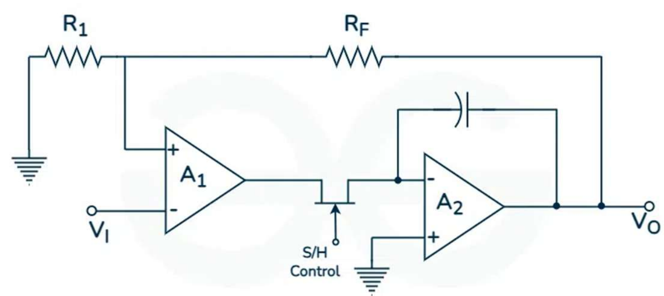
UNIT – III
SIGNAL CONDITIONING CIRCUITS

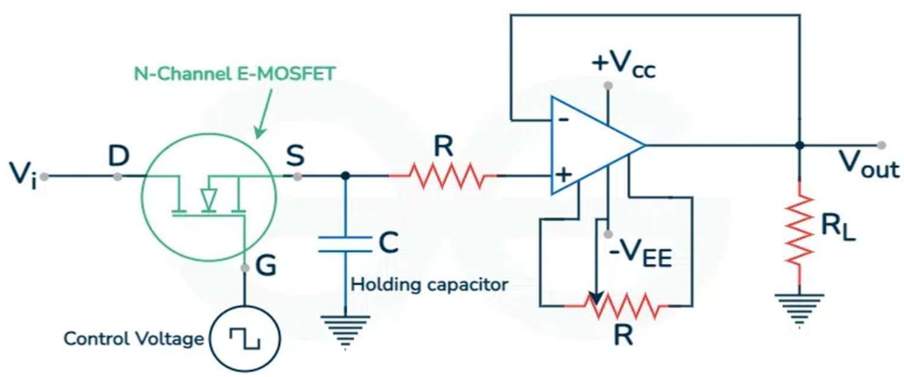
Sample and Hold System:

A Sample and Hold circuit are used to capture (sample) an input voltage and hold it for a specific time. The sampling time is when the circuit takes the input sample, and the holding time is when it keeps the sampled value. The circuit works using a capacitor, which charges to the input voltage, and a switch that opens to hold the voltage steady.



Working of Sample and Hold Circuit

A Sample and Hold circuit uses an N-channel E-MOSFET as a switch, a capacitor to store and hold charge, and a high-performance operational amplifier. When a positive voltage is applied to the MOSFET's gate, it turns ON, allowing the input voltage to charge the capacitor. When the MOSFET turns OFF (at zero voltage), the capacitor stops charging. The operational amplifier provides high impedance, preventing the capacitor from discharging, so it holds the voltage for a specific time (holding time). The time during which the circuit samples the input voltage is called the sampling time.
The processed voltage by amplifier during the holding period. Hence, holding period holds significance for OP-AMPs.



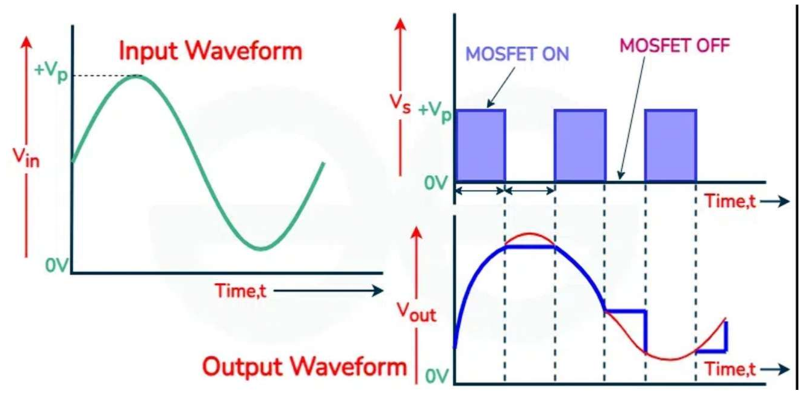
Input and Output Waveforms

The waveforms in the diagram show how the Sample and Hold circuit works. When the switch (MOSFET) is ON (open), the output voltage follows the input voltage, and the capacitor charges to match it. When the switch is OFF (closed), the output voltage stays constant at the last sampled value, held by the capacitor.

The operational amplifier (OP-AMP) ensures the held voltage remains stable during the OFF duration. In short:

ON (Open): Output voltage = Input voltage (sampling).

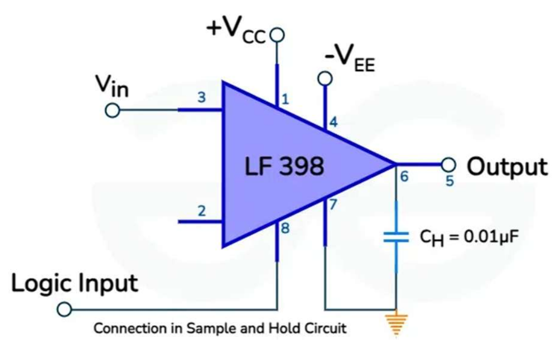
OFF (Closed): Output voltage = Held voltage (constant value from the capacitor).



Connection in Sample and Hold Circuit

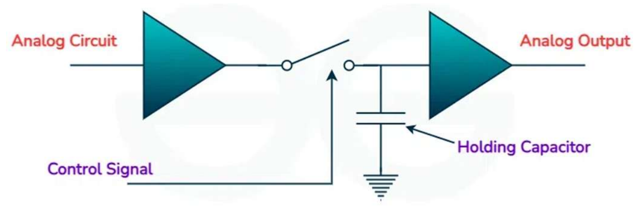
To sample the input signal, the switch connects the capacitor to the output of a buffer amplifier. The connection tells about the control voltage and input voltage and how both of them applied on the OP-AMPs. In this circuit the capacitor is made up of Polyethylene and Teflon. In above diagram, the frequency of analog input signal and control signal is noted and it is very important to balance the power of this circuit to note the frequency.

The control voltage's frequency should be higher than input voltage's frequency that's why the simple signal can be sampled two times in a whole cycle. During the sample phase, the input signal is connected to the capacitor through a switch. The capacitor charges or discharges to the input signal voltage. And in the hold phase, the switch is opened, disconnecting the input signal from the capacitor.



Functional Diagram

A sample-and-hold (S/H) circuit captures the value of an input signal at specific moments and holds that value steady at its output for a period, even if the input changes. It's commonly used in analog-to digital conversion to take snapshots of a signal at regular intervals, ensuring stable output for processing



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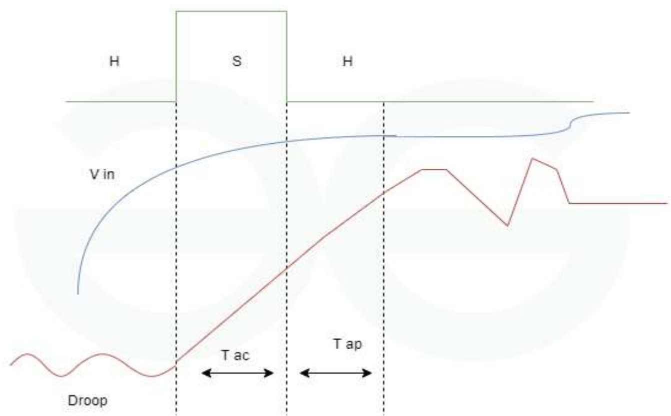
Types of Sample and Hold Circuit

There are many types of S and H circuit:

- Switched Capacitor Sample and Hold Circuit
- Track and Hold (T&H) Circuit
- Holding Amplifier Sample and Hold Circuit
- MOSFET Switch Sample and Hold Circuit
- Voltage-Controlled Sample and Hold Circuit
- Pulse Sample and Hold Circuit

Performance Parameters of Sample and Hold Circuit

- Aperture Time (TAP)
- Acquisition Time (TAC)
- Voltage Droop
- Hold Mode Settling



Performance Parameters

Applications of Sample and Hold Circuit

- The main application of sample and hold circuit is in simple to advance or analog to digital converters (ADCs) and it is used to catch and keep the simple incoming pr input voltage until it is change into advance value.
- These circuits are often used in communication programs or applications and in processing of signs to remake the simple or analog signals from the different samples.

Advantages of Sample and Hold Circuit

- It increases the stability of signals by sampling and holding the signals and also prevents from any changes at this time.
- It also helps in conversion of simple signals into advance signals by the use of this circuit in analog to digital converters (ADCs).
- It also used in changing the circuits to remove unwanted or undesirable things that may be occur during changing process. It also reduces the noise in simple signals.

Disadvantages of Sample and Hold Circuit

- Due to limited, exact or specific period of time interval the chances of errors are increases during processing of signals.
- The application with very heavy physical size and intricacy or complexity is also bad and disadvantage for this circuit.

Active filters:
An electric filter is often a frequency selective circuit that passes a specified band of Frequencies and blocks or alternates signal and frequencies outside this band. Filters may be Classified as

1. Analog or digital.
2. Active or passive
3. Audio (AF) or Radio Frequency (RF)

Analog or digital filters:
Analog filters are designed to process analog signals, while digital filters process analog signals using digital technique.
Active or Passive:
Depending on the type of elements used in their construction, filter may be classified as passive or Active elements used in passive filters are Resistors, capacitors, inductors. Elements used in active filters are transistor, or op-amp.

Active filters are more economical than passive filter. This is because of the variety of cheaper
Op-amps and the absence of inductors.
The most commonly used filters are these:

1. Low pass Filters
2. High pass Filters
3. Band pass filters
4. Band –reject filters

FILTERS:

Filters are electronic circuits that allow certain frequency components and / or reject some other. You might have come across filters in network theory tutorial. They are passive and are the electric circuits or networks that consist of passive elements like resistor, capacitor, and (or) an inductor.

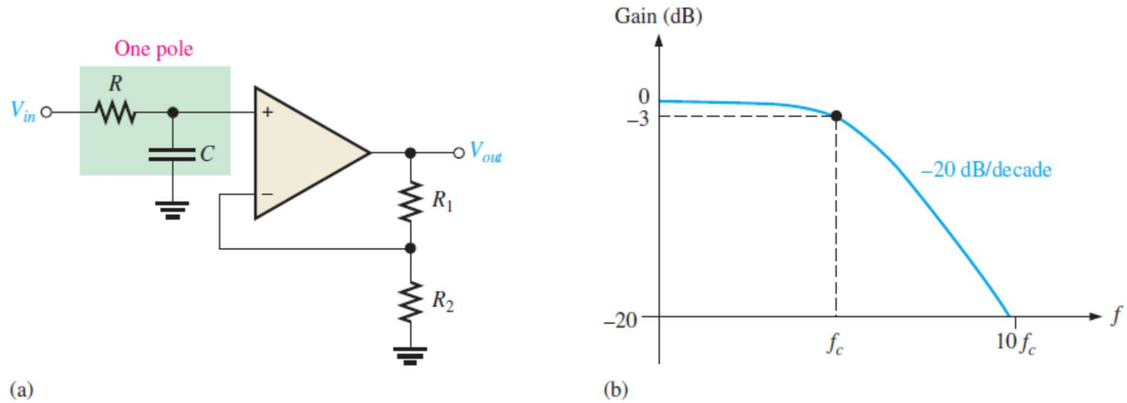
Types of Active Filters

Active filters are the electronic circuits, which consist of active element like op-amp(s) along with passive elements like resistor(s) and capacitor(s).

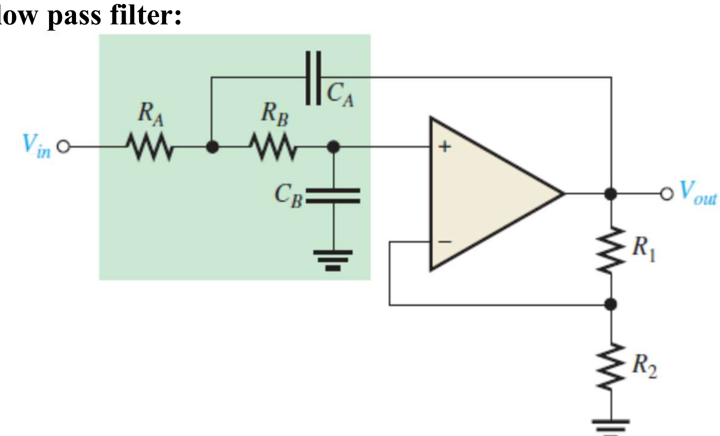
Active filters are mainly classified into the following **four types** based on the band of frequencies that they are allowing and / or rejecting −

- Active Low Pass Filter
- Active High Pass Filter
- Active Band Pass Filter
- Active Band Stop Filter/Band Reject Ratio

Active low pass filters
First Order low pass filter:
Figure (a) shows an active filter with a single low-pass RC frequency-selective circuit that Provides a roll-off of -20 dB/decade above the critical frequency, as indicated by the response Curve in Figure (b). The critical frequency of the single-pole filter is fc = 1/(2πRC).



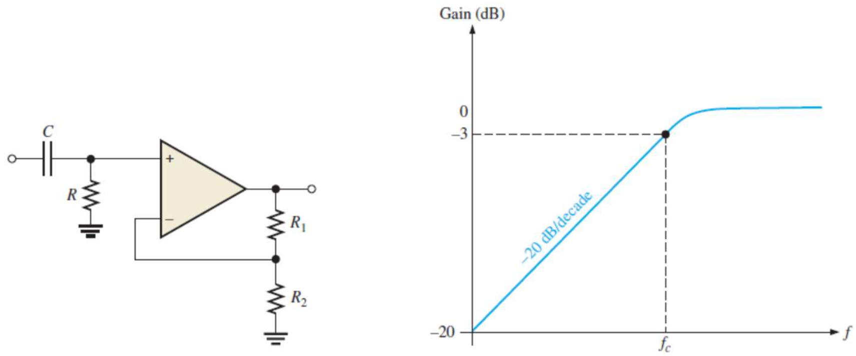
Second Order low pass filter:



The Sallen-Key is one of the most common configurations for a second-order (two-pole) filter. It is also known as a VCVS (voltage-controlled voltage source) filter. A low-pass version of the Sallen-Key filter is shown in Figure. Notice that there are two low pass RC circuits that provide a roll-off of -40 dB/decade above the critical frequency (assuming a Butterworth characteristic). One RC circuit consists of R_A and C_A, and the second circuit consists of R_B and C_B. A unique feature of the Sallen-Key low-pass filter is the capacitor C_A that provides feedback for shaping the response near the edge of the pass band. The critical frequency for the Sallen-Key filter is

$$fc \frac{1}{\sqrt{2\pi R_A R_B C_A C_B}}$$

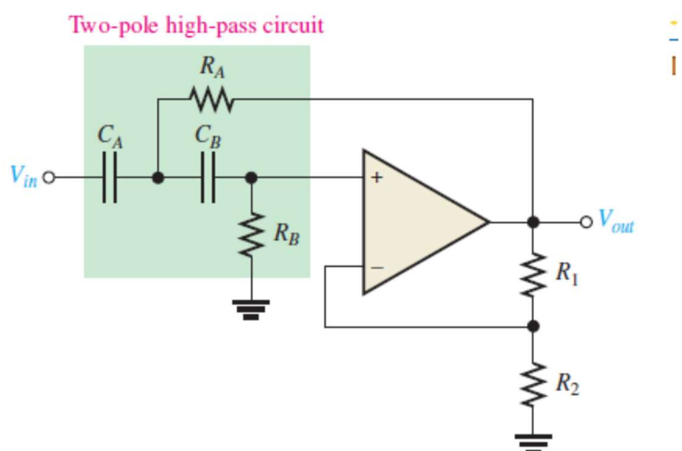
Active High pass filters
First order High pass filter



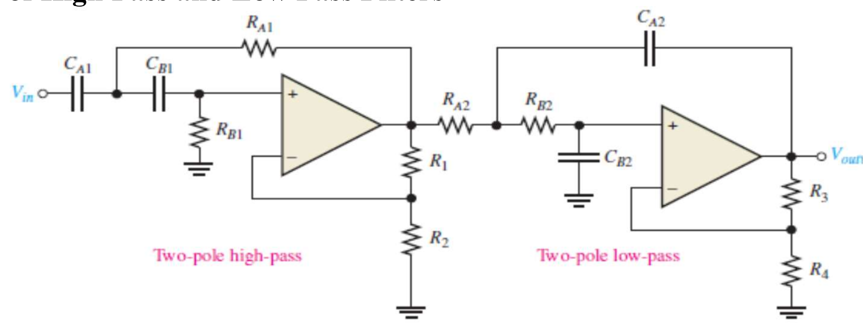
(a) (b)

A high-pass active filter with a -20 dB/decade roll-off is shown in Figure (a). Notice that the input circuit is a single high-pass *RC* circuit. The negative feedback circuit is the same as for the low-pass filters previously discussed. The high-pass response curve is shown in Figure (b).

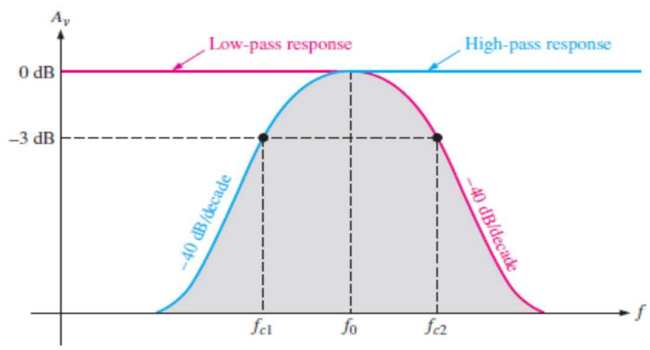
Second order High pass filter
A high-pass Sallen-Key configuration is shown in Figure. The components R_A, C_A, R_B, and C_B form the two-pole frequency-selective circuit. Notice that the positions of the resistors and capacitors in the frequency-selective circuit are opposite to those in the low-pass configuration. As with the other filters, the response characteristic can be optimized by proper selection of the feedback resistors, R_1 and R_2.



Active Band pass filter
Cascading of High Pass and Low Pass Filters



(a)



(b)

One way to implement a band-pass filter is a cascaded arrangement of a high-pass filter and a low-pass filter, as shown in Figure (a), as long as the critical frequencies are sufficiently separated. Each of the filters shown is a Sallen-Key Butterworth configuration so that the roll-off rates are -40 dB/decade, indicated in the composite response curve of Figure (b).The critical frequency of each filter is chosen so that the response curves overlap sufficiently, as indicated. The critical frequency of the high-pass filter must be sufficiently lower than that of the low-pass stage. This filter is generally limited to wide bandwidth applications. The lower frequency *fc*1 of the passband is the critical frequency of the high-pass filter. The upper frequency *fc*2 is the critical frequency of the low-pass filter. Ideally, as discussed earlier, the center frequency *f*0 of the passband is the geometric mean of *fc*1 and *fc*2.

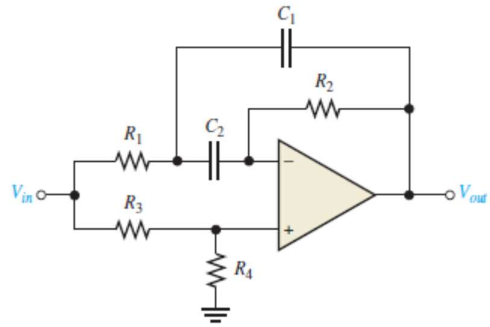
$$fc1 = \frac{1}{\sqrt{2\pi R_A R_B C_A C_B}}$$

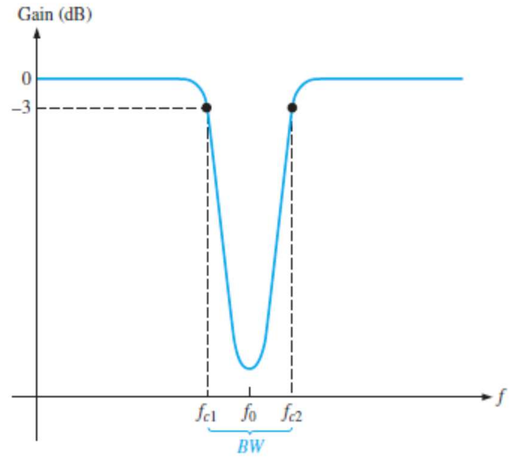
$$fc2 = \frac{1}{\sqrt{2\pi R_A R_B C_A C_B}}$$

$$f_0 = \sqrt{fc1fc2}$$

Band Reject Filter
Multiple Feedback Band Reject Filter

Another category of active filter is the **band-stop filter**, shown in Figure also known as *notch, Band Stop Filter*, or *band-elimination* filter. You can think of the operation as opposite to that of the band pass filter because frequencies within a certain bandwidth are rejected, and frequencies outside the bandwidth are passed. A general response curve for a band- stop filter is shown in Figure3.10. Notice that the bandwidth is the band of frequencies between the 3 dB points, just as in the case of the band-pass filter response.





All-pass filters

An all-pass filter is a filter that has a magnitude response of unity, but which provides a phase shift. You can use all-pass filters to tailor group delay responses in your signal-processing chain. You may find that you will need to cascade your filter with an all-pass filter to meet the group delay specification. A first-order all-pass circuit is shown in Figure (a). Note that this all-pass provides a DC gain of −1. If you want, you can cascade an inverting op-amp stage with the all-pass to take care of this phase inversion.