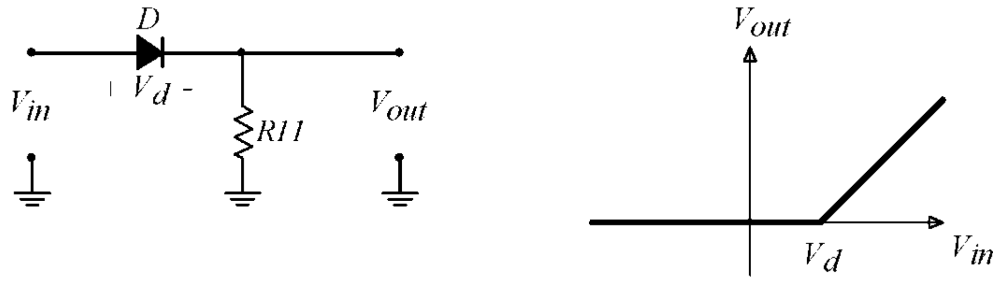
Lecture 11. MEASURING RECTIFIERS

1.1. Superdiode. Precision half - wave Rectifier

The diode rectifier circuit and its associated voltage transfer characteristic curve are shown on Figure 1(a) and (b).



(a) (b)

Figure 1. Diode rectifier circuit (a) and voltage transfer curve (b)

The offset voltage V_d is about 0.7 Volts and this offset value is unacceptable in many practical applications. The operational amplifier and the diode in the circuit of Figure 2 form an ideal diode, a superdiode, and thus they eliminate the offset voltage Vd from the voltage transfer curve forming an ideal half wave rectifier.

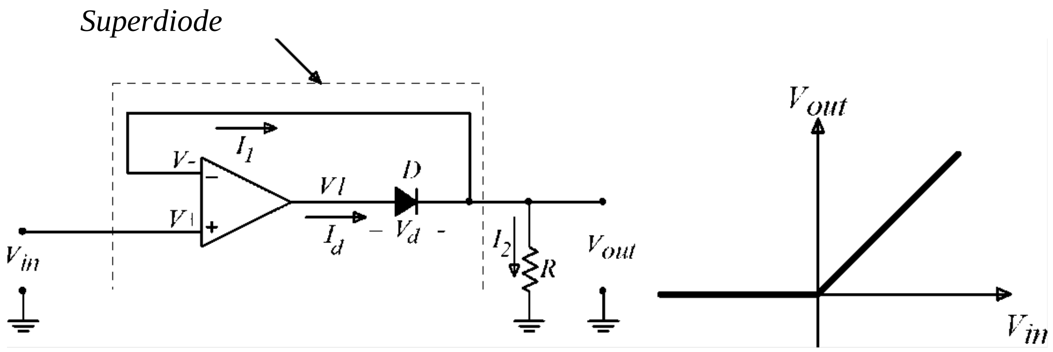


Figure 2. Precision half wave rectifier circuit and its voltage transfer curve.

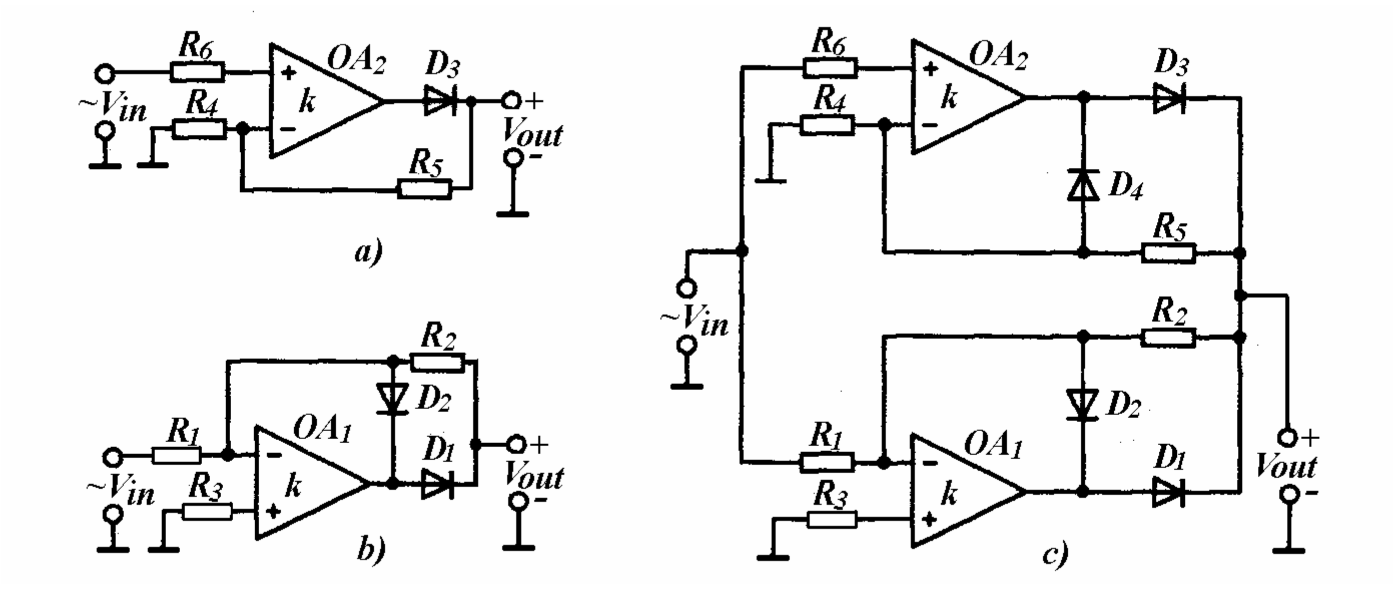
Let's analyze the circuit by considering the two cases of interest: $V_{in}>0$ and $V_{in}<0$.
For $V_{in}<0$ the current I_2 and I_d will be less than zero (point in a opposite direction to the one indicated). However, negative current can not go through the diode and thus the diode is reverse biased and the feedback loop is broken. Therefore the current I_2 is zero and so the output voltage is also zero, $V_{out}=0$. Since the feedback loop is open the voltage VI at the output of the op-amp will saturate at the negative supply voltage.

For $V_{in}>0$, $V_{out}=V_{in}$ and the current $I_2 = I_d$ and the diode is forward biased. The feedback loop is closed through the diode. Note that there is still a voltage drop V_d across the diode and so the op-amp output voltage V_{out} is adjusted so that $V_{out} = V_d + V_{in}$.

MEASURING RECTIFIERS (MR)

AVERAGE RESPONDING MEASURING RECTIFIERS

$$V_{OUT} = \frac{1}{T}\int_{0}^{T} \left|V_{IN}\right|.dt$$



Measuring rectifiers

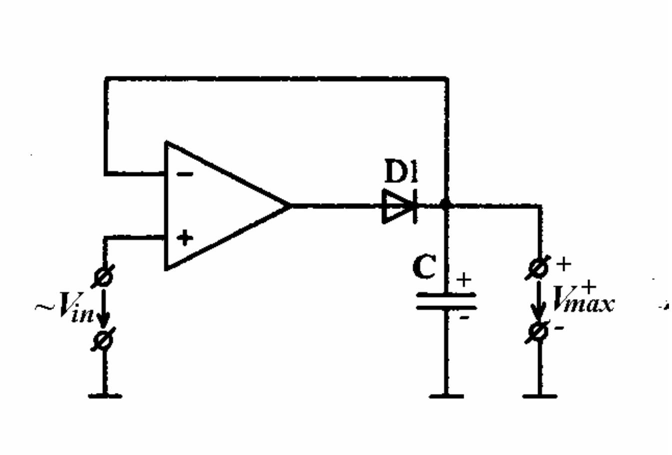
a) One wave noninverting configuration; b) One wave inverting configuration; c) Two wave rectifier

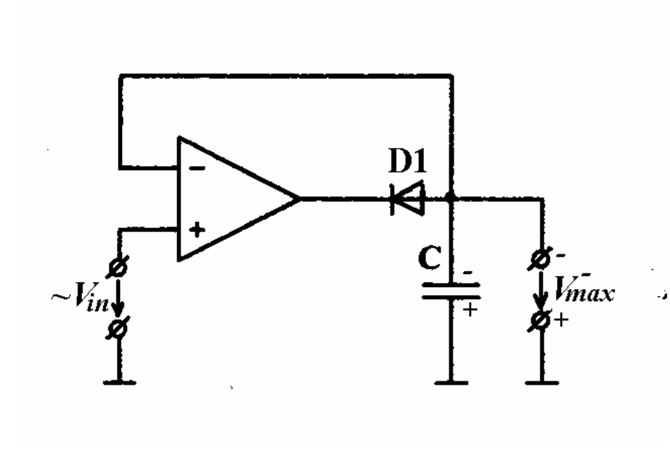
Gain &Errors: the same as for Amplifiers

For c) the both gains mast be equal:

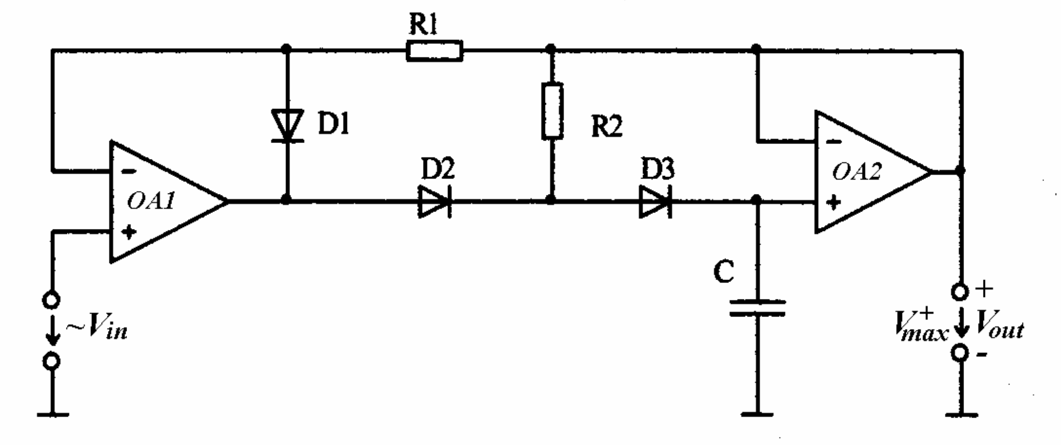
$$R_2 / R_1 = (1+ R_5 / R_4)$$

AMPLITUDE RESPONDING MEASURING RECTIFIERS

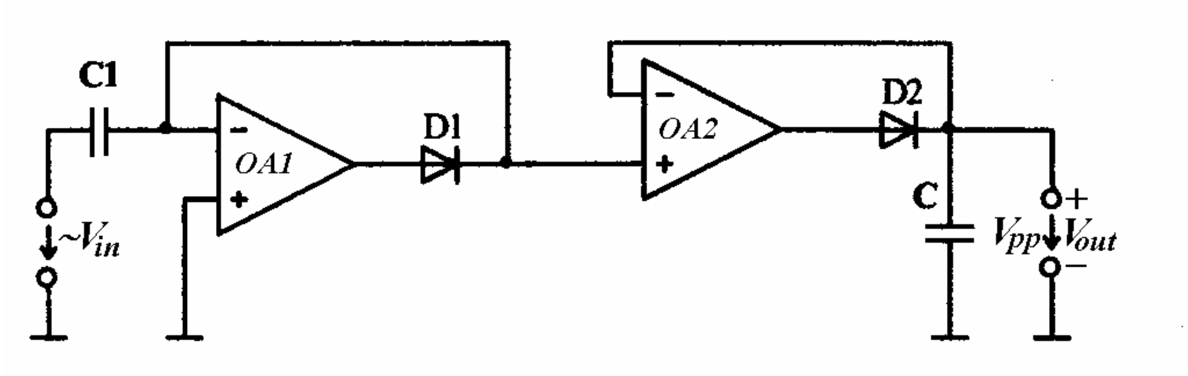




a) b)



c)



d)
Gain &Errors: the same as for Amplifiers

1.2. Practically circuit diagrams of Precision Rectifiers

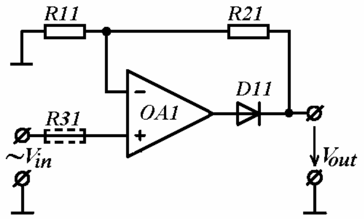
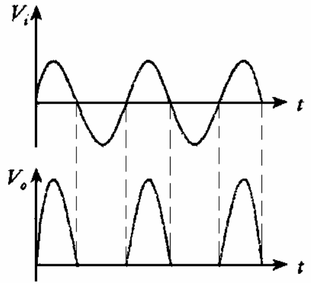
		$V_{OUT} = \begin{cases} V_{IN}\left(1+\frac{R_{21}}{R_{11}}\right), when V_{IN} > 0 \\ 0, when V_{IN} < 0 \end{cases}$

Figure 3. Precision half wave non-inverting rectifier circuit and its time-diagram and transfer function.

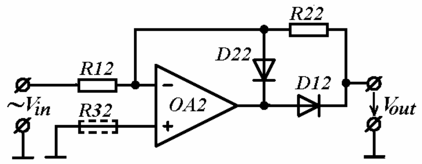
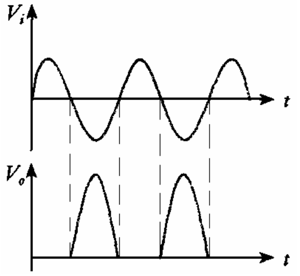
		$V_{OUT} = \begin{cases} -V_{IN}\frac{R_{22}}{R_{12}}, when V_{IN} < 0 \\ 0, when V_{IN} > 0 \end{cases}$

Figure 4. Precision half wave inverting rectifier circuit and its time-diagram and transfer function.

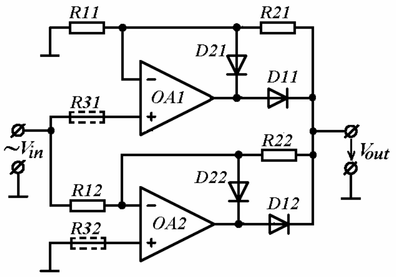
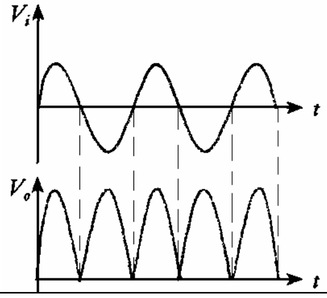
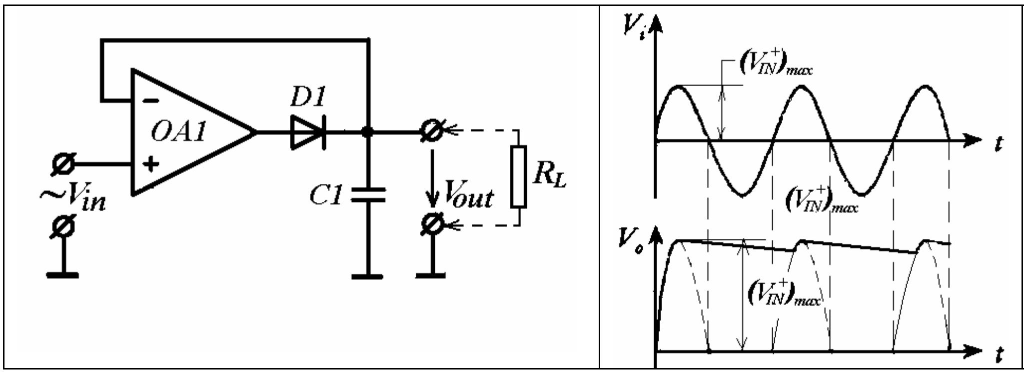
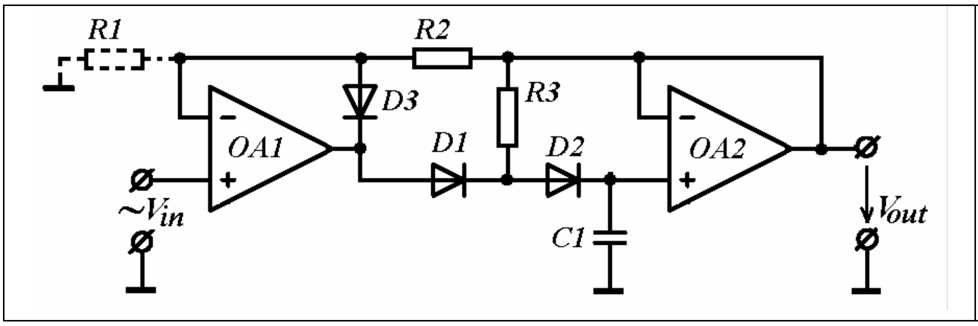
		$\frac{R_{22}}{R_{12}} = 1+\frac{R_{21}}{R_{11}}$ $V_{OUT} = \lvert V_{IN} \rvert \frac{R_{22}}{R_{12}}$

Figure 5. Precision full-wave inverting rectifier circuit and its time-diagram and transfer function.



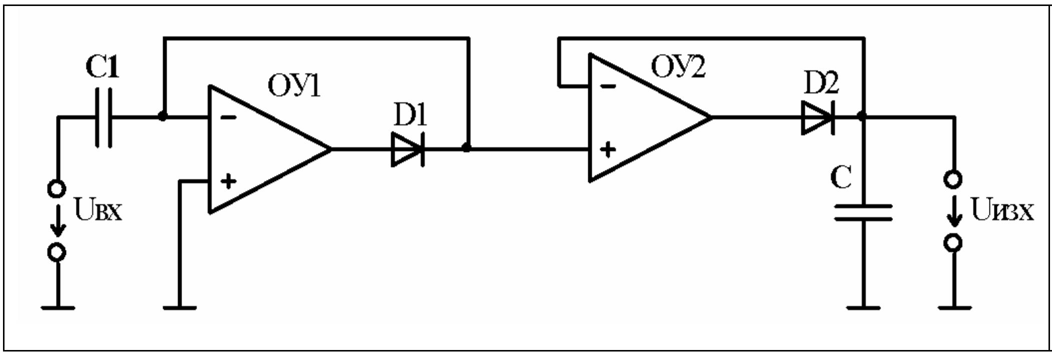
$$V_{OUT} = (V_{IN}^+)_{\max}$$

Figure 6. Precision non-inverting amplitude rectifier circuit and its time-diagram and transfer function.



$$V_{OUT} = (V_{IN}^+)_{\max}$$

Figure 7. Investigated precision non-inverting amplitude rectifier circuit and its transfer function.



$$V_{OUT} = (V_{IN})_{pp}$$

Figure 8. Precision pic-to-pic rectifier circuit and its transfer function.

1.3. Active Low Pass Filters

1.3.1. First - Order Active Low Pass Filter.

The Active Low Pass Filter using an electronic integrator is shown in Fig.9, where the input voltage is: $v_{in} = V_A \sin \omega t$ and the feedback impedance Z_F is:

$$Z_F = \frac{R_F}{1 + j\omega R_F C}\,.$$

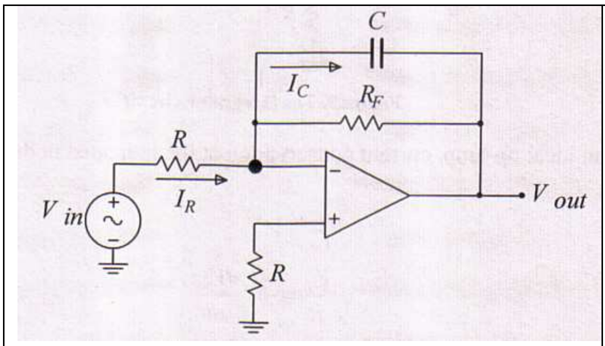


Fig.9 An Active Low-Pass Filter

$$v_{in} = V_{IN} \sin \omega t$$

Transfer function:

$$A^*(\omega) = \frac{V^*_{out}}{V^*_{in}} = -\frac{Z_F}{Z_R} = -\frac{R_F}{R}\frac{1}{1+j\omega R_F C}$$

and gain:

$$A(\omega) = \left|\frac{V^*_{out}}{V^*_{in}}\right| = -\frac{R_F}{R}\frac{1}{\sqrt{1+\left(\omega R_F C\right)^2}}$$

As you can see, the diagram in Fig.10 shows the logarithmic plot of gain *A(ω)* versus frequency.

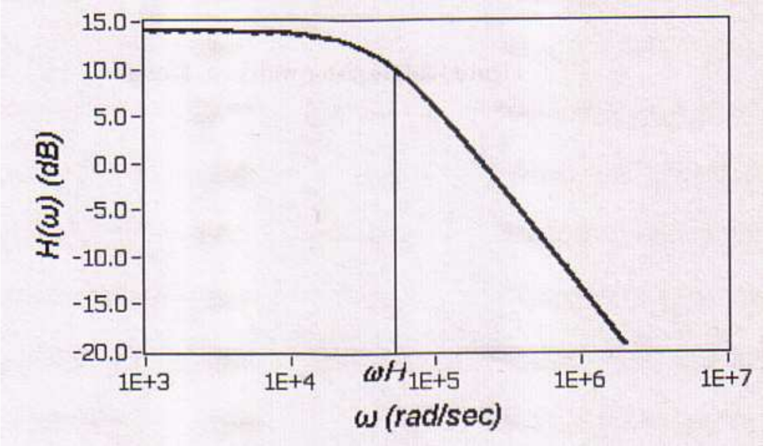


Fig.10. Bode plot of active low pass filter with gain of 5

were $\omega_H = \frac{1}{R_F C}$

is called

cut-off frequency

At frequencies much less than ω_H ($\omega << \omega_H$) the voltage gain becomes equal to R_F/R, while at frequencies higher than ω_H ($\omega >> \omega_H$) the voltage gain decreases at a rate of 20dB per decade.

1.3.2. Second - Order Active Low Pass Filter Circuits.

The Second Order Active Low Pass Filter using an electronic integrator is shown in Fig.11(a) and (b):

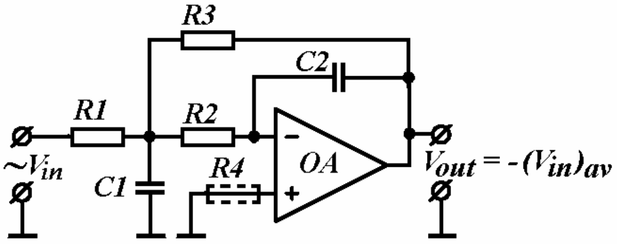


Figure 11-a. Rauch's Inverting Low-Pass Filter Structure.

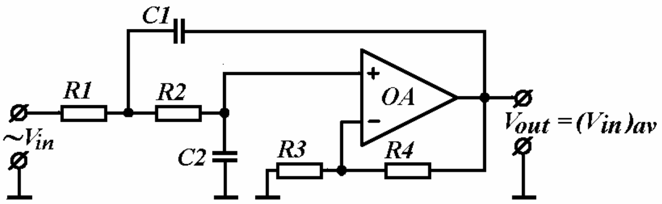
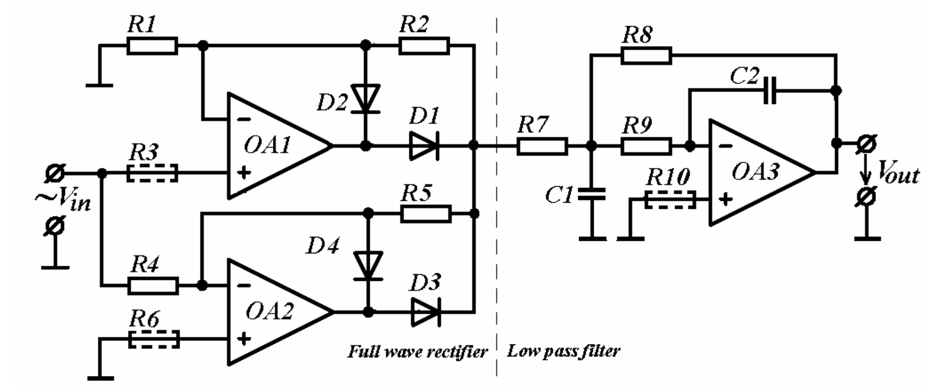


Figure 11-b. Sallen-Key's Non-inverting Low-Pass Filter Structure.

1.3.3. Average responding full wave rectifier.



$$1+\frac{R_2}{R_1}=\frac{R_5}{R_4}$$

$$V_{out}=-\frac{R_5}{R_4}\frac{R_8}{R_7}V_{inAV}$$

Figure 12. Average responding full wave rectifier

Varna, Autumn, 2009 Assoc. Prof. Dr Eng. Hristo Gigov