Pulse Shaping and Filtering Circuit

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Introduction

A pulse shaper is a circuit that is used to reshape an input signal into a desired output signal.

- Pulse shaping modifies the signal waveform for better accuracy
- Filtering attenuates or amplifies signal frequency
- Different filters are used based on signal characteristics and goals

Importance of pulse shaping in Particle Physics:

- Reducing noise and optimizing S/N ratio
- Reducing the effect of pile-up
- Meet the requirement of DAQ components

Introduction

Nuclear Physics

- Enhancement of sensitivity to low-level radiation sources
- To enable detection and analysis of rare decay events
- Helps in improving discrimination of different types of radiation

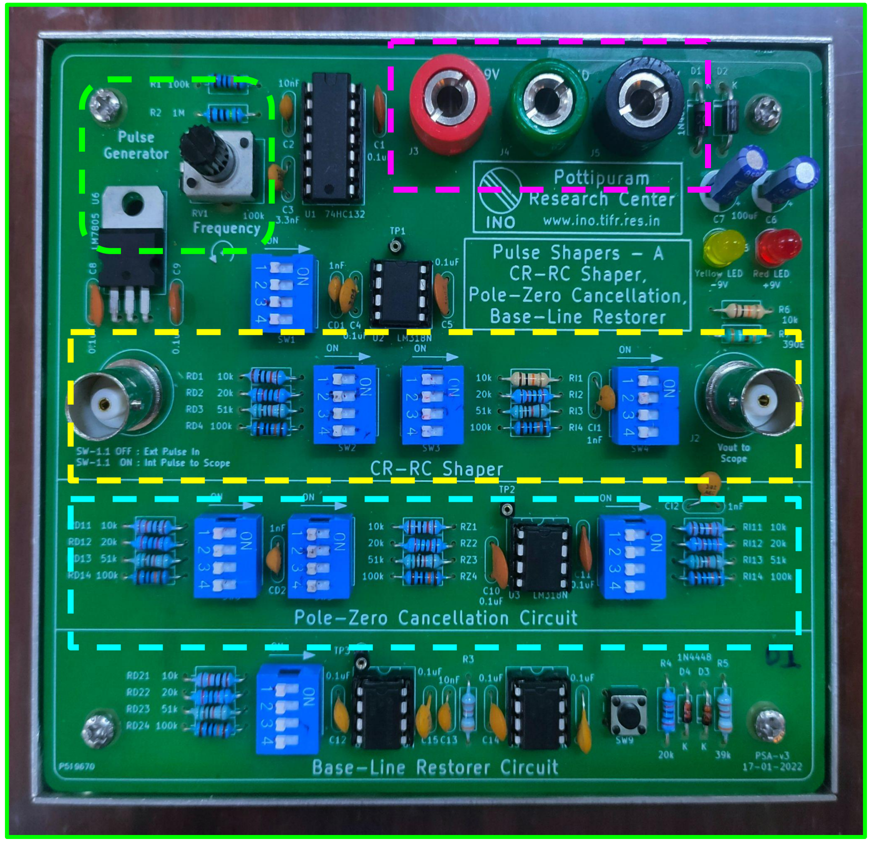
Particle Physics Experiments

- Improve measurement of particle properties and interactions.
- To enhance energy resolution and particle identification
- To increase data acquisition rates for high-energy collision

Experimental Setup

- **Board A**
  - CR-RC Shaping
  - Pole-Zero Cancellation

- **Board B**
  - Semi-Gaussian Shaping



Power Supply

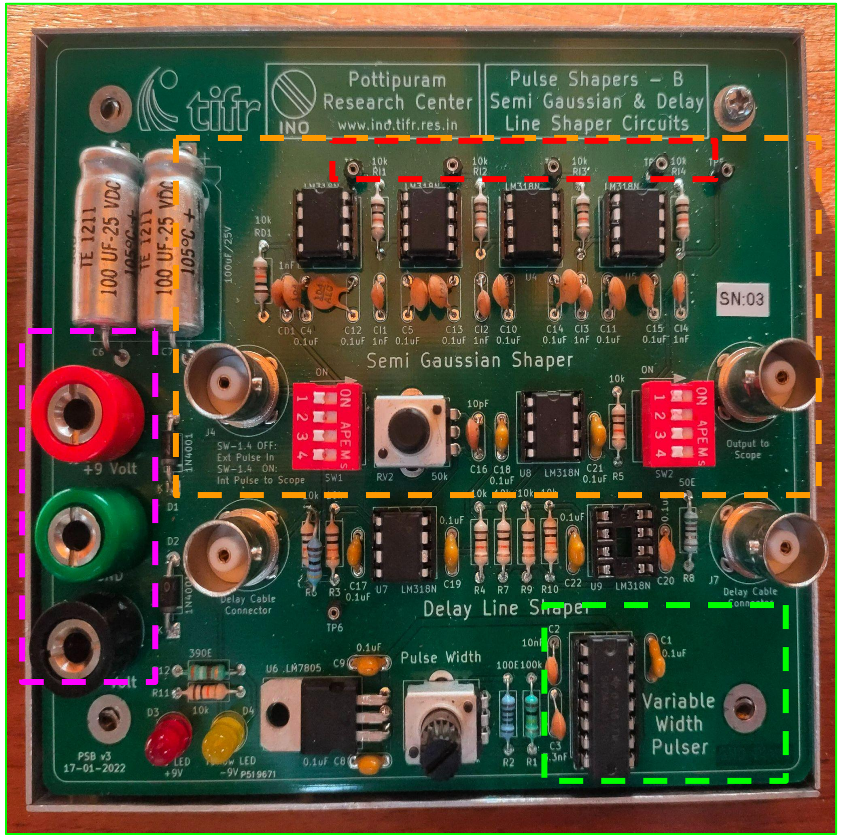
Pulse Generator

CR-RC Shaper Circuit

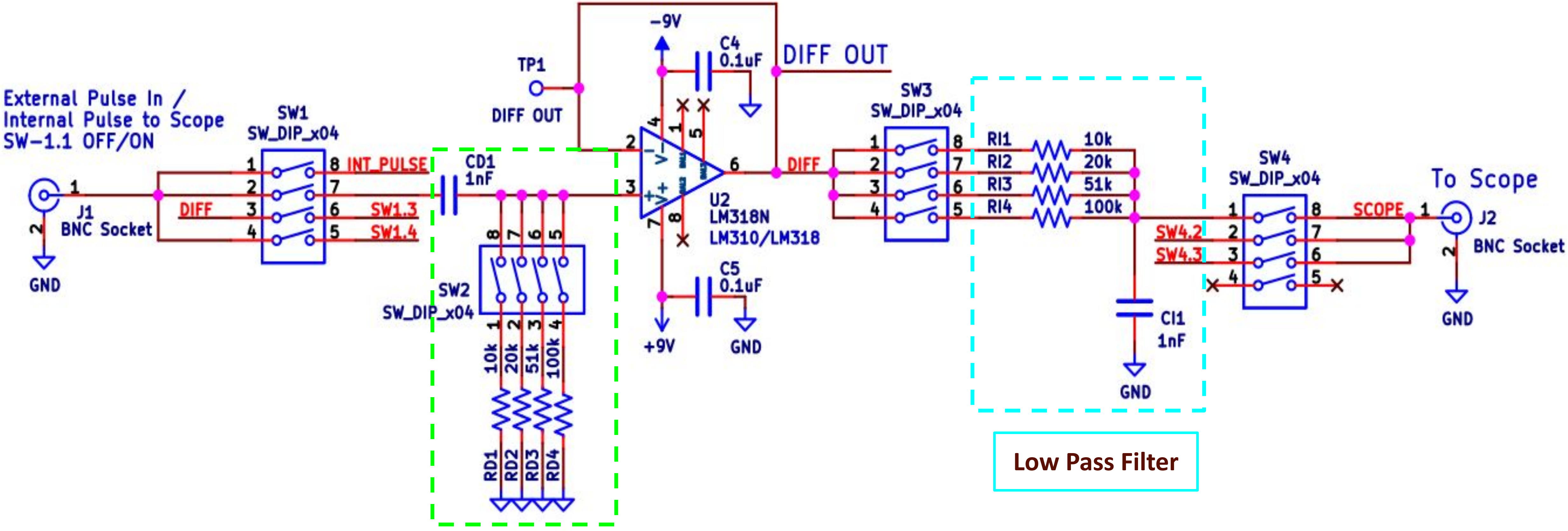
Pole Zero Cancellation Circuit

Semi- Gaussian Shaper Circuit

Test points



CR - RC Circuit



High Pass Filter

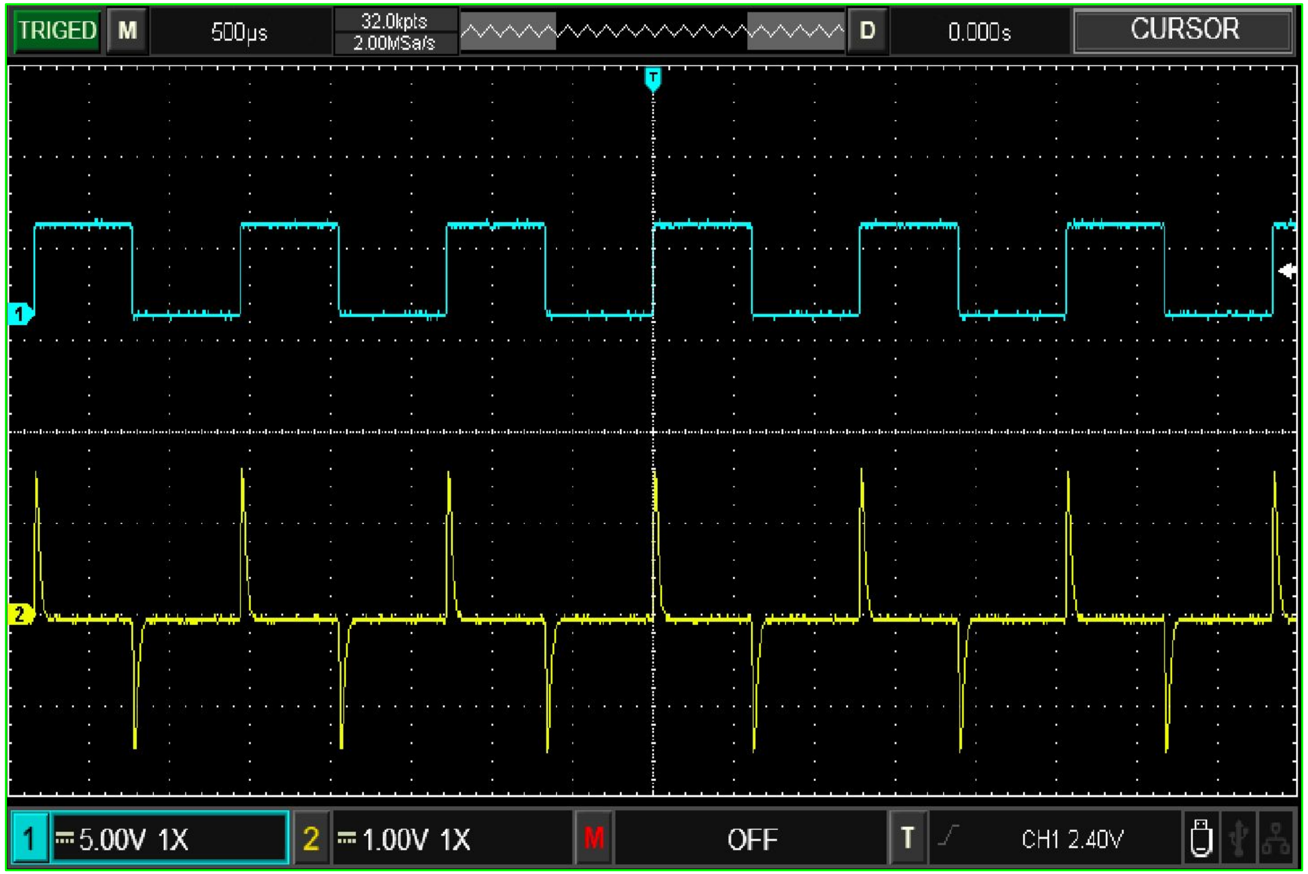
Low Pass Filter

CR - RC Circuit

- The combination of a CR differentiator and RC integrator is commonly used as a pulse shaper in linear amplifiers.
- The response of this CR-RC network to a step voltage of amplitude Vi is:

$$V_0 = \frac{V_i \tau_1}{\tau_1 - \tau_2}\left(e^{-t/\tau_1} - e^{-t/\tau_2}\right)$$

τ_1 and τ_2 are the time constants of the differentiating and integrating circuits



To minimize pile-up effects, the time constants should be kept short so that the pulse returns to baseline as quickly as possible.

CR - RC Circuit

E_{in} = 5 V

CR's τ (μs)	RC's τ (μs)	E_{out} (V)	τs to pulse peak (μs)	τs to base (μs)
10	10	3.10	11.6	52.8
10	51	1.08	24	164
20	51	1.76	26	206
51	20	4.71	40	234
100	20	5.80	47	448

Pole Zero Cancellation

Pole: A point of infinite magnitude and 90-degree phase shift

Zero: A point of zero magnitude and unchanged phase

- **Pole-zero cancellation:** technique to improve ckt performance using poles/zeros.
- **Undershoot:** output falls below expected value before settling.
- Pole-zero cancellation overcomes undershoot by damping it using poles/zeros.

Condition: $R_{PZ}C_D = \tau_i$

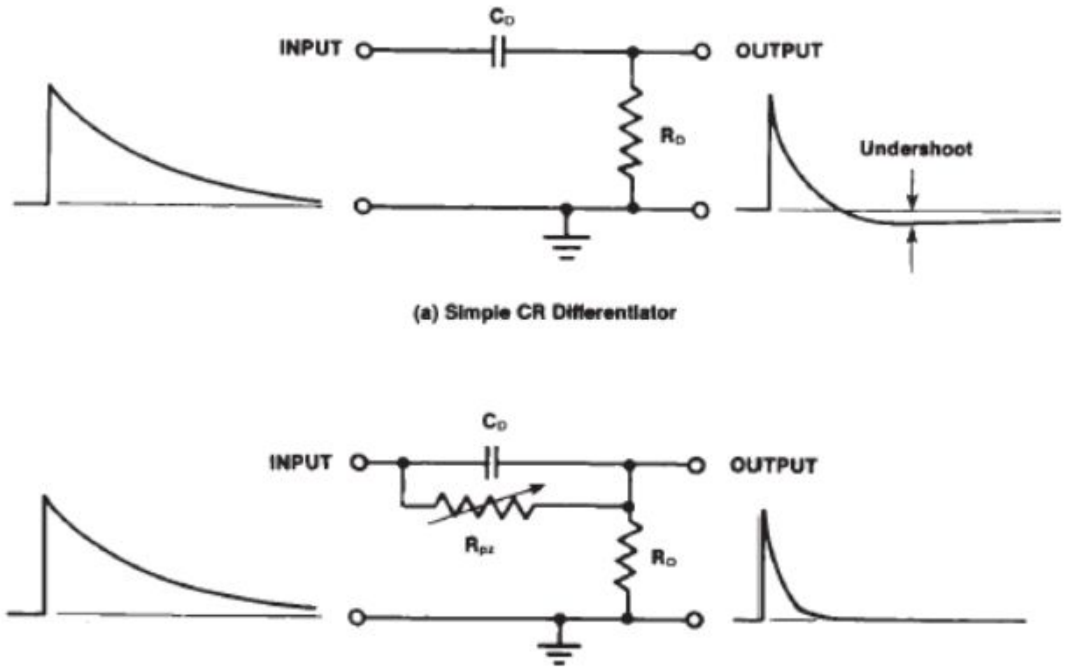
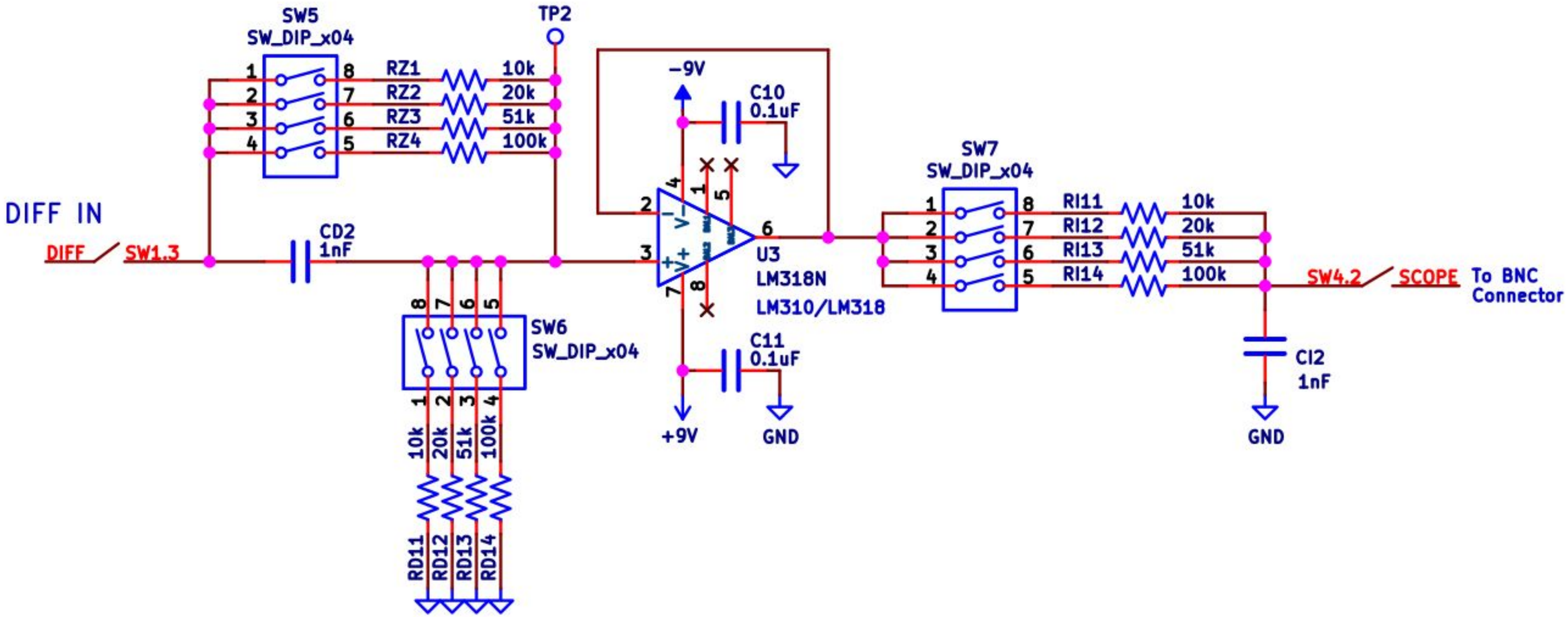


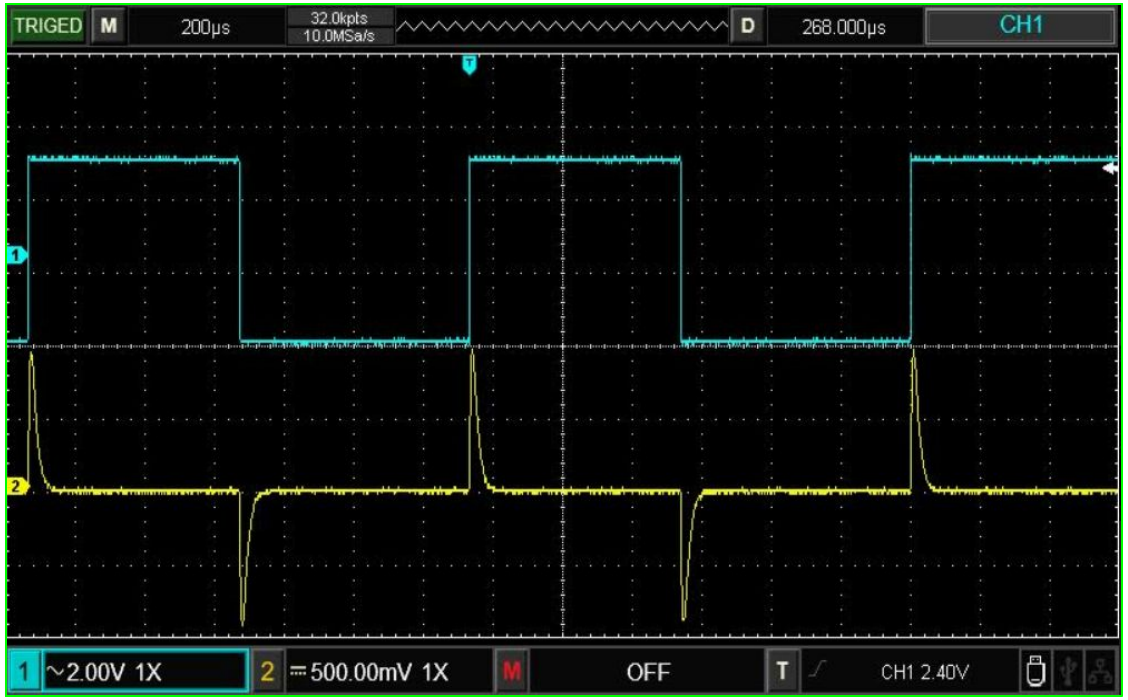
Fig: Pole-zero cancellation circuit

Pole Zero Cancellation



Pole Zero Cancellation

Before Pole Zero Cancellation

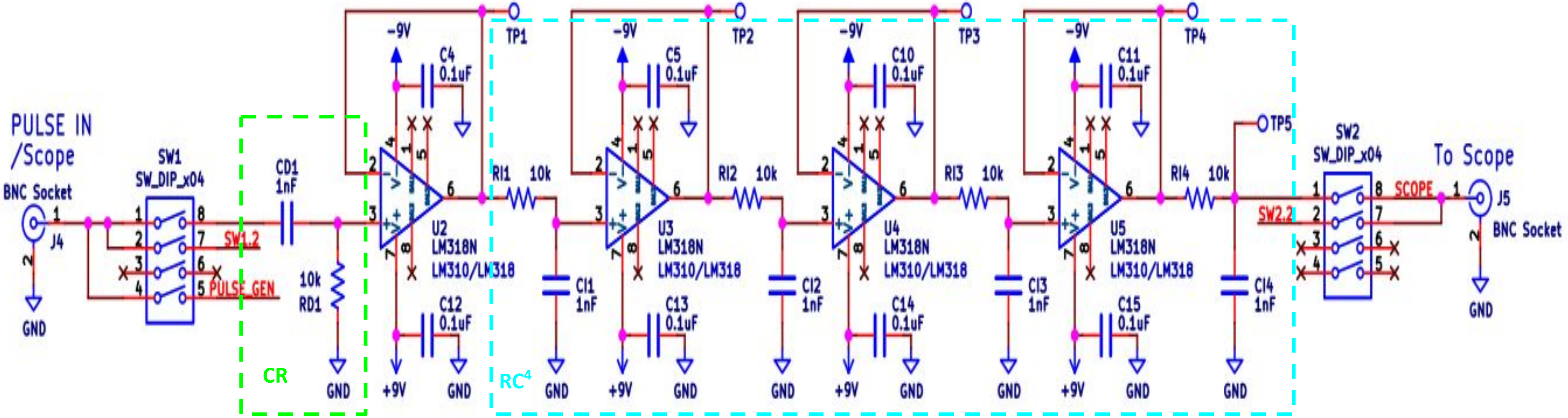


After Pole Zero Cancellation

Pole zero cancellation

CR’s Resistance, kΩ	Undershoot, Volts	Rz required, kΩ
10	0.44	10
20	0.60	20
51	0.68	51
100	0.72	100

Semi-Gaussian Shaper Circuit

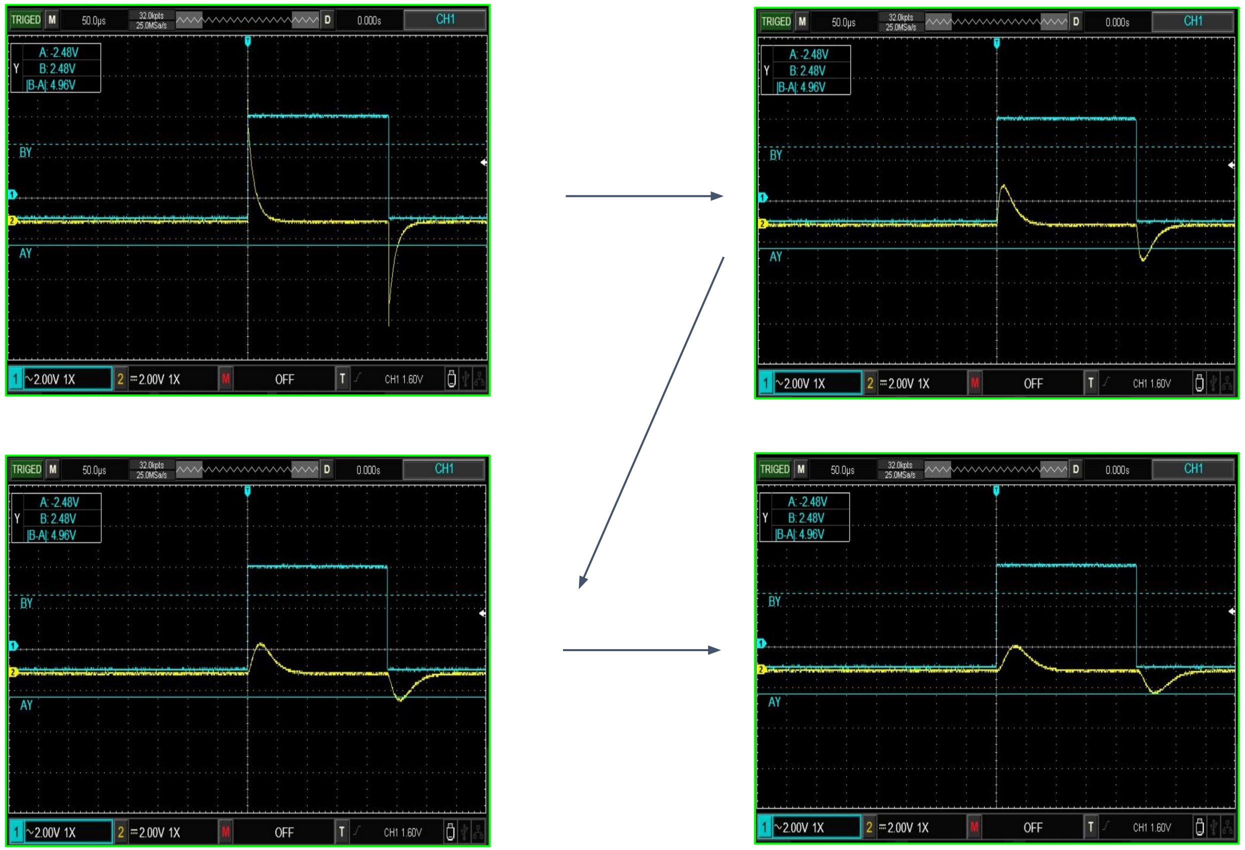


Semi-Gaussian Shaper Circuit

1. Designed to generate a response that has a shape similar to a semi-Gaussian pulse.

2. Implemented using a combination of CR and a series of RC stages

$$V_{out}(t) \propto \left(\frac{t}{\tau}\right)^n e^{-t/\tau}$$



Semi-Gaussian Shaper Circuit

Stage No.	Pulse Peak (V)	Left HWHM (μs)	Right HWHM (μs)
1	1.84	2.40	16.80
2	1.36	7.60	20.80
3	1.12	14.00	15.40
4	0.92	21.20	17.00

- Circuit with more stages will generate a response closer to a true Gaussian pulse

Summary and Conclusion

- We have discussed a few pulse shaping and filtering techniques
- They can be used to eliminate the unwanted components and improve the accuracy of the measurements.
- As technology continues to advance, it is likely that these techniques will become even more important and widely used in a range of applications.


Thank You for your kind attention
Questions/Comments ?

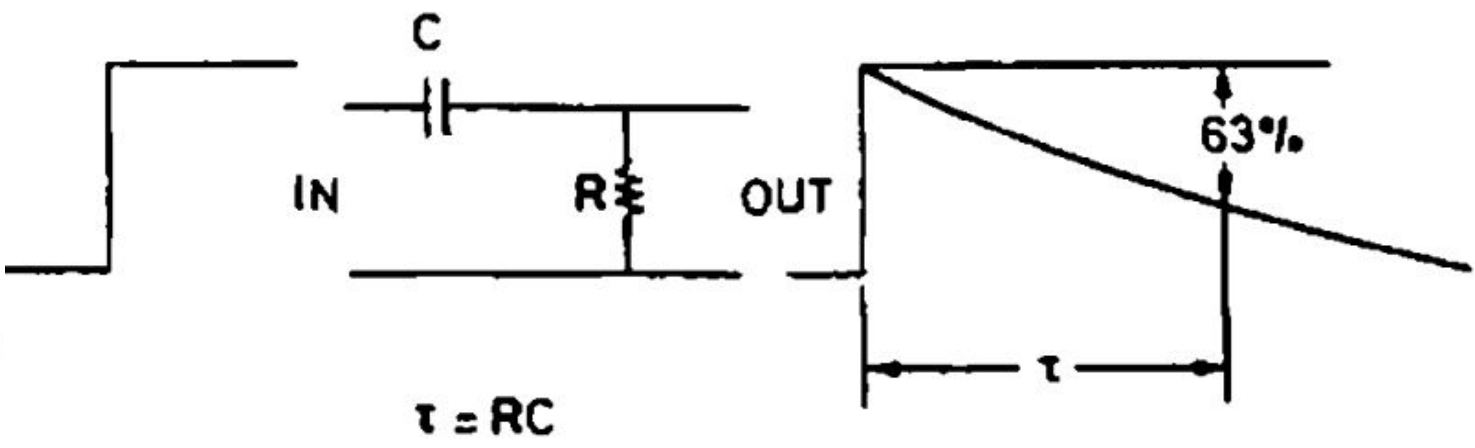
Back Up

High pass filter (CR circuit)

$$V_{in} = \frac{Q}{C} + V_{out} \; .$$

Differentiating both sides

$$\frac{dV_{in}}{dt} = \frac{1}{C}\,\frac{dQ}{dt} + \frac{dV_{out}}{dt} \, .$$



The term dQ/dt is just the current, i, so that

$$\frac{dQ}{dt} = i = \frac{V_{out}}{R} \, .$$

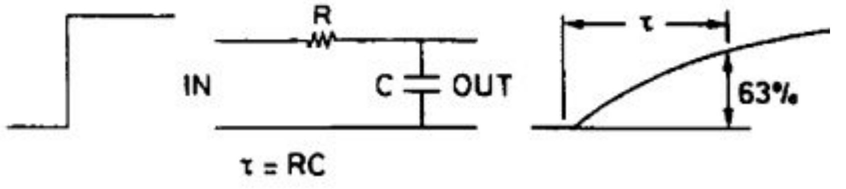
Equation (14.8) then becomes

$$\frac{dV_{in}}{dt} = \frac{1}{RC} V_{out} + \frac{dV_{out}}{dt} \, .$$

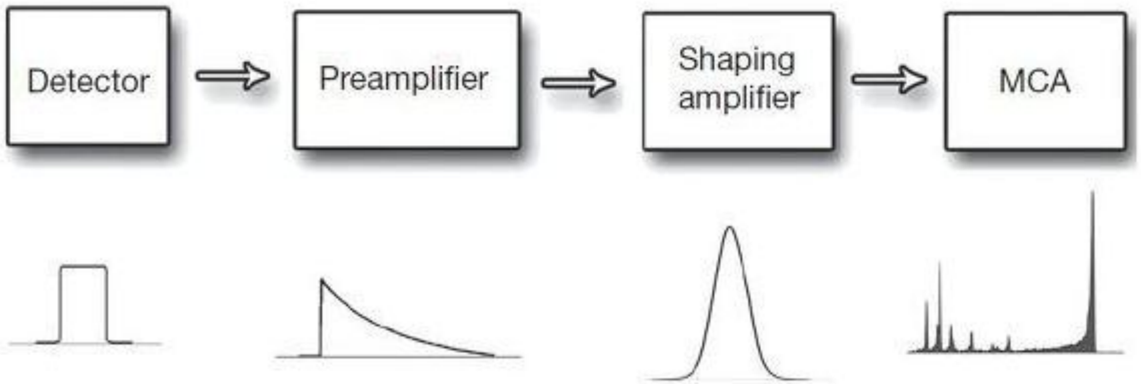
If RC is small such that the last term is negligible, then

$$\frac{dV_{in}}{dt} \simeq \frac{1}{\tau} V_{out} \, ,$$

Low pass filter (RC circuit)



CR's τ, μs	RC's τ, μs	E_{out}(V)	τs to pulse peak (μs)	τs to base (μs)
10	10	3.10	11.6	52.8
10	20	2.1		
10	51	1.08	24	164
10	100	0.64		
20	10	4.24		
20	20	3.04		
20	51	1.76	26	206
20	100	1.08		
51	10	5.88		
51	20	4.71	40	234
51	51	3.08		
51	100	2.12		
100	10	6.88		
100	20	5.80	47	448
100	51	4.2		
100	100	3.00		



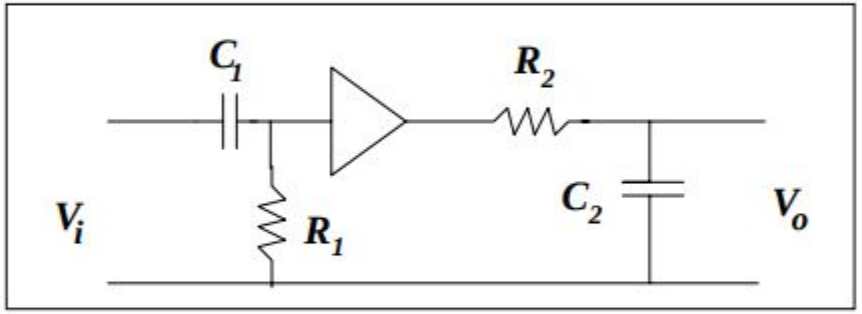


Figure 2.9 A CR-RC shaping network.

The response of this CR-RC network to a step voltage of amplitude V_i is

$$V_0 = \frac{V_i \tau_1}{\tau_1 - \tau_2}(e^{-t/\tau_1} - e^{-t/\tau_2})$$