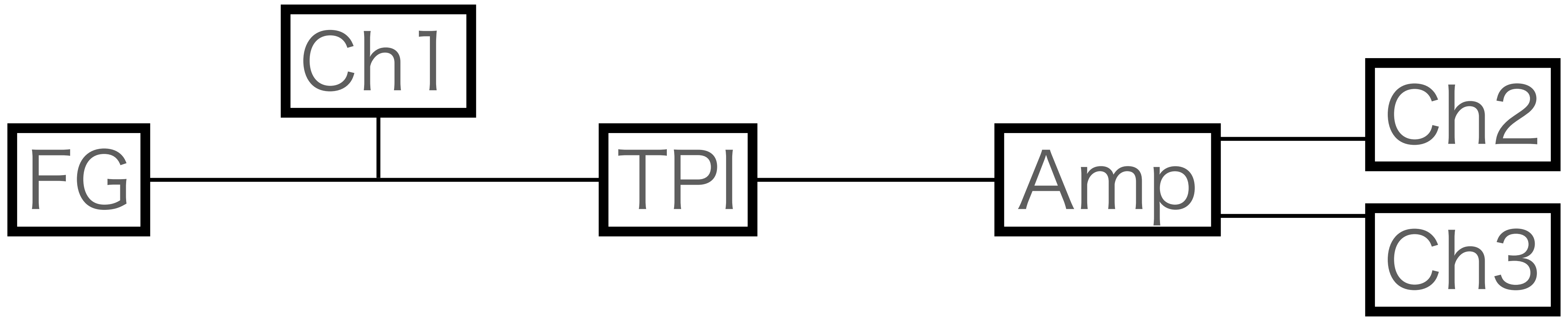


Operation check

Output waveform





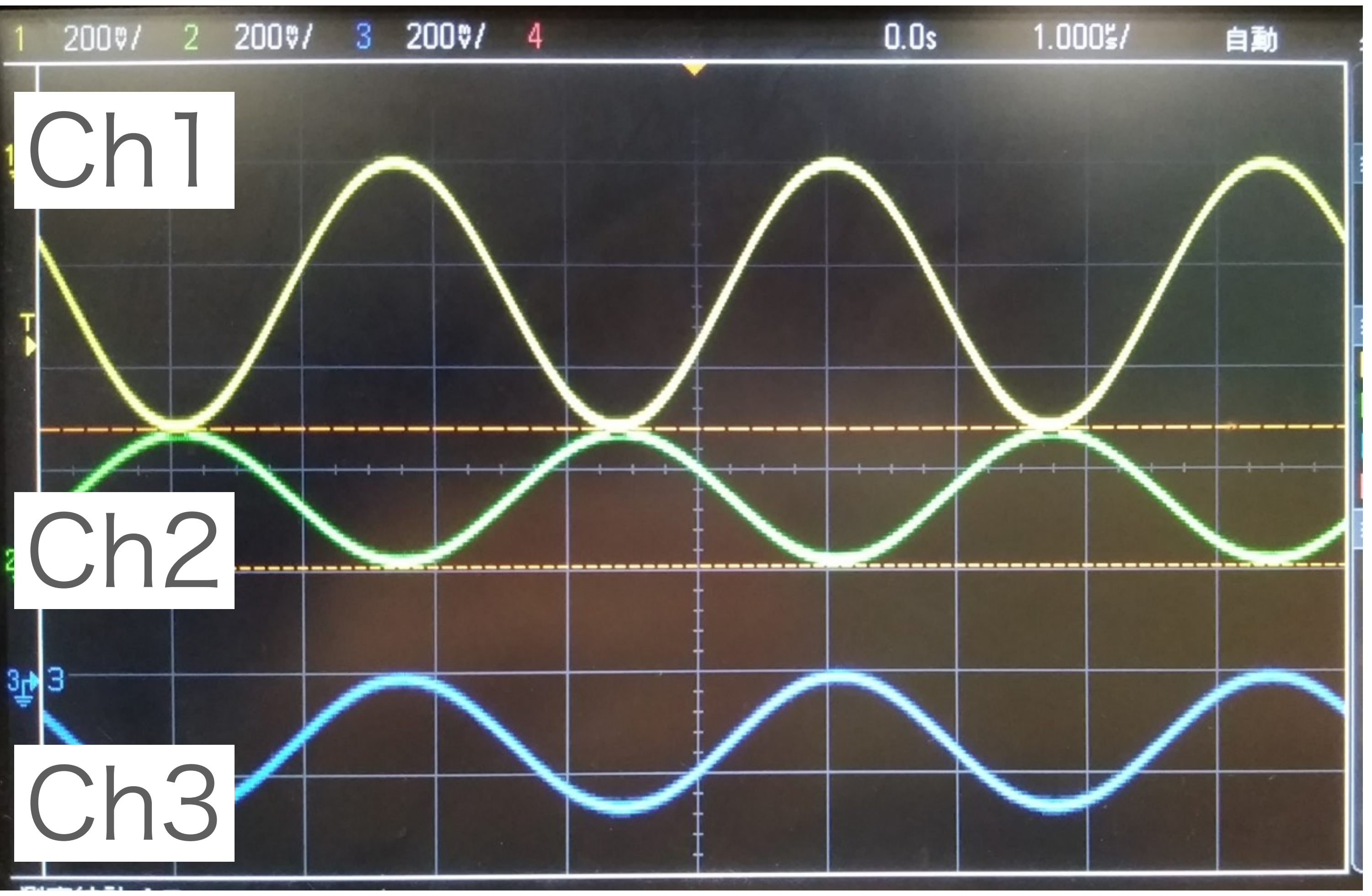


Calculated time constant : $1k\Omega \times 10pF = 10ns$

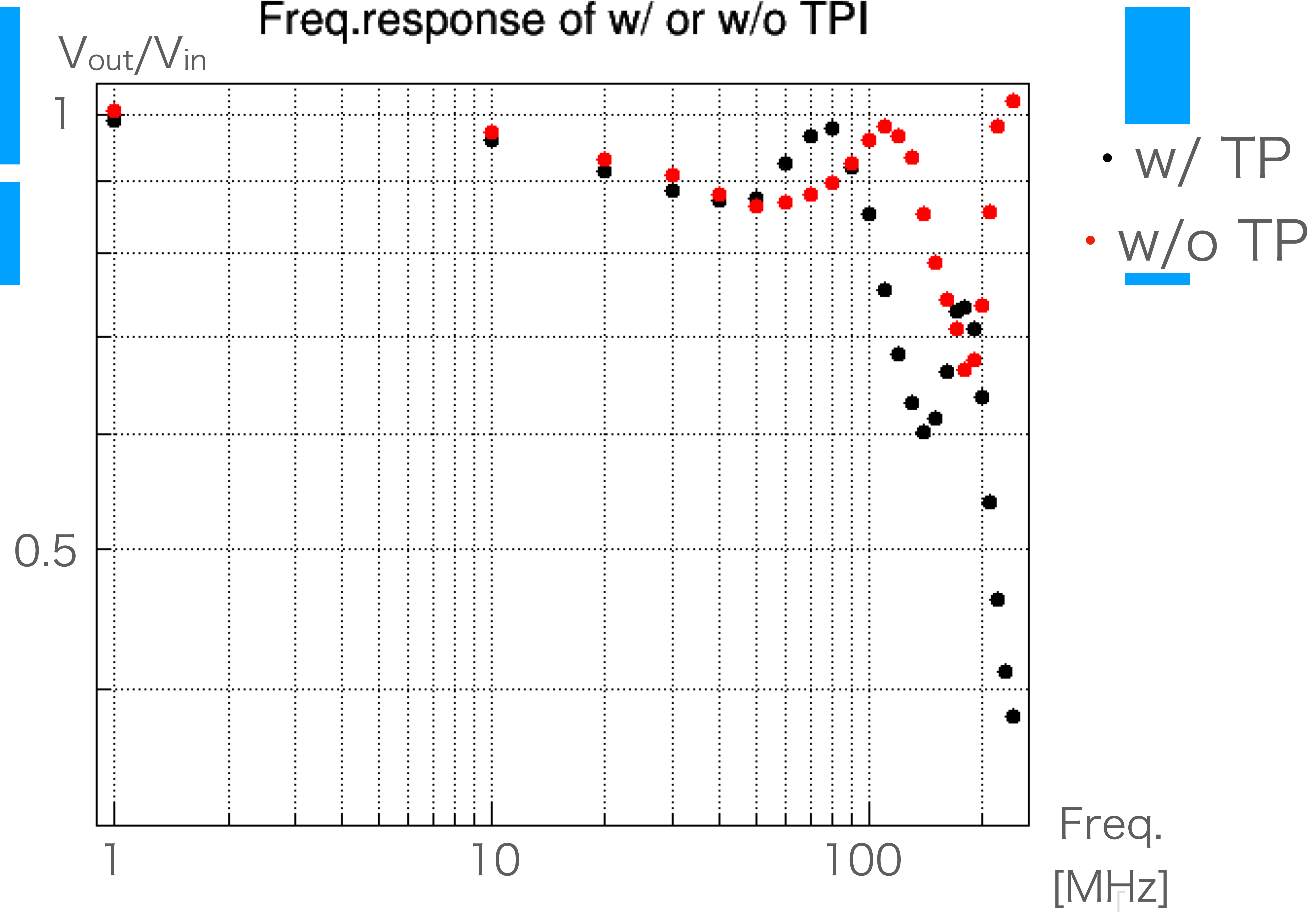
Measured time : 15 ns

Operation check

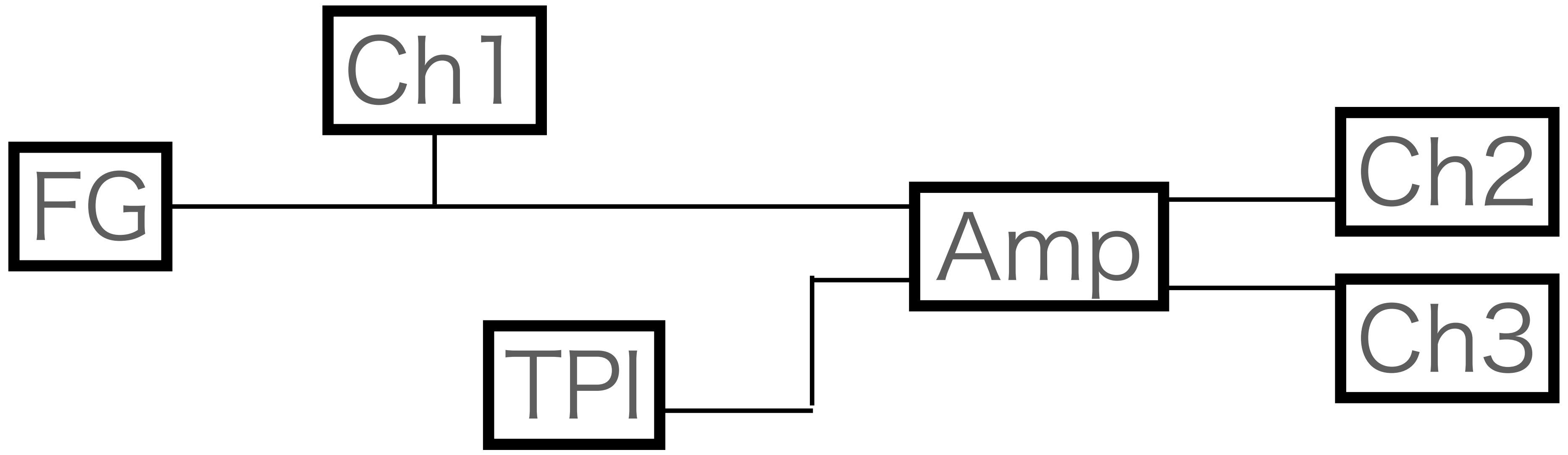
Effect on main signal



Used sine wave, measured Vpp, calculated ratio



- Ratio was about 1 up to 10MHz
- Both plots are consistent up to 50 MHz

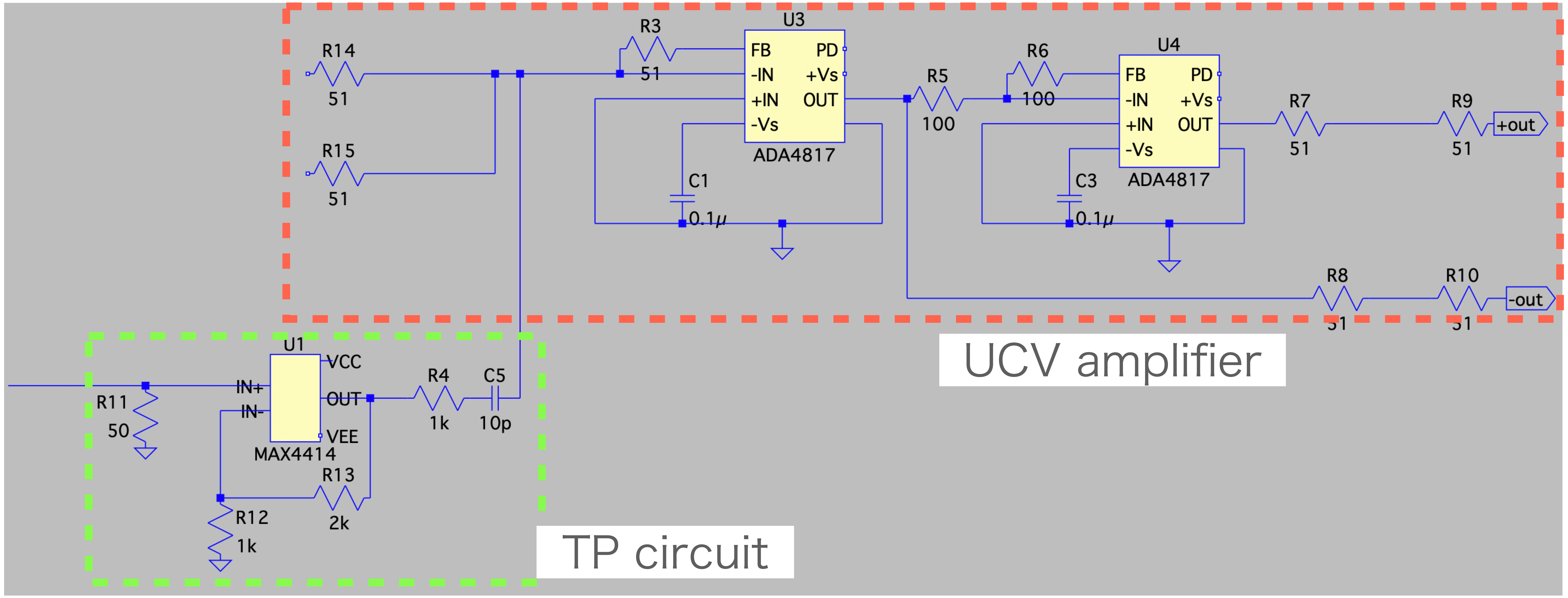


Setup

Design of a new board

Differences from previous one

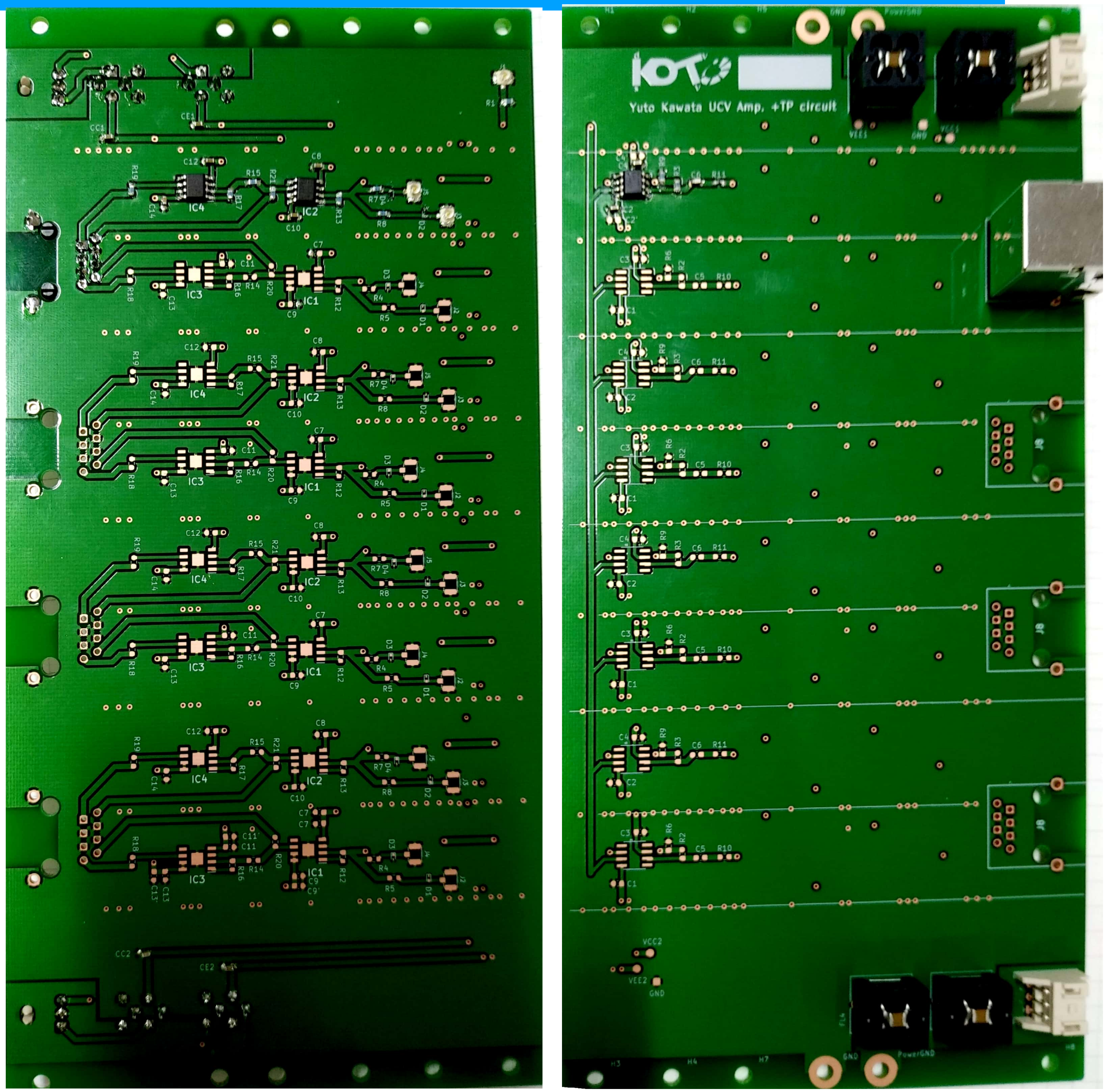
- The new design adds TP circuit to the original board



TP circuit and UCV amplifier are on the same board

Conclusion and Current status

- I developed TP circuit, did operation check -> meet demands
- I designed new board of UCV amplifier, ordered it
- Next -> operation check of new board



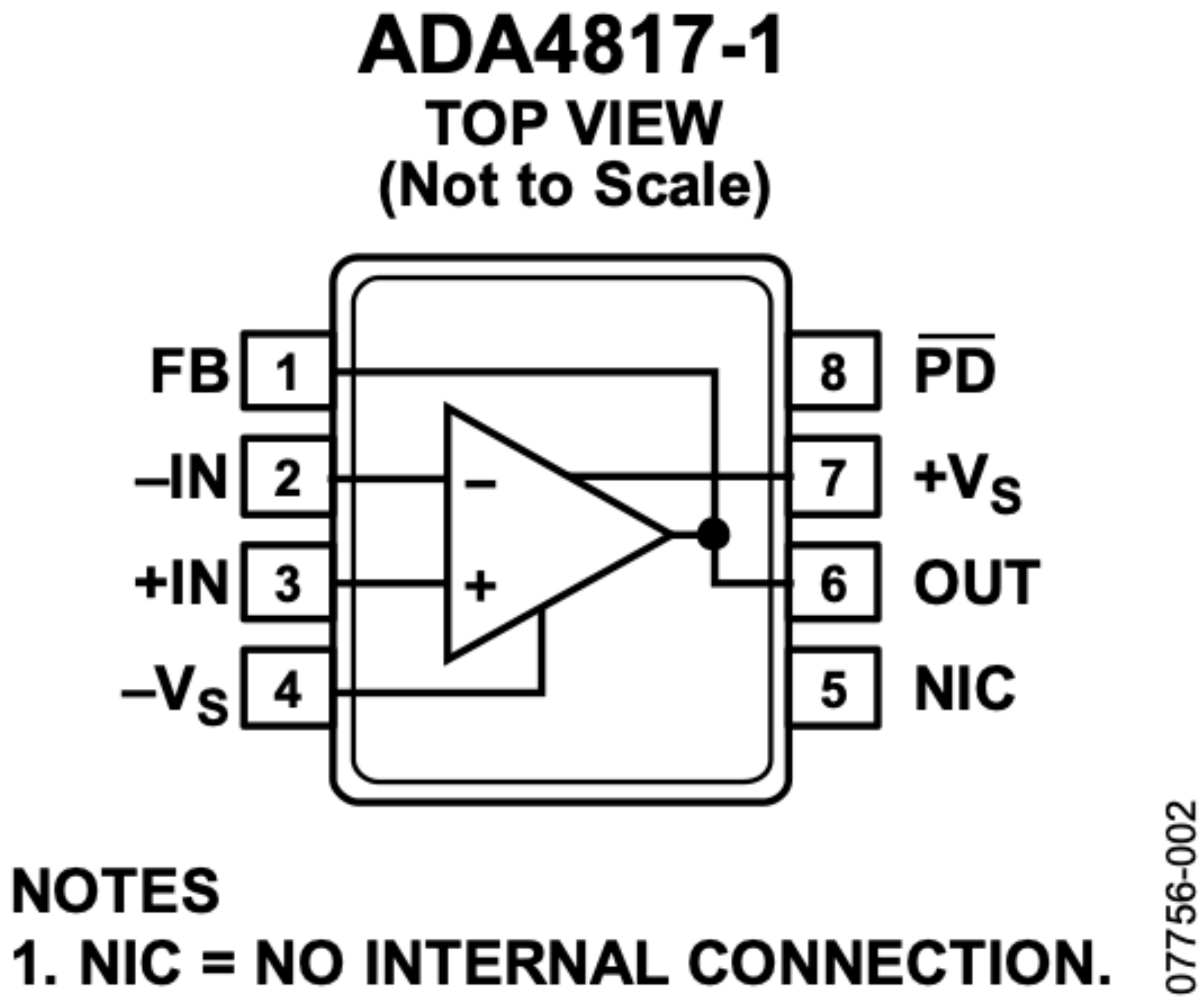
Back　　Front

Backup

Design

Op amp that is used in the UCV amplifier

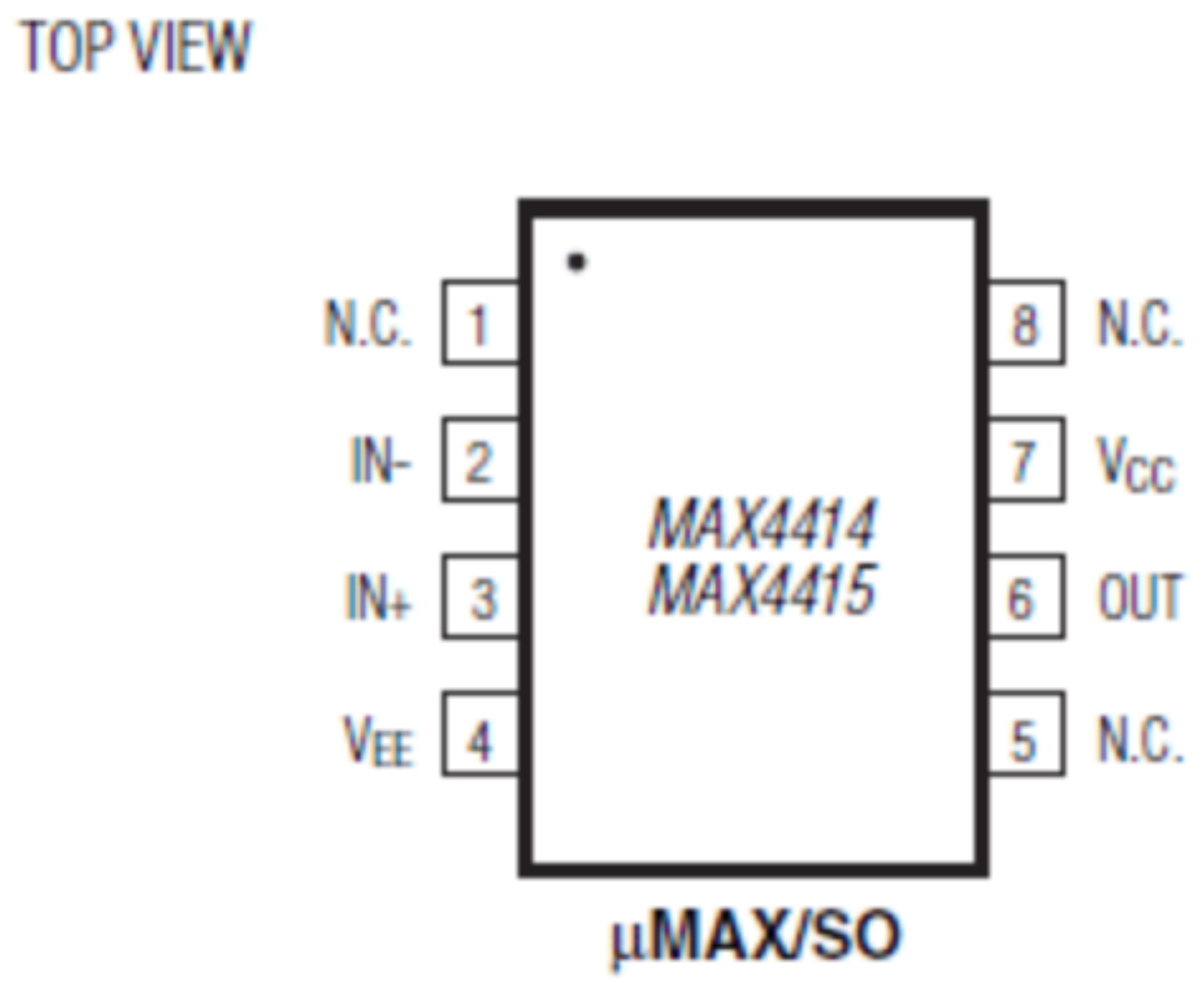
- ADA4817-1ARDZ
- https://www.mouser.jp/datasheet/2/609/ADA4817_1_4817_2-2955817.pdf



Design

Op amp that is used in the TPI circuit

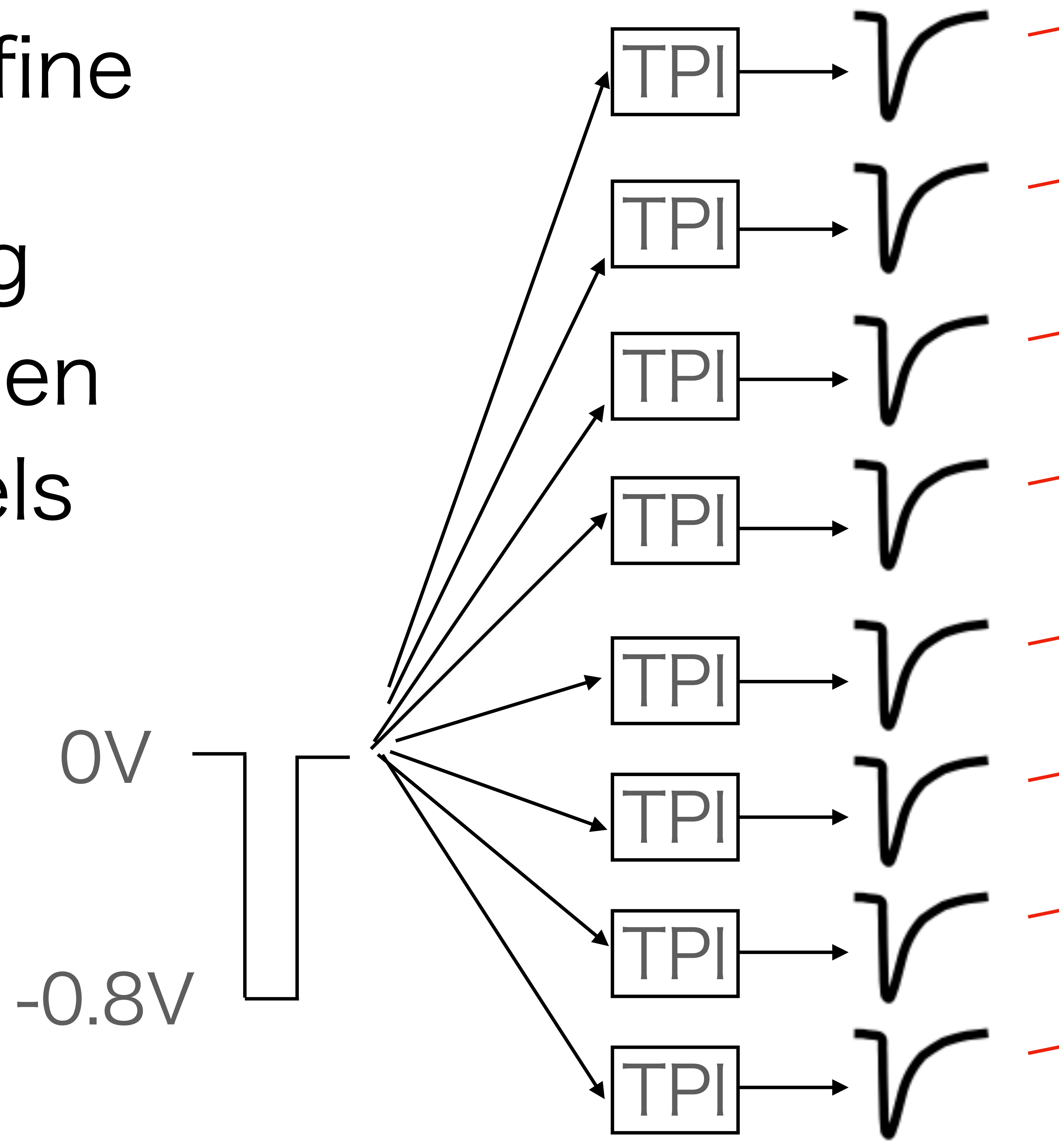
- MAX4414
- https://datasheets.maximintegrated.com/jp/ds/MAX4414-MAX4419_jp.pdf

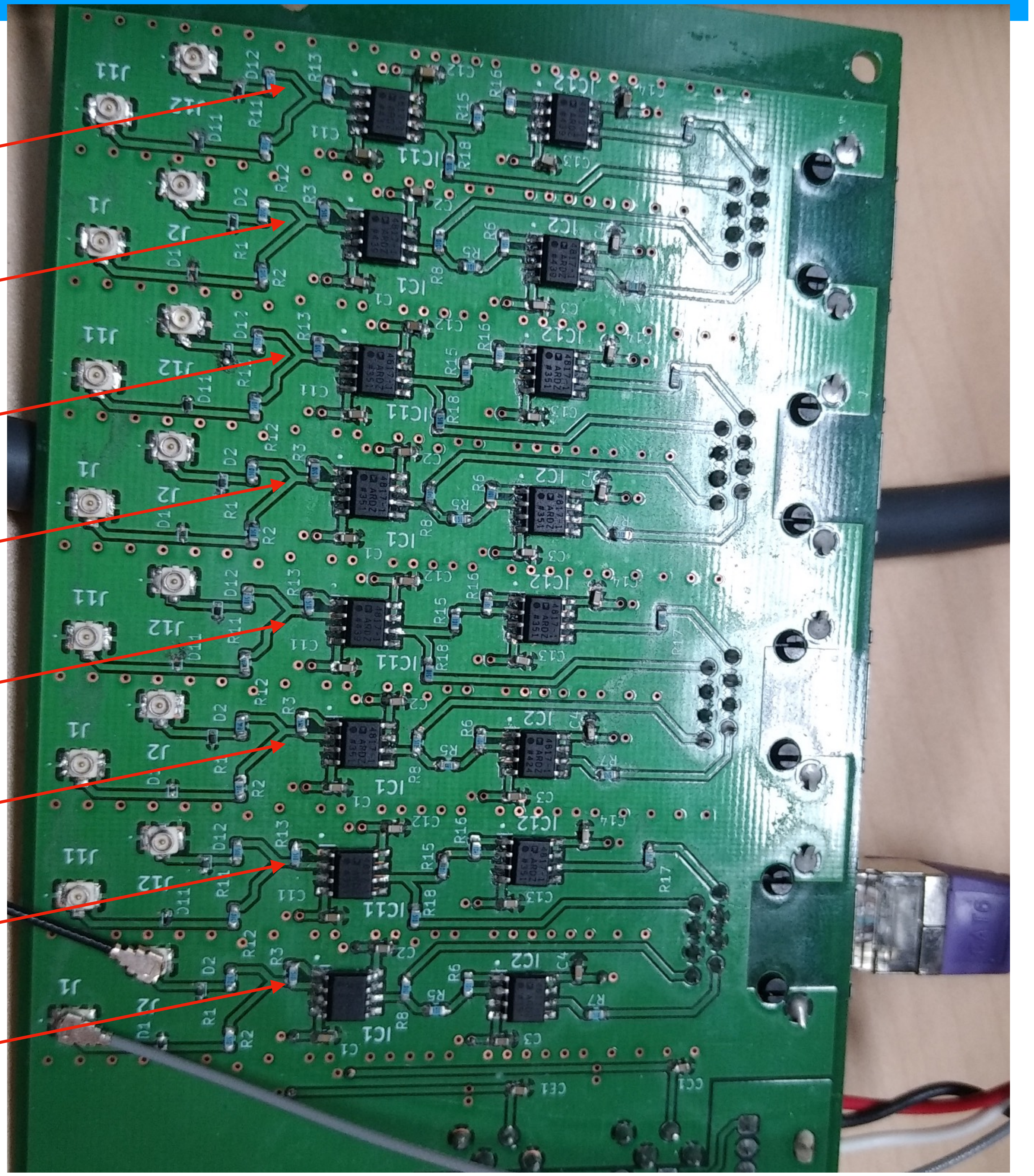


Test Pulse (TP) circuit

Role & Motivation

- Check the UCV amplifier works fine
- Check the timing variations between amplifier channels

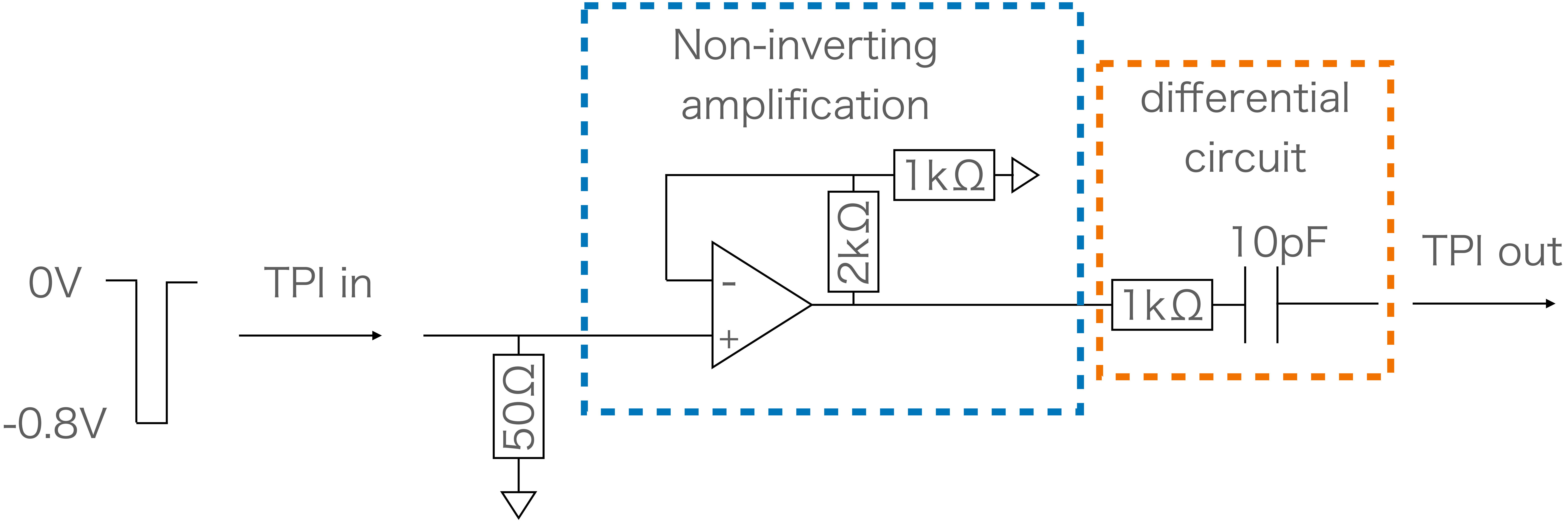




Test Pulse (TP) circuit

Circuit diagram

- Op amp of TP circuit has the same performance as in the MPPC test pulse circuit
- Op amp has high enough frequency response(400 MHz for -3dB bandwidth)



Simulation

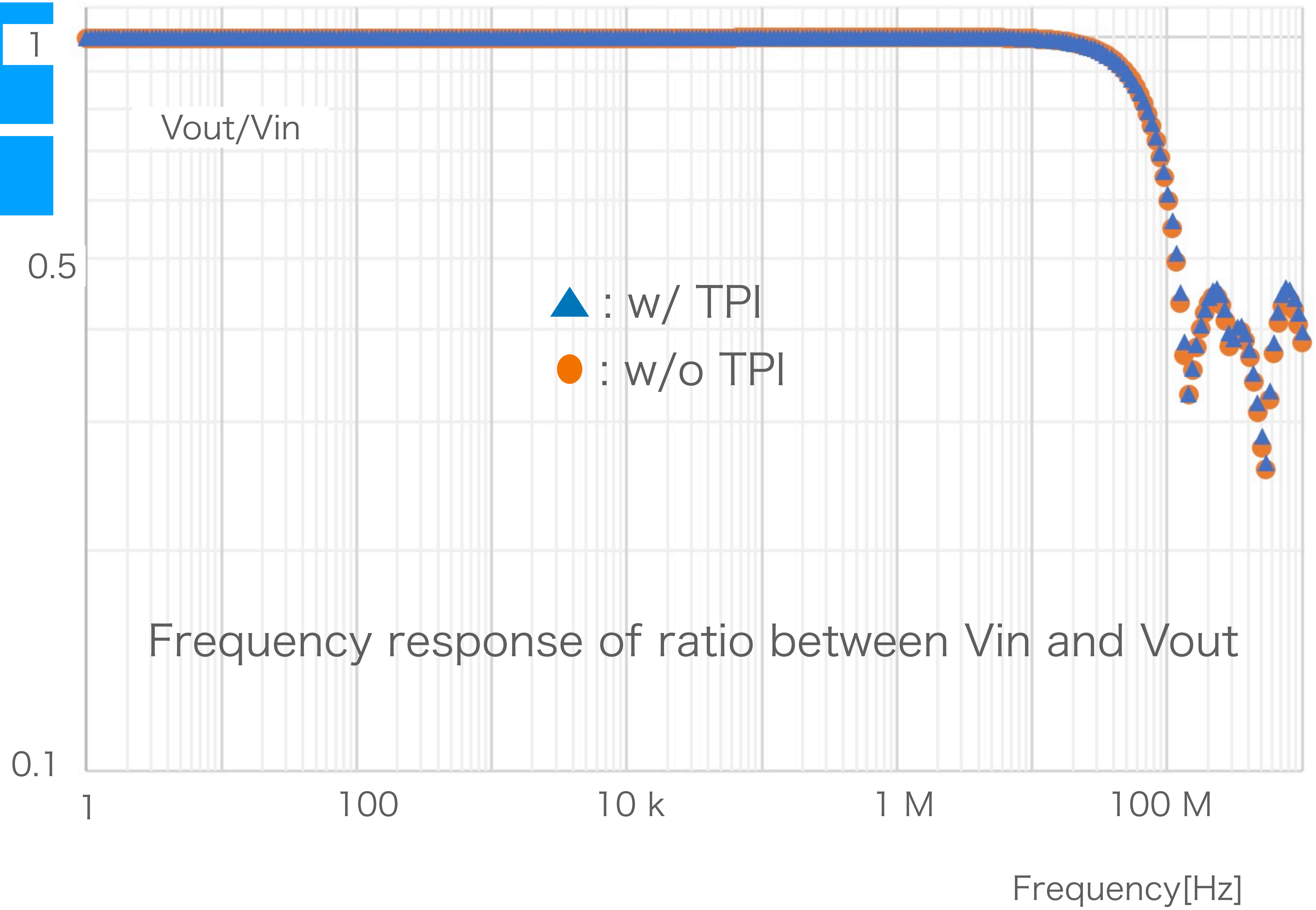
Result(check1)

- time constant : 1 kΩ × 10 pF = 10 ns
- Measured time : 10 ns(TPI out), 9.5 ns(UCV Amp out)

Simulation

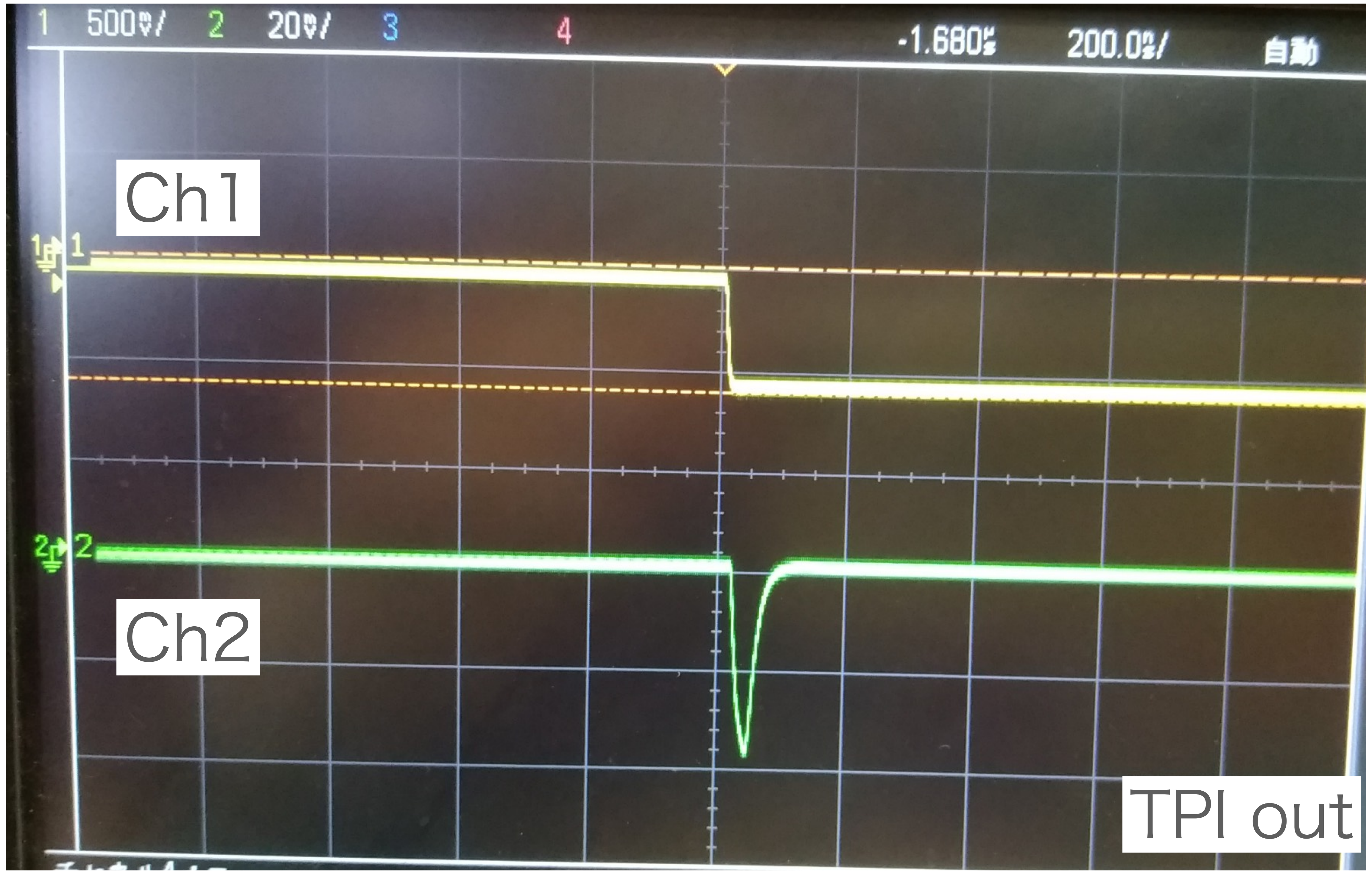
Result(check2)

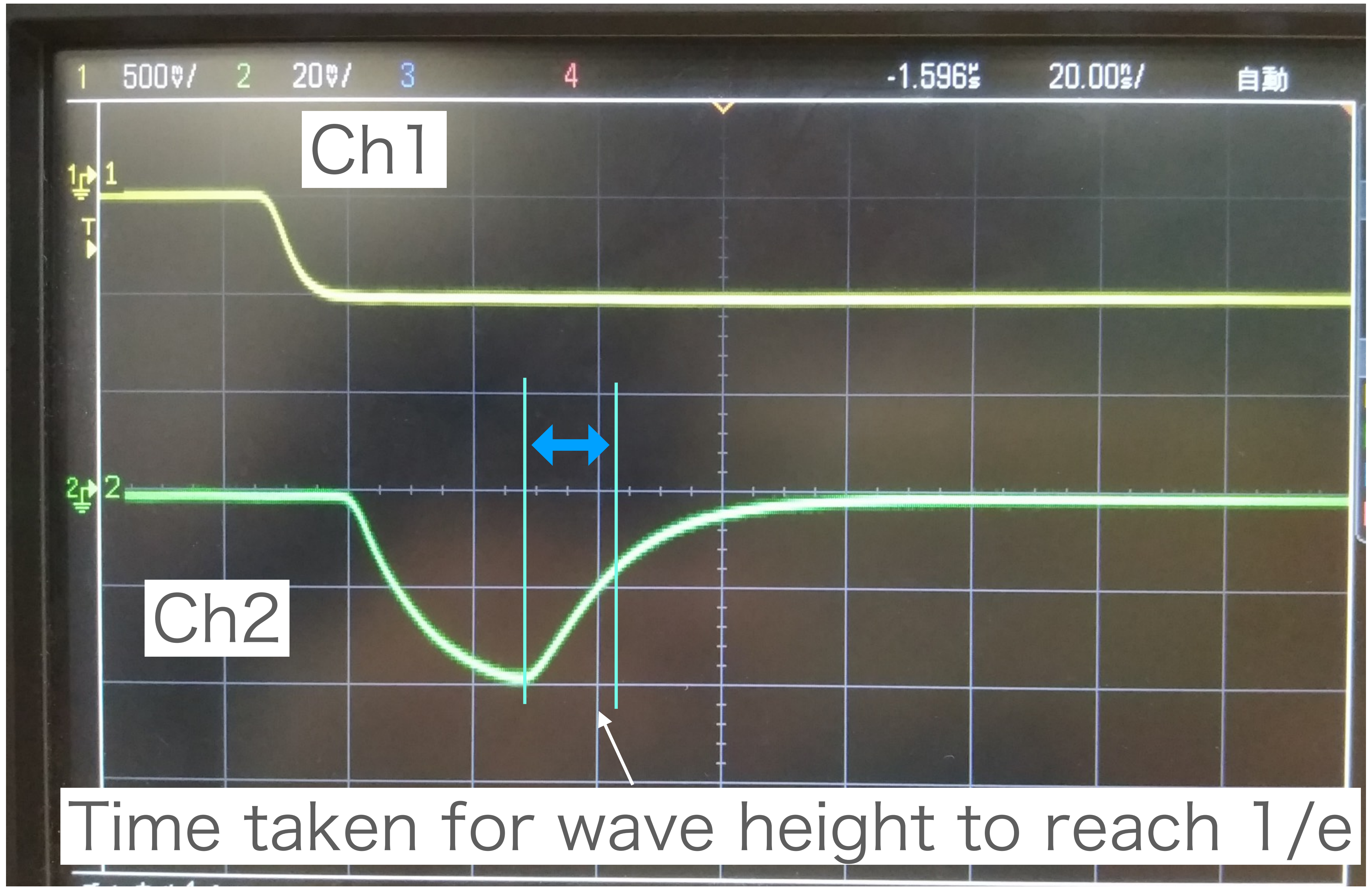
- Vout = |(+out)| + |(-out)|
- Input-output ratio was about 1 up to 20 MHz



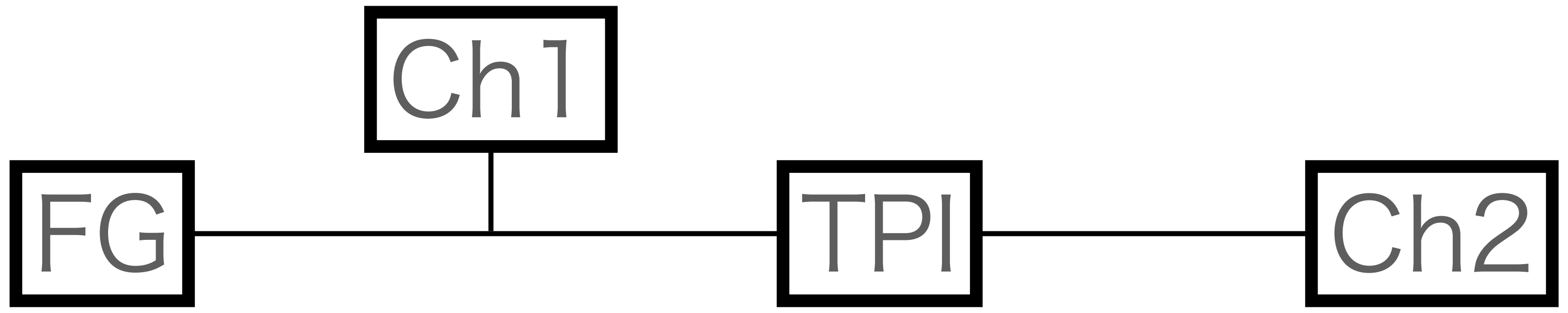
Operation check

Output waveform

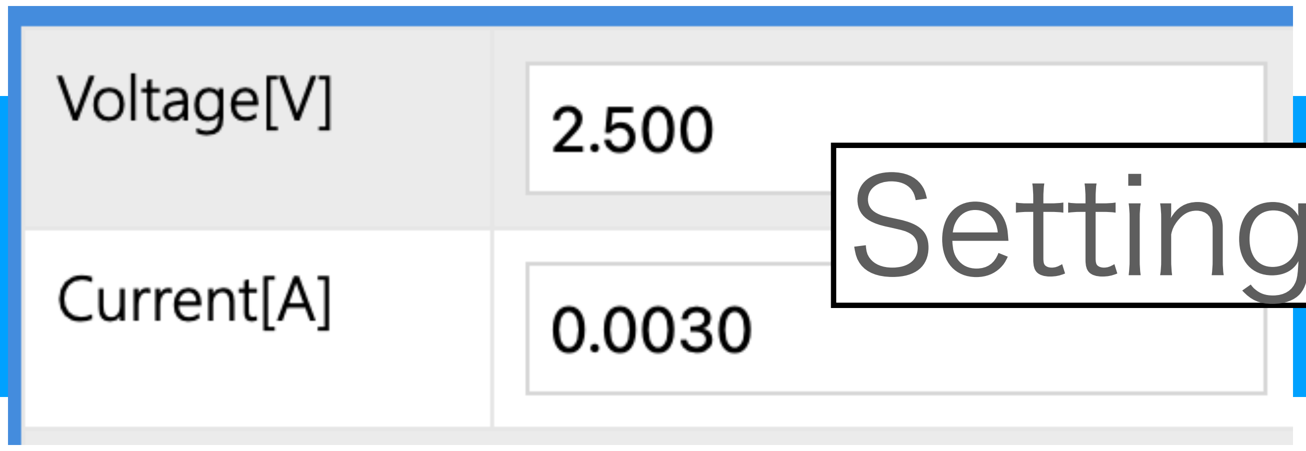




- Time constant(calculated) : 10 ns
- Measured time : 15 ns



Problem



Setting of DC power supply

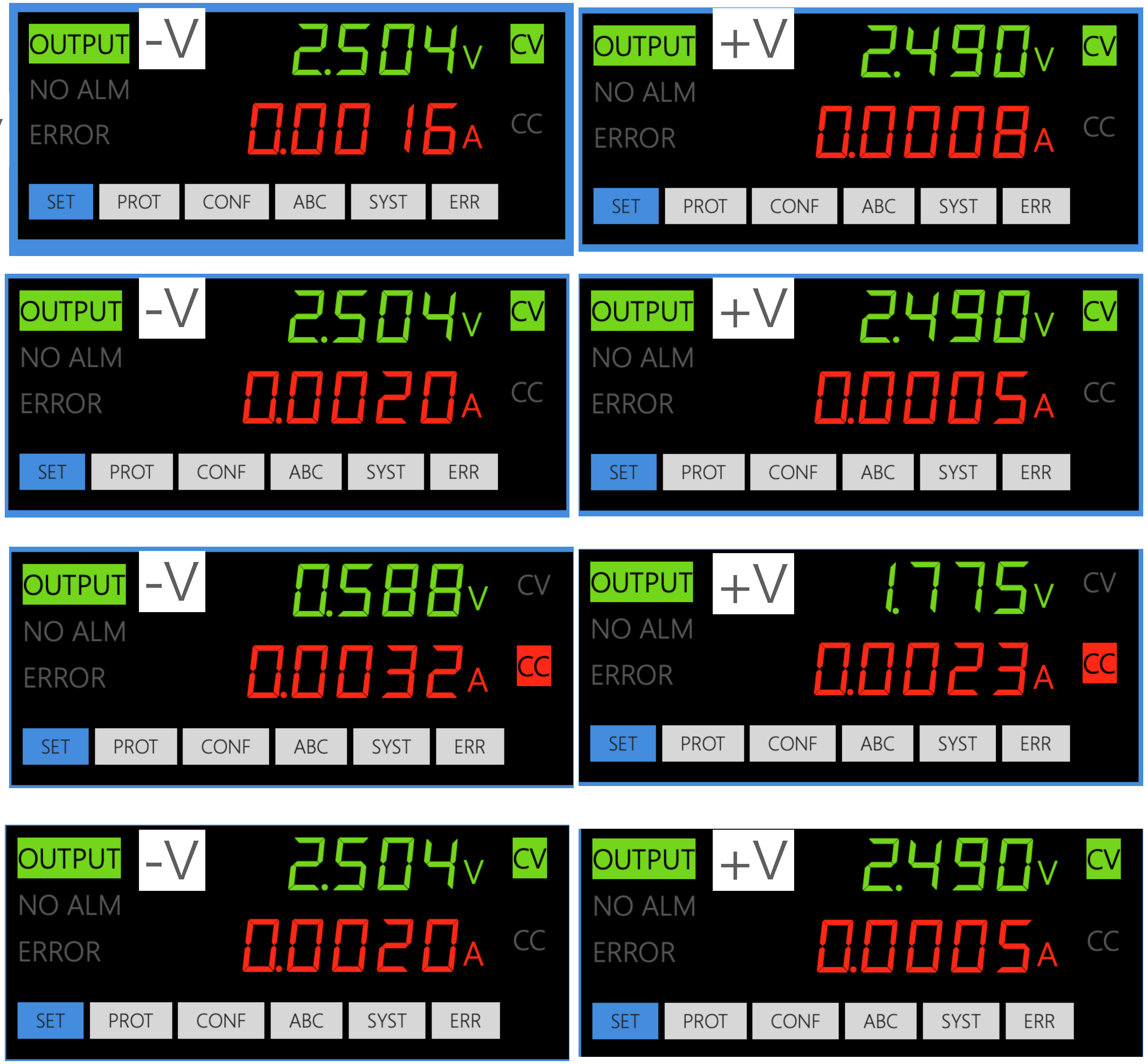
- When I touched the pattern, supply voltage dropped. It didn’t occur with insulators
- Voltage drop was recovered by cycling power
- Masking the trace with Kapton tape prevented the voltage drop
- Cycling the DC power with remotely control can fix the problem if it occurs in the beam time

Standby

Signal in

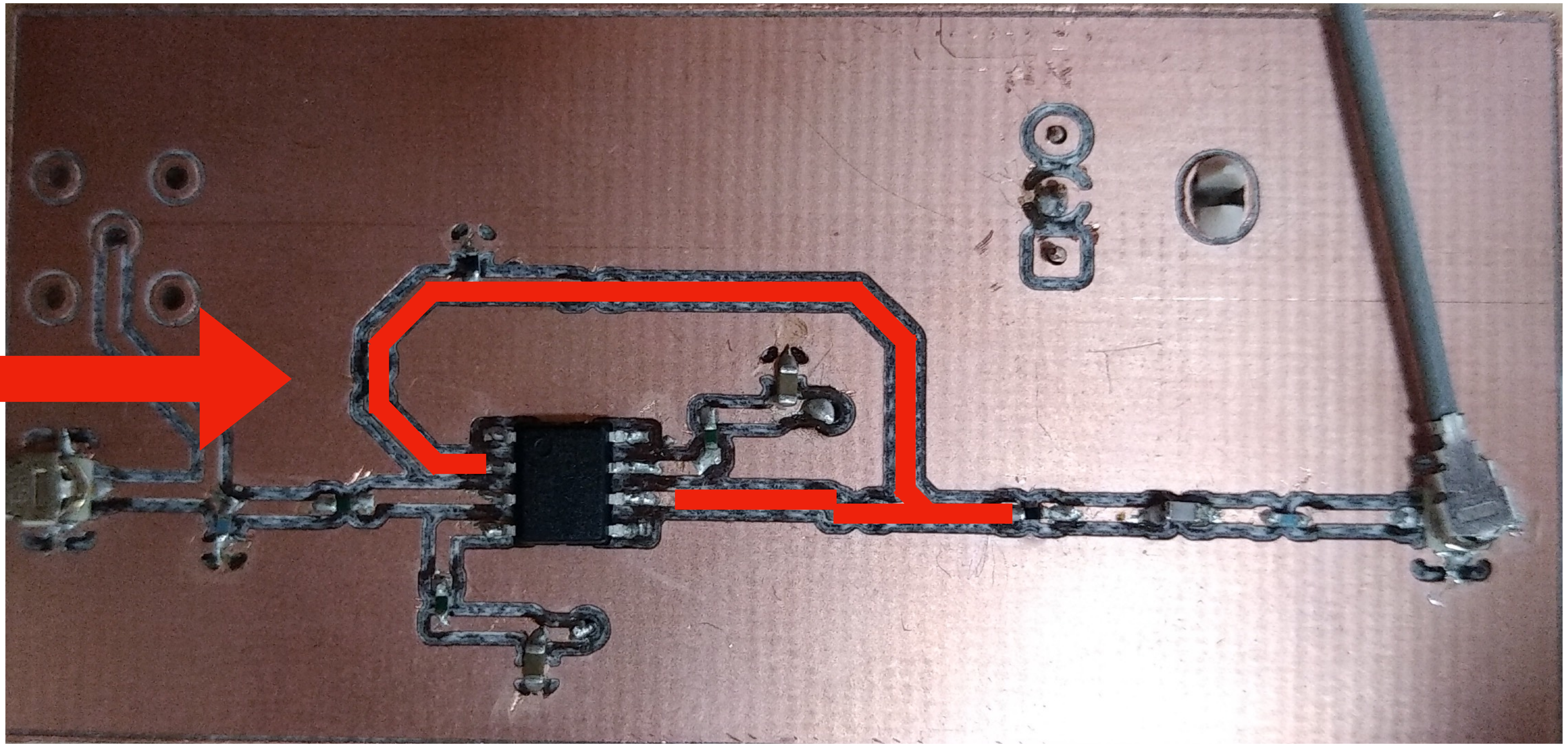
Touch

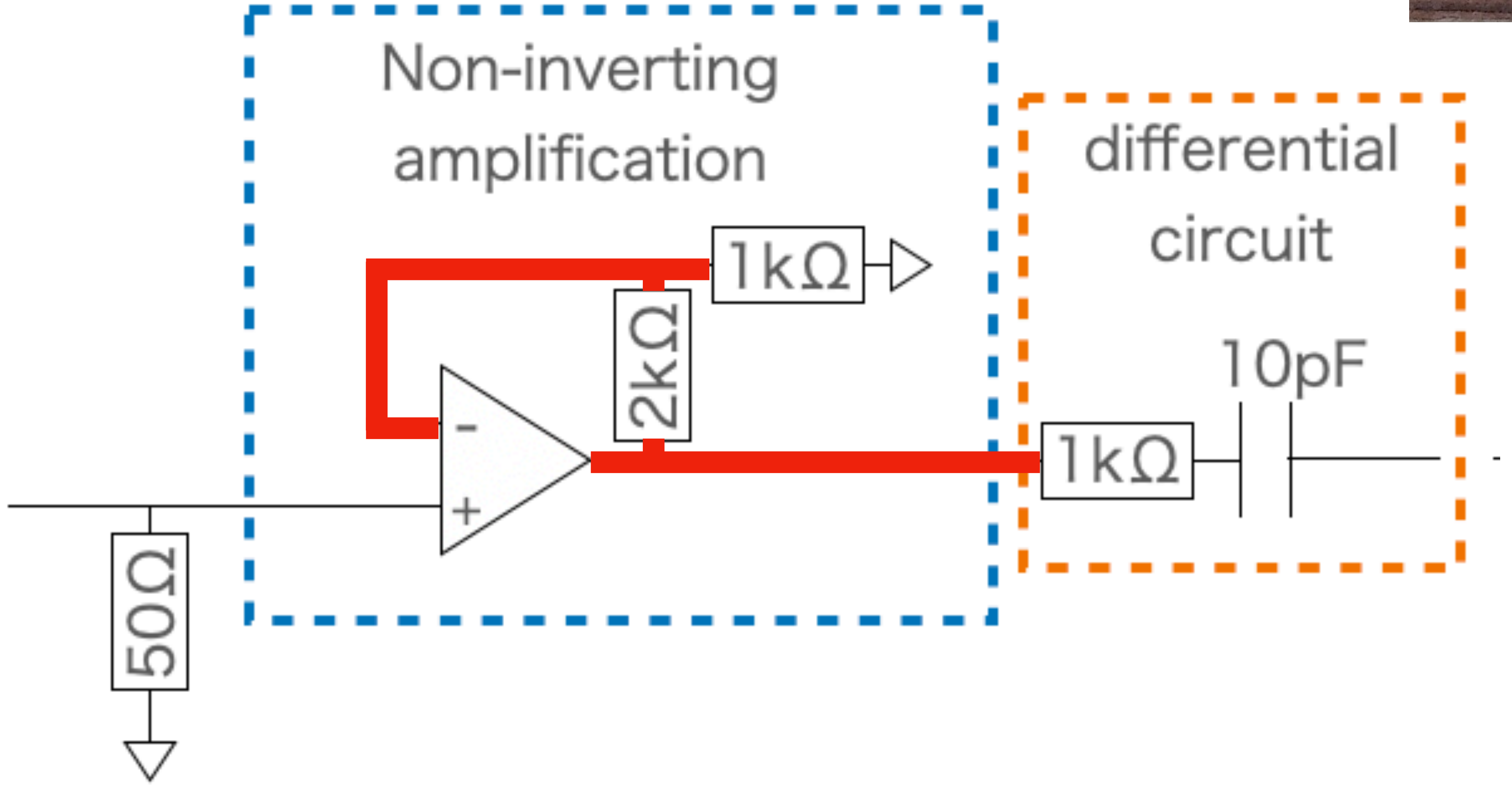
Output off->on



Problem

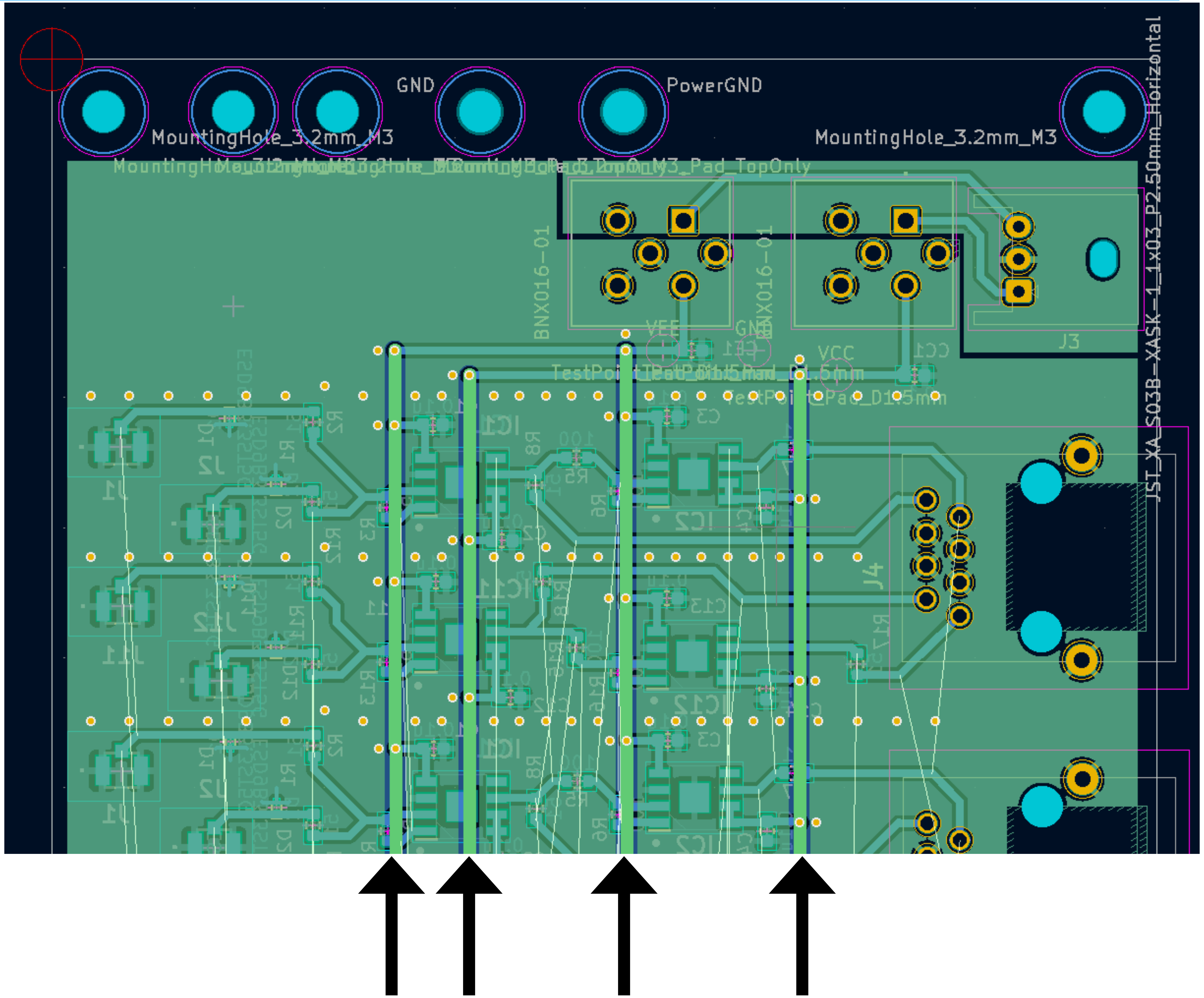
- Red line ;
  voltage drop occurred when
  we touched





Problem of current amp

- Amplifier far from power supply input was unstable -> wider trace may help



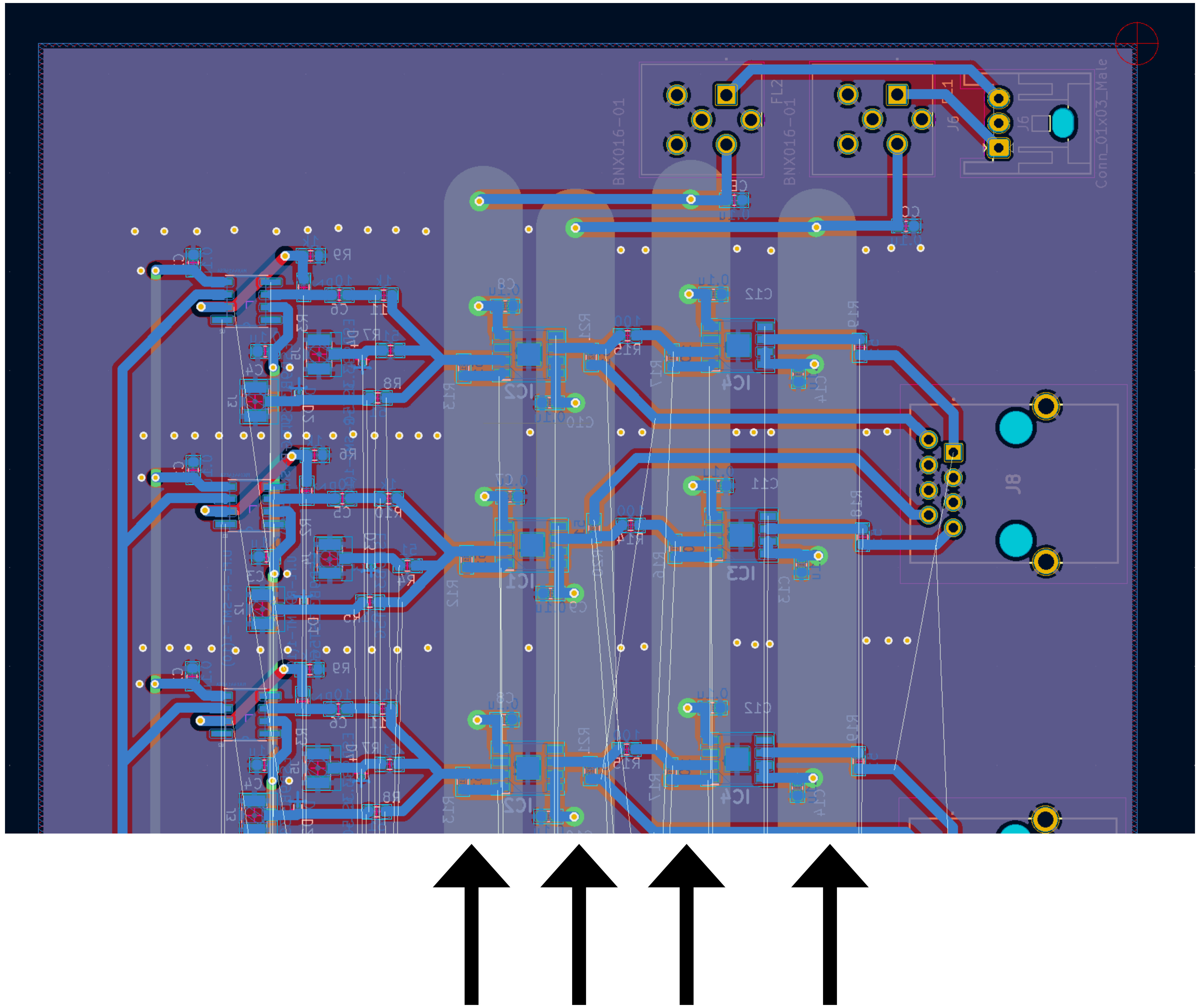
Power supply trace

Problem of current amp

Design of new board

- Amp + TP circuit

- Wider power supply trace



Power supply trace