Development of a general-purpose preamplifier for silicon sensors with high frequency compatibility and noise reduction for high energy nuclear experiments

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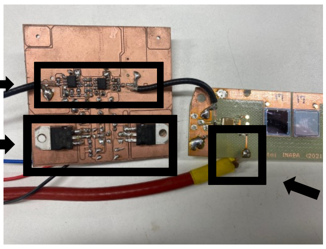
Motivation

- To investigate the dynamic range and noise of silicon pad sensors with large regulatory capacity
- need a much simpler preamplifier for detector R & D

- Design concept for the amplifier
  - highly versatile readout circuit.
  - High frequency and low noise
  - Simple setup in a test beam and a laboratory

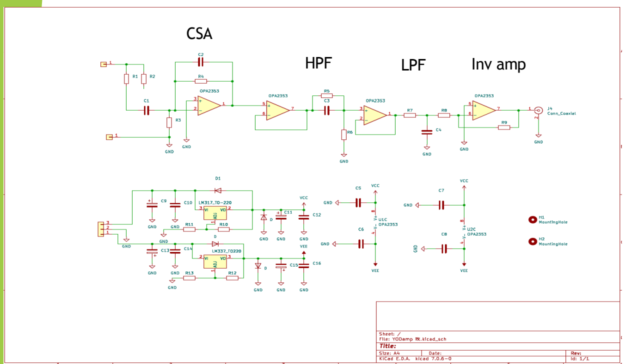
preamplifier

Power source



HV

Circuit Configuration



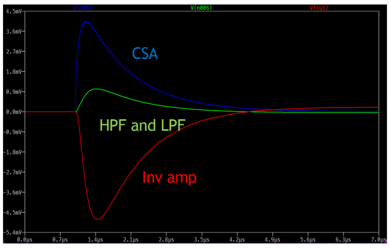
- CSA (Charge sensitive amplifier)
  - Role in converting current values to voltage values
- Filter (High-pass filter and Low –pass filter)
  - Allow high frequency signal to pass through and block low frequency signal (Cut-off frequency: 6.6kHz)
  - Allow low frequency signal to pass through and block high frequency signal (Cut-off frequency: 300kHz)
- Inverting amplifier
  - Role of inverting and amplifying input signal
- Voltage follower
  - Role in lowering output impedance
- Power supply source
  - Stable power supply using 3-terminal regulator (±2.5V)

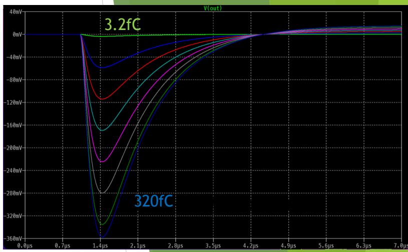
Noise Countermeasures

- countermeasure plan
  - Opeamp OPA2353
    Select low bias current opeamp to accommodate small currents
    Bias current ±50pA
  - Circuit Board Configuration
    Addition of guard ring at the input signal entrance to prevent noise
    Composed of chip components to eliminate transmission distance loss
  - Noise
    Addition of HPF and LPF to cut out unneeded frequency bands
    Addition of 3-terminal regulator for stable power supply
  - Frequency
    Changed to 300k frequency band required for R&D to reduce noise

Results : Ltspice Simulation

- Condition
  - Input current 3.2fC(Equivalent to 1 MIP) Current pulse width 1ns signal delay 1μs





- Simulation Results
  - ✓ Fig1
    CSA(blue),HPF and LPF (green),Inv amp (red)
    Shaping time is 4.5 μs
    → Signals up to 220 kHz
    output is ideal for each output.
  - ✓ Fig2
    Simulation of the amount of charge equivalent to 1〜100 MIP
    Input signal from 3.2fC~320fC by 50fC
    Successful without saturation at any value.

Results : output of laser on silicon sensor

- Condition
  - HV : 100V opeamp : ±2.5V Laser intensity : 15〜5

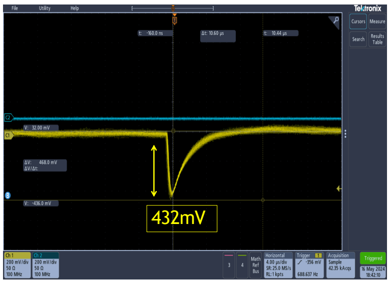


Fig3: intensity 11 output

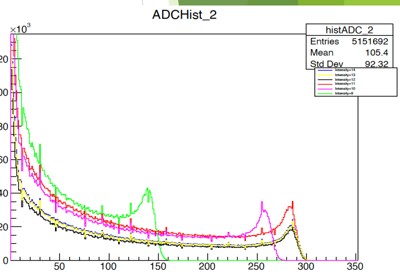
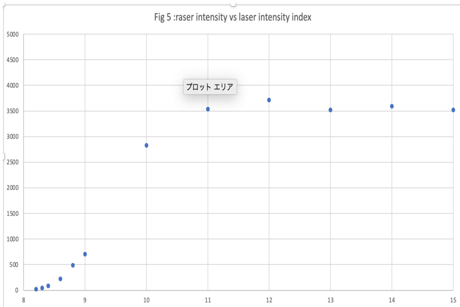
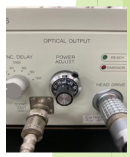
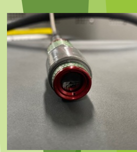


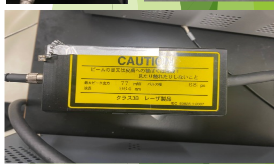
Fig4 :ADC vs Count intensity 15~9 each plot

- Signal results
  - ✓ Fig3 : intensity 11 output
    Output voltage 432mV, shaping time 6.2μs
    Ideal output with low noise
    The shaping time was longer than simulated
    → Response up to 160 kHz
  - ✓ Fig4 : Data readout results using a digitizer
    ADC vs Count intensity 15-9 each plot
    The output was confirmed by the intensity of each laser.
    Output values did not change at intensities of 12 to 15.









- Fig5 : Estimating the number of photoelectrons vs Laser Intensity Index
  - Calculation method for estimating the number of photoelectrons from the ADC graph using (M/σ)^2 (M : Mean, σ : Std Dev)
  - Linearity was observed between laser intensity and Estimating the number of photoelectrons up to intensity 11
  - However, after intensity 11, the signal was saturated.

    ➡ this is due to the high intensity of the laser and the maximum current from the silicon sensor.
  - No output signal could be seen when the intensity was less than 8.

    ➡ To change the resistance of CSA from 1M to 10M to increase the gain
    Reduce noise by checking CSA shaping time and using tighter HPF and LPF cut-off frequency

Summary

- Successfully circuit simulation using LTspice
- Successfully produced a preamplifier that is easy to set up.
- Preamplifier successfully produce low noise output results

➡

- Narrower frequency band limitation of LPF and HPF from CSA output for noise reduction.
- Silicon sensor evaluation experiments in ELPH and other experimental facilities.
- Aiming to create a circuit capable of reading out multiple channels.