Charge Sensitive PreAmplifier

Group-15

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Overview

- ❖ Preamplifier
- ❖ Charge sensitive preamplifier
- ❖ Experimental set-up and circuit diagram
- ❖ Experimental data
  - Sensitivity measurement
  - Effect of detector capacitance on charge/voltage sensitive preamplifier
- ❖ Conclusion

PreAmplifier

- A preamplifier is an electronic amplifier that converts a weak electric signal into a strong output signal
- Why do we need preamplifier?
  - Impedance matching: To get maximum power transfer from detector output to amplifier/other external circuits
  - Converting charge pulse to voltage pulse: We get a charge pulse from detector output, to convert it into a voltage pulse and send it to other external circuit we need a preamplifier
- Types of preamplifier
  - Current sensitive preamplifier
  - Voltage sensitive preamplifier
  - Current sensitive preamplifier

Voltage Sensitive PreAmplifier

$$V_{in} = \frac{Q}{C_{total}}$$

Stray capacitance of the detector
+
Intrinsic capacitance of the detector

$$V_{out} = -\frac{R_2}{R_1} \times V_{in} \quad \left(A \gg \frac{R_2}{R_1}\right)$$

$$V_{out} = -\frac{R_2}{R_1} \times \frac{Q}{C_{total}}$$

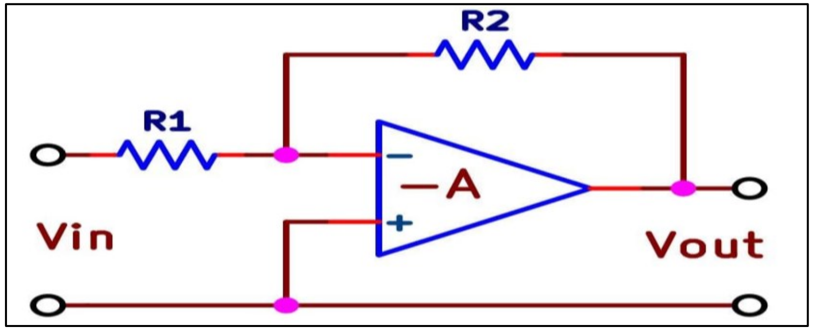


Fig 1: Voltage sensitive preamplifier

- If C_{total} is fixed, it is proportional to the input charge of the preamplifier
- C_{total} is not constant for certain semiconductor detectors
- Intrinsic capacitance of the detector varies with different operating parameters
- Gain of Voltage Sensitive Preamplifier becomes a function of both charge and detector's intrinsic capacitance

Charge Sensitive PreAmplifier

$$C_i = C_{detector} + C_{stray}$$

$$C_f \Rightarrow C_f(1 + A)$$

(Miller effect)

Effective input capacitance

$$C_{eff} = C_i + C_f(1 + A)$$

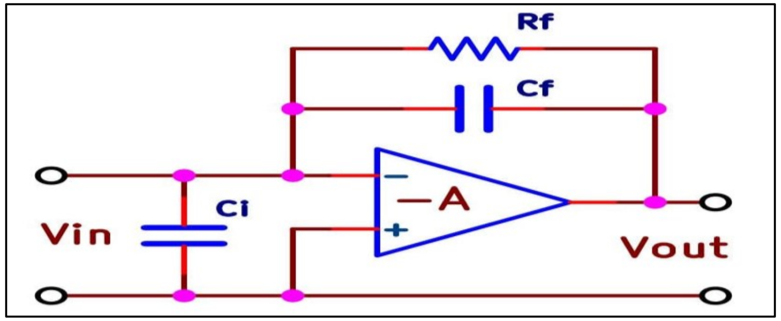


Fig 2: Charge Sensitive Preamplifier

$$V_{out} = -A \times V_{in}$$

$$V_{in} = \frac{Q}{C_i + C_f(1 + A)}$$

A is very large

$$V_{in} \sim \frac{Q}{C_f A}$$

$$V_{out} = -A \times \frac{Q}{C_f A}$$

$$V_{out} = -\frac{Q}{C_f}$$

- Output pulse amplitude becomes independent of the input capacitance
- V_{out} is proportional to the input charge
- R_f is used to stabilize the DC conditions

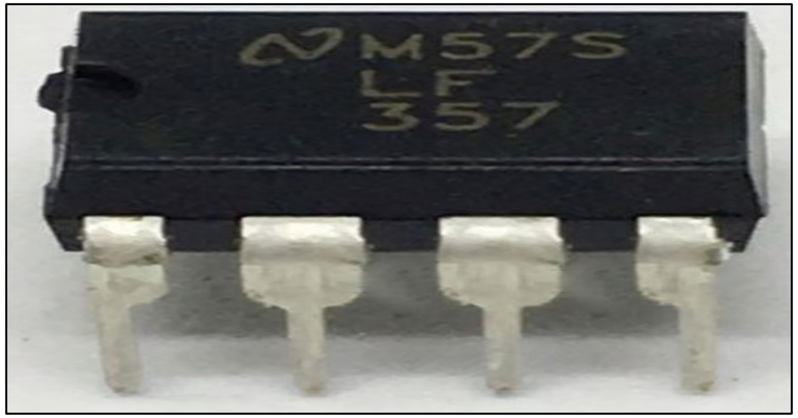
Gain $= \frac{V_{out}}{Q} = \frac{-1}{C_f}$

$(\textit{not a dimensionless quantity})$

Sensitivity $\Rightarrow \frac{V_{out}}{Q}$ (mV/pC)

EXPERIMENTAL SET-UP

- ❖ Printed Circuit Board with components
- ❖ Oscilloscope
- ❖ Power supply
- ❖ Connecting wires



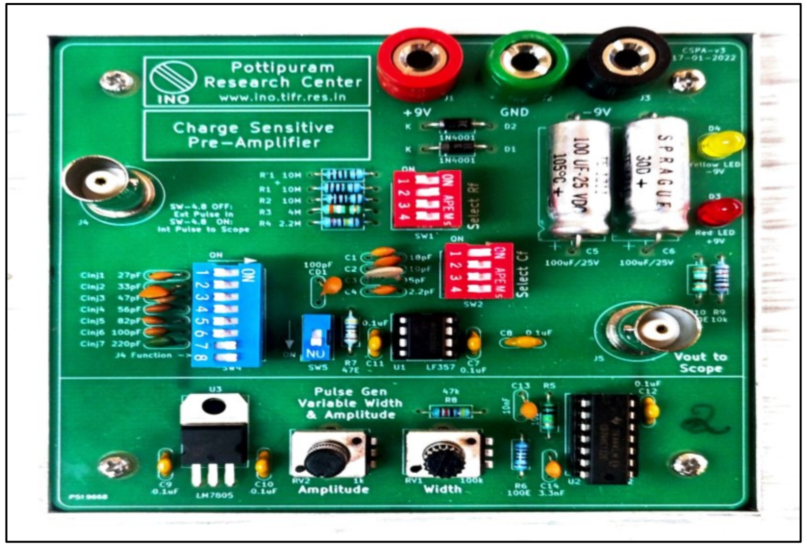


Fig 3: Circuit board with components

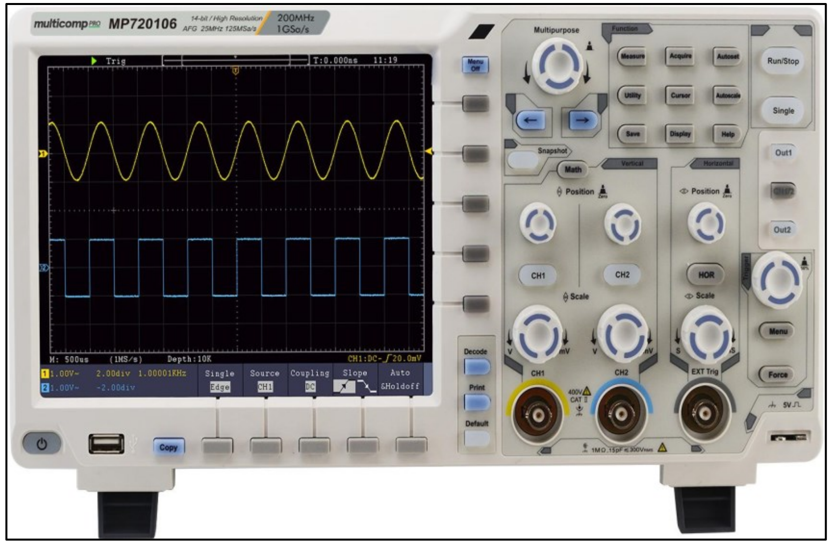


Fig 4: Oscilloscope

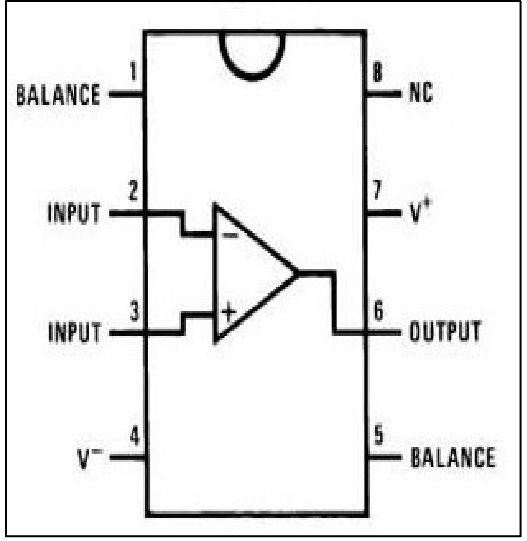
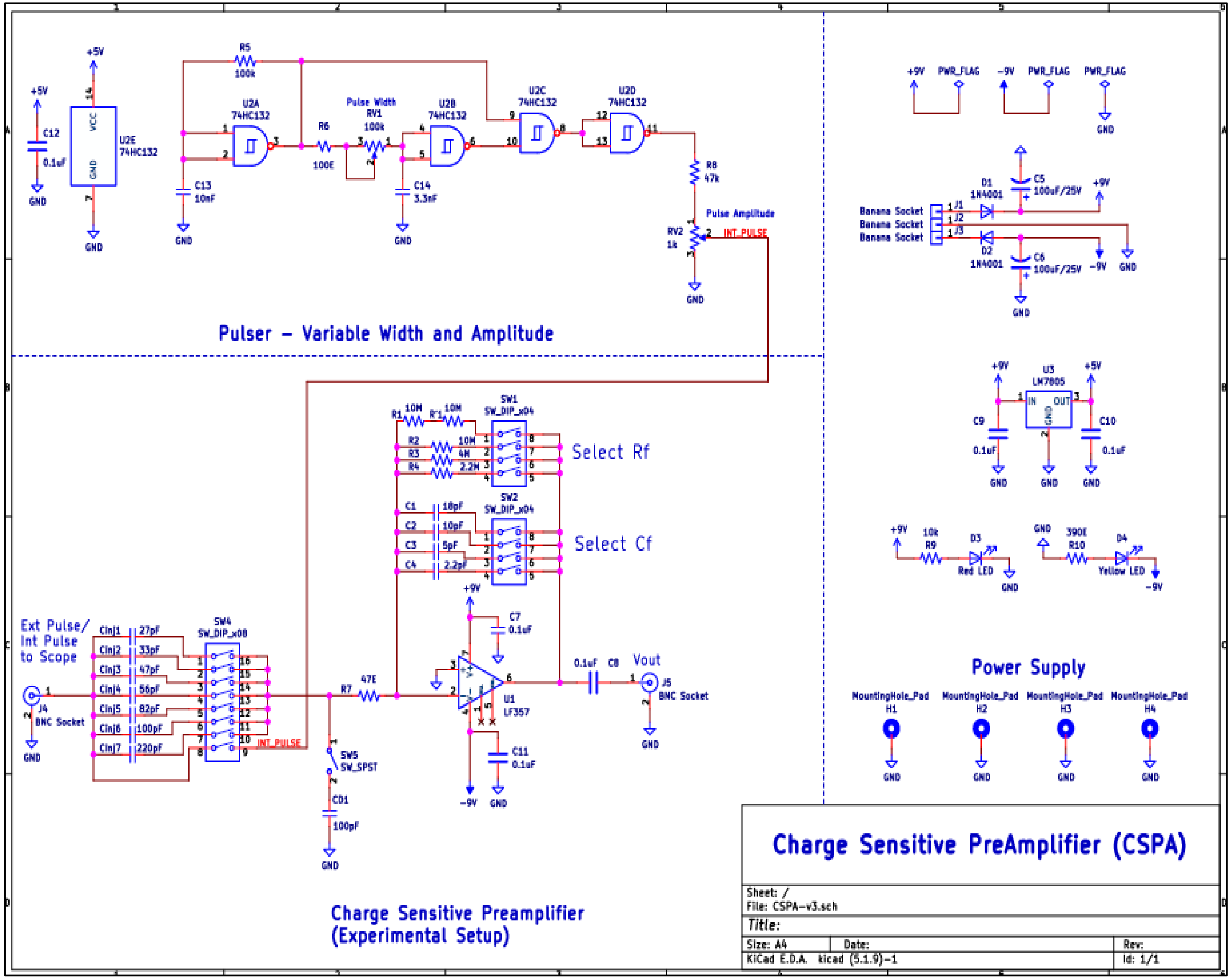
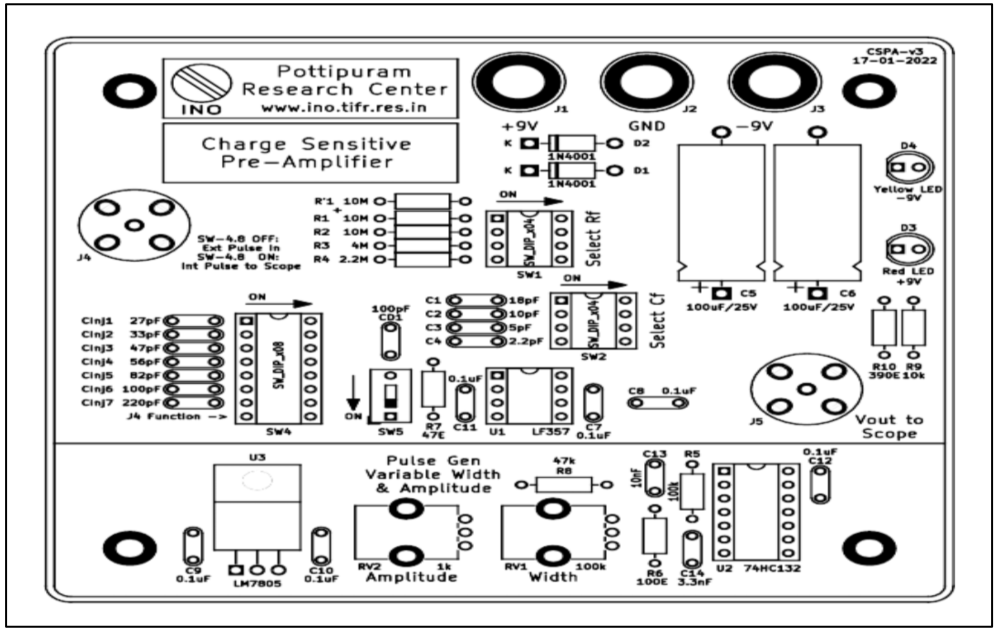
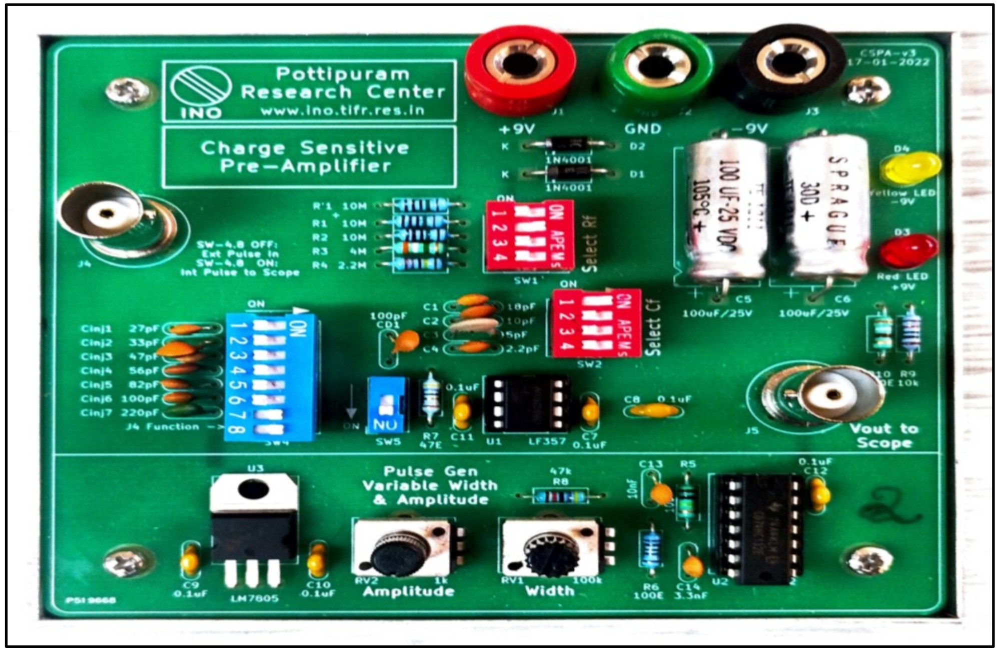


Fig 5: LF357 Pinout

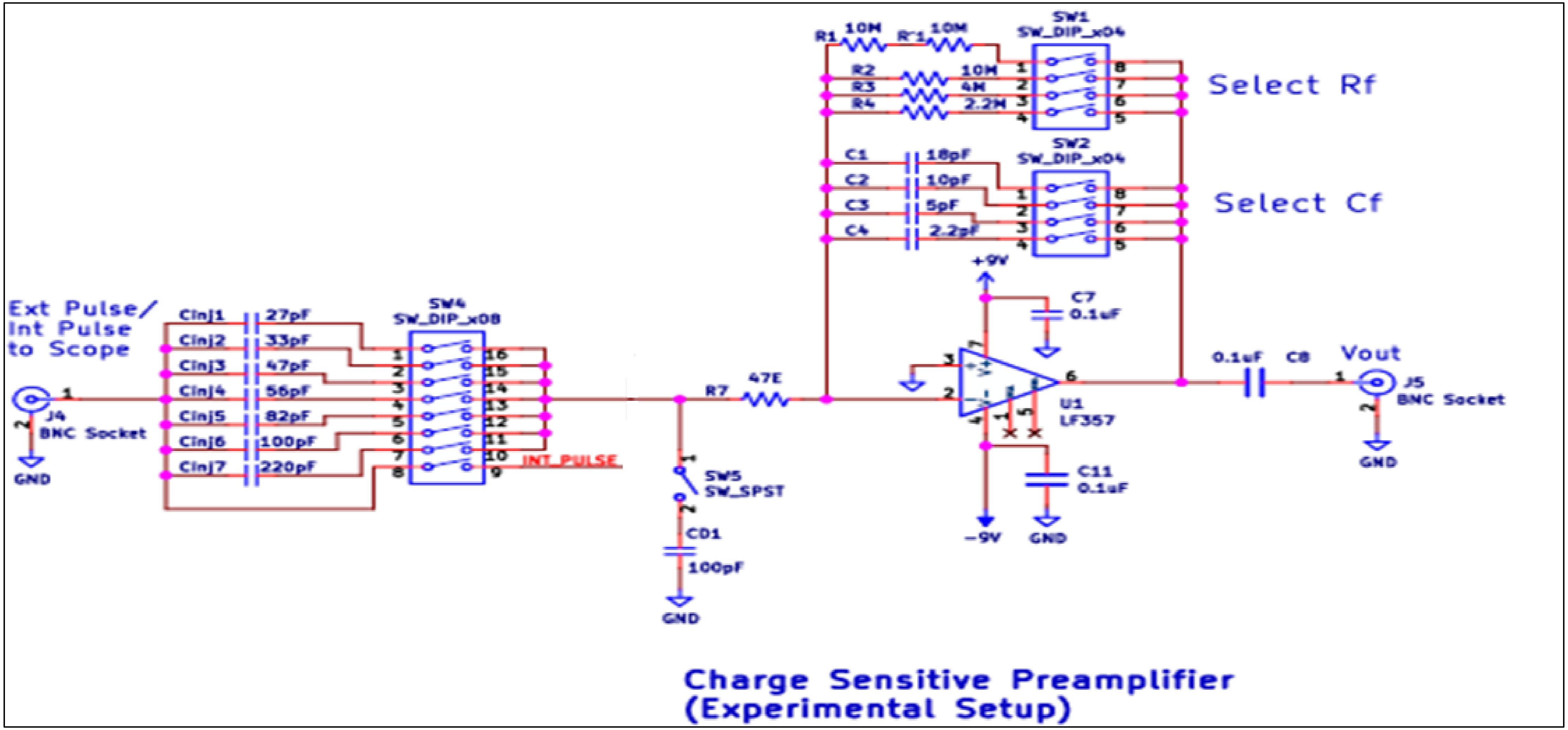
CIRCUIT DIAGRAM







Circuit Diagram



Experimental Data

- ❖ Sensitivity measurement
  - ➢ Changing the charge injecting capacitor
  - ➢ Changing the input pulse amplitude

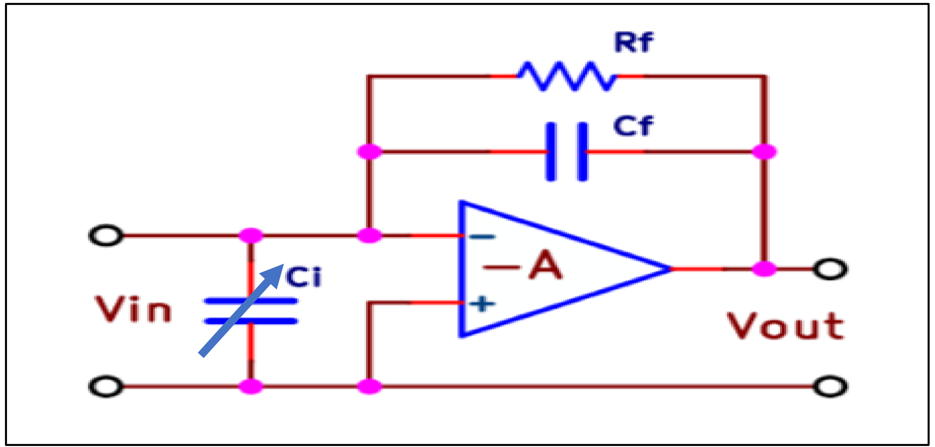
- ❖ Effect of detector capacitance on charge amplifier

- ❖ Effect of detector capacitance on Voltage amplifier

SENSITIVITY MEASUREMENTS

- **Changing the charge injecting capacitor, C_{inj} :**

V_{in} = 20 mV
$C_f = 10$ pF
$R_f = 10$ MΩ



Sr. No.	C_{inj} (pF)	V_{out} (mV)	Q_{in} (pC)	Sensitivity (mV/pC)
1	27	60.8	0.54	112.59
2	33	68.0	0.66	103.03
3	47	97.6	0.94	103.83
4	56	114.4	1.12	103.83
5	82	158.0	1.64	96.34
6	100	190.0	2.00	95.00

V_{out} → oscilloscope

Q_{inj} → $V_{in} \times C_{inj}$

Sensitivity → V_{out} / Q_{inj}

(b) Changing the input pulse amplitude, V_{in} :

$C_f = 10$ pF
$R_f = 10$ MΩ
$C_{inj} = 33$ pF

Sr. No.	V_{inj} (mV)	Q_{in} (pC)	V_o (mV)	Sensitivity (mV/ pC)
1	20	0.66	68.0	103.03
2	30	0.99	99.2	100.20
3	40	1.32	128.0	96.96
4	50	1.65	160.0	96.96

For $C_f = 10$ pF , Sensitivity ~ 100

(c) Changing the input pulse amplitude, V_{in} :

$C_f = 2.2$ pF
$R_f = 10$ MΩ
$C_{inj} = 33$ pF

Sr. No.	V_{inj} (mV)	Q_{in} (pC)	V_o (mV)	Sensitivity (mV/ pC)
1	20	0.66	206.0	312.12
2	30	0.99	314.0	317.17
3	40	1.32	432.0	327.27
4	50	1.65	536.0	324.84

For $C_f = 2.2$ pF , Sensitivity ~ 320

We can conclude that Sensitivity is inversely proportional to the feedback capacitance (**C_f**)

Effect of detector capacitance on Charge /Voltage amplifier

$V_{in} = 20\ \mathrm{mV},\ R_f = 10\ \mathrm{M\Omega},\ C_{inj} = 220\ \mathrm{pF}$

$C_f\,(\mathrm{pF})$	$V_{out}(\mathrm{mV})$		$\Delta V_{out}(\mathrm{mV})$
	Without C_d	With C_d	
10	392.0	376.0	16
18	256.0	248.0	8

$C_f = 0, V_{in} = 20\ \mathrm{mV},\ R_f = 2.2\ \mathrm{M\Omega},\ C_{inj} = 220\ \mathrm{pF}$

$V_{out}(\mathrm{mV})$		$\Delta V_{out}(\mathrm{mV})$
Without C_d	With $C_d = 100\mathrm{pF}$	
1560	1440	120

When feedback capacitor$(C_f) = 0$, it becomes a voltage amplifier. In that case, change in output voltage i.e ΔV_{out} varies significantly with detector capacitance compared to a charge sensitive amplifier

Another observation: The decay of the tail of output pulse varies proportionally to the magnitude of R_f

Conclusion

- The voltage sensitive preamplifiers are more conventional preamplifier
- However, when detector capacitance varies then sensitivity/gain becomes a function of detector capacitance. In such cases, we use charge sensitive preamplifier so that its sensitivity becomes independent of the detector capacitance
- Although originally charge sensitive preamplifier were designed to use with semiconductor detectors, it has been proven to be so superior that it is often used even when there is no need for its specific properties

THANK YOU