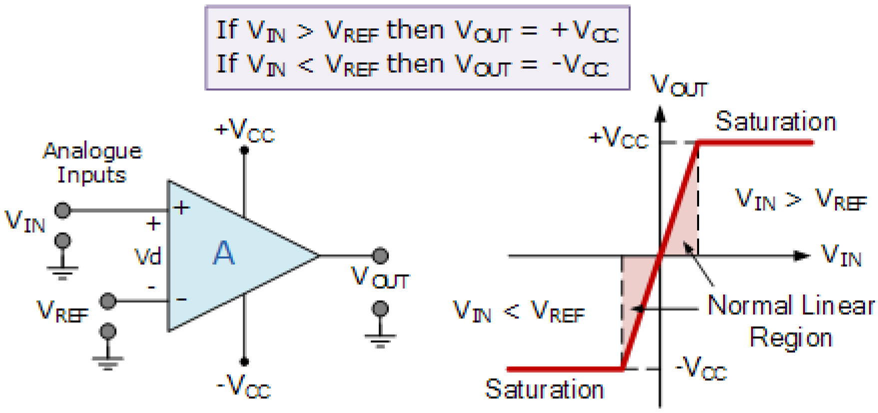
Nonlinear Circuit Applications

Comparator

Op-amp Comparator Circuit:



Operation:

With reference to the op-amp comparator circuit above, lets first assume that V_{IN} is less than the DC voltage level at V_{REF}, ($V_{IN} < V_{REF}$). As the non-inverting (positive) input of the comparator is less than the inverting (negative) input, the output will be LOW and at the negative supply voltage, -Vcc resulting in a negative saturation of the output.

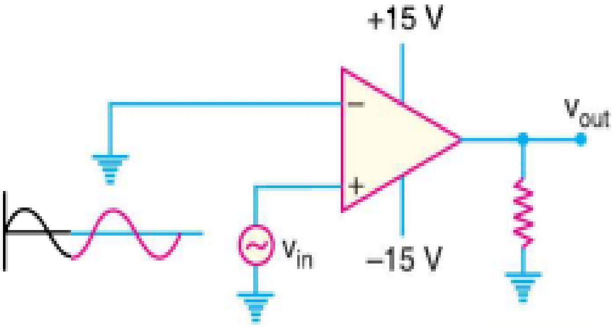
If we now increase the input voltage, V_{IN} so that its value is greater than the reference voltage V_{REF} on the inverting input, the output voltage rapidly switches HIGH towards the positive supply voltage, +Vcc resulting in a positive saturation of the output. If we reduce again the input voltage V_{IN}, so that it is slightly less than the reference voltage, the op-amp's output switches back to its negative saturation voltage acting as a threshold detector.

Then we can see that the op-amp voltage comparator is a device whose output is dependent on the value of the input voltage, V_{IN} with respect to some DC voltage level as the output is HIGH when the voltage on the non-inverting input is greater than the voltage on the inverting input, and LOW when the non-inverting input is less than the inverting input voltage. This condition is true regardless of whether the input signal is connected to the inverting or the non-inverting input of the comparator.

We can also see that the value of the output voltage is completely dependent on the op-amps power supply voltage. In theory due to the op-amps high open-loop gain the magnitude of its output voltage could be infinite in both directions, ($\pm\infty$). However practically, and for obvious reasons it is limited by the op-amps supply rails giving V_{OUT} = +Vcc or V_{OUT} = -Vcc.

Mathematical Problem (Comparator):

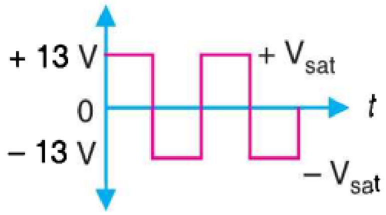
Draw the output waveform for the input in the comparator circuit in the following figure.



Solution:

Apply

$\pm V_{sat} = \pm V_{supply} \pm 2$



Precision Rectifier

Why we need Precision Rectifier:

A rectifier is a circuit that converts alternating current (AC) to Direct current (DC). An alternating current always changes its direction over time, but the direct current flows continuously in one direction. In a typical rectifier circuit, we use diodes to rectify AC to DC. But this rectification method can only be used if the input voltage to the circuit is greater than the forward voltage of the diode which is typically 0.7V. We previously explained diode-based half-wave rectifier and full-wave rectifier circuit.

To overcome this issue, the **Precision Rectifier Circuit** was introduced. The precision rectifier is another rectifier that converts AC to DC, but in a precision rectifier we use an op-amp to compensate for the voltage drop across the diode, that is why we are not losing the 0.6V or 0.7V voltage drop across the diode, also the circuit can be constructed to have some gain at the output of the amplifier as well.

Circuit and Operation:

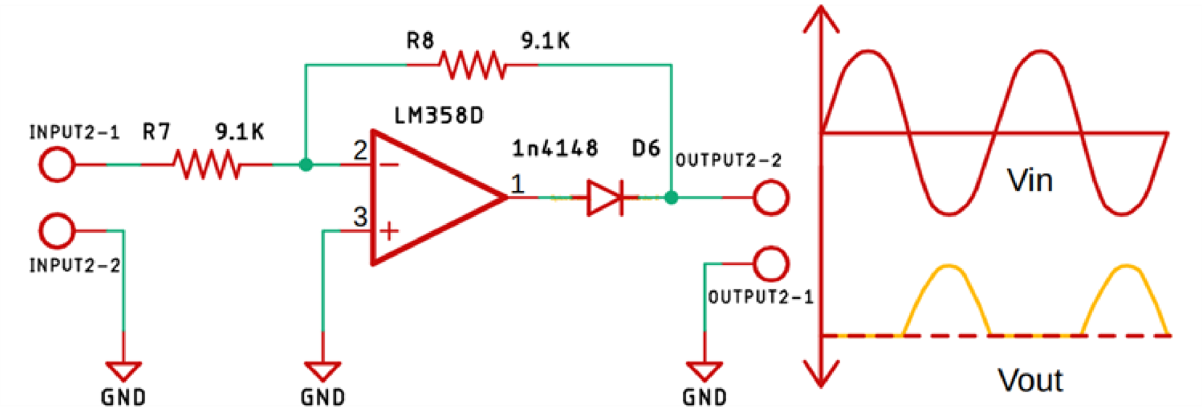


Fig. 1

The above circuit in Fig. 1 shows a basic, **half-wave precision rectifier circuit** with an LM358 Op-Amp and a 1n4148 diode. The above circuit also shows you the input and output waveform of the precision rectifier circuit, which is exactly equal to the input. That's because we are taking the feedback from the output of the diode and the op-amp compensates for any voltage drop across the diode. So, the diode behaves like an ideal diode.

Now in the circuit in Fig. 2, you can clearly see what happens when a positive and a negative half cycle of the input signal is applied in the input terminal of the Op-Amp. The circuit also shows the transfer characteristics of the circuit.

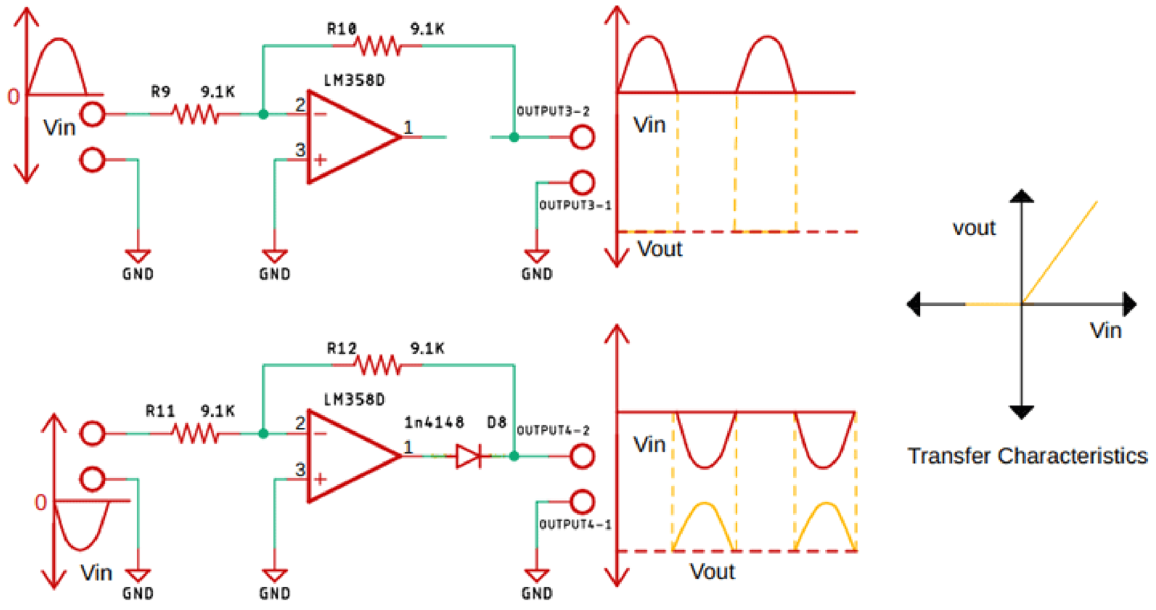
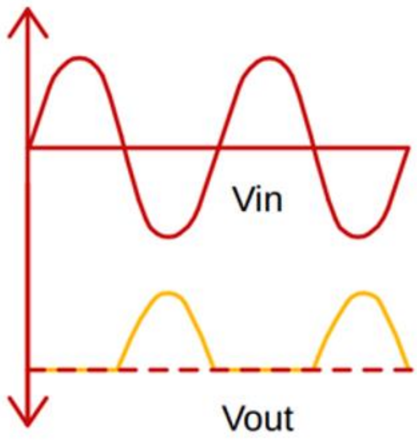


Fig. 2

Mathematical Problem (Precision Rectifier):

A sinusoidal wave with peak amplitude ±10 Volt is given as input to an inverting half-wave precision rectifier. Draw its output wave and determine its average output voltage.

Solution:



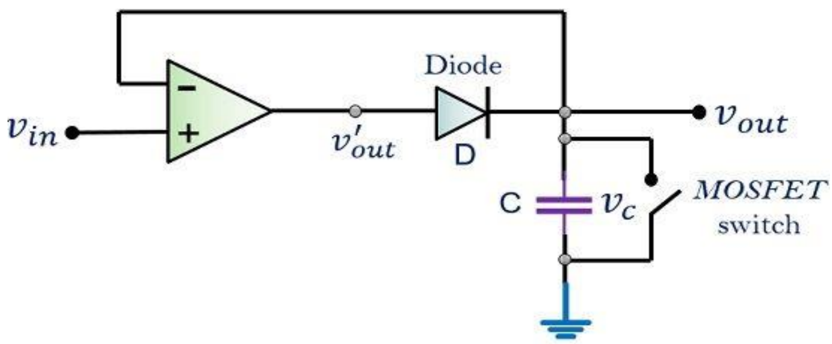
$V_{av} = V_m/\pi = 10/\pi = 3.18$ Volt

Peak Detector

Definition: Peak detector circuits are used to determine the peak (maximum) value of an input signal. It stores the peak value of input voltages for infinite time duration until it comes to reset condition. The peak detector circuit utilizes its property of following the highest value of an input signal and storing it. Rectifier circuits usually provide an output in proportion to the average value of the input. However, some application requires measurement of the peak value of the signal. Thus, peak detectors are used. Usually, the peak of non-sinusoidal waveforms is measured using a peak detector. As traditional ac voltmeter cannot measure the peak of such signals.

Circuit and Operation:

The figure below shows the circuit of a basic positive peak detector-



Peak detector circuit

It consists of a diode and capacitor along with an op-amp as shown above. The circuit does not require any complex component in order to determine the peak of the input waveform.

The working principle of the circuit is such that, the peak of the input waveform is followed and stored in terms of voltage in the capacitor.

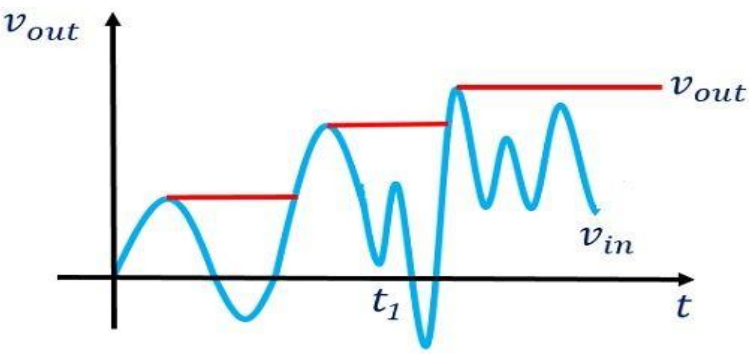
By the time on moving further, if the circuit detects a higher peak, the new peak value is stored in the capacitor until it is discharged.

The capacitor employed in the circuit is charged through the diode by the applied input signal. The small voltage drop across the diode is ignored and the capacitor is charged up to the highest peak of the applied input signal.

Let us consider initially the capacitor is charged to voltage $\mathbf{V_c}$. The diode employed in the circuit gets forward biased when the applied input voltage $\mathbf{V_{in}}$ exceeds the capacitor voltage $\mathbf{V_c}$. Thereby allowing the circuit to behave as a voltage follower**.** The output voltage follows the applied input voltage until $\mathbf{V_{in}}$ is more than $\mathbf{V_c}$**.**

As the input voltage V_{in} reduces below the value of capacitive voltage $\mathbf{V_c}$, it causes the diode to get reverse biased. In such condition, the capacitor retains the value until the input again exceeds the value stored in the capacitor.

The figure below shows the output voltage waveform for an applied input signal.



Output waveform for an applied input waveform

As we can see in the waveform shown above, at time t_1, the circuit misses the peak of the input signal as it is less than the previous peak of the input signal. Thereby allowing the capacitor to hold the value of the previously occurred peak.

As it is a positive peak detector, one can also construct a negative peak detector circuit, that will hold the lowest or most negative signal voltage. This is basically done by **reversing** the **polarities** of the diode in the circuit.