- **Instrumentation amplifiers** use a three op-amp configuration to obtain high input resistance and improved common mode rejection.

- **Isolation amplifiers** have no galvanic connection between input and output and have excellent common mode rejection.

- **Phase sensitive detectors** use the known frequency and phase to extract a signal from noise.

Signals are often buried in noise.

Obtain as clean a signal as possible.

Rectification does not separate signal from noise.

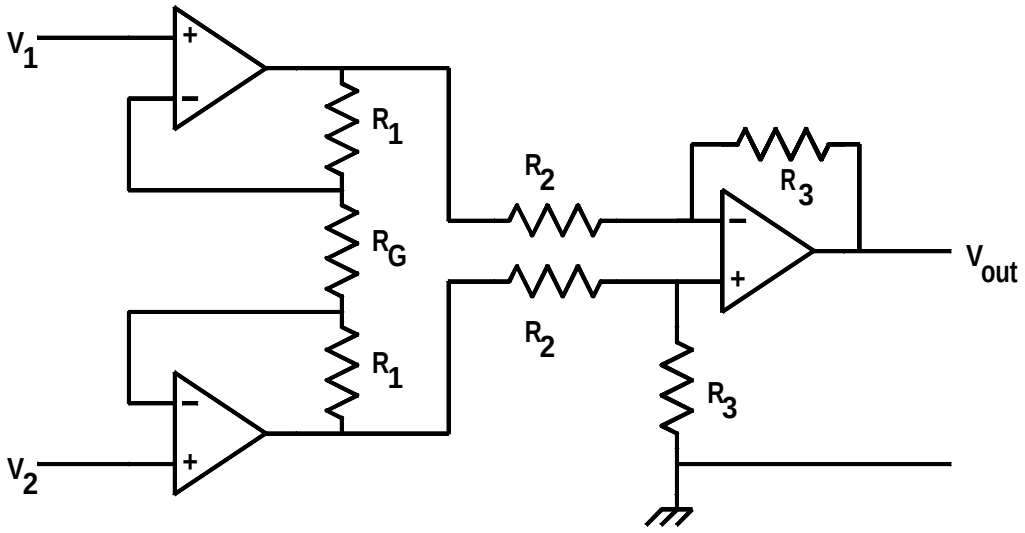
Signal to noise ratio disimproves on recitfication.

Instrumentation amplifier.

We require

- High input resistance
- Precise gain
- Perfect common mode rejection.

The traditional instrumentation amplifier uses three op-amps.



Consider the resistor chain R_1, R_G and R_1. Voltage across the gain setting resistor, R_G, is $V_1 - V_2$

$$I = \frac{V_1 - V_2}{R_G}$$

$$V_{diff} = \frac{V_1 - V_2}{R_G} \times (R_1 + R_G + R_1)$$

The differential amplifier has a gain of $\frac{R_3}{R_2}$

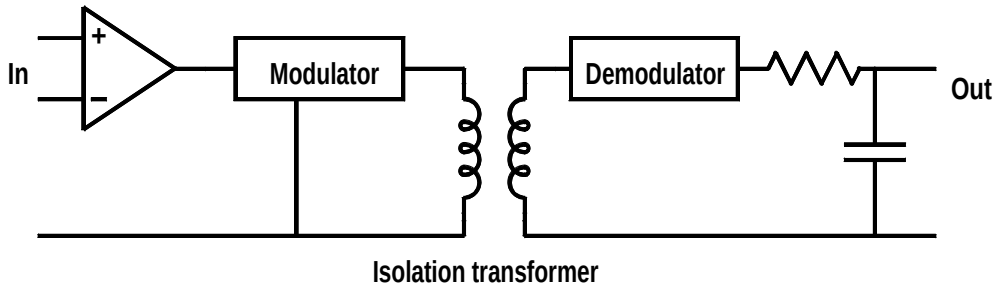
$$V_{out} = \frac{2R_1 + R_G}{R_G} \times \frac{R_3}{R_2} \times (V_1 - V_2)$$

Isolation amplifier.

Gives the ultimate in common mode rejection

No galvanic connection between the input and output.

Analog Devices or National Semiconductors.



Voltage to frequency converter

Frequency output is proportional to the input differential voltage.

Coupled through an isolating transformer

DC is blocked.

Applications:

Patient isolation

Electrodes connected for electrocardiography, ECG, (heart monitoring) and electroencephalography, EEG, (brain wave monitoring).

Isolation amplifier prevents the patient receiving a shock.

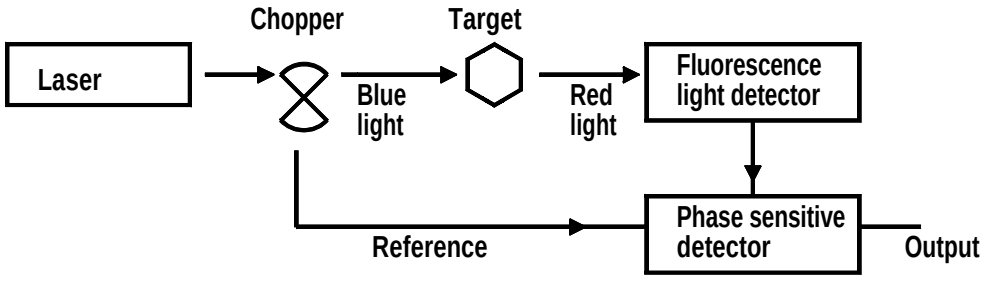
Possible to use heart resuscitation, electro shock equipment

Phase sensitive detection.

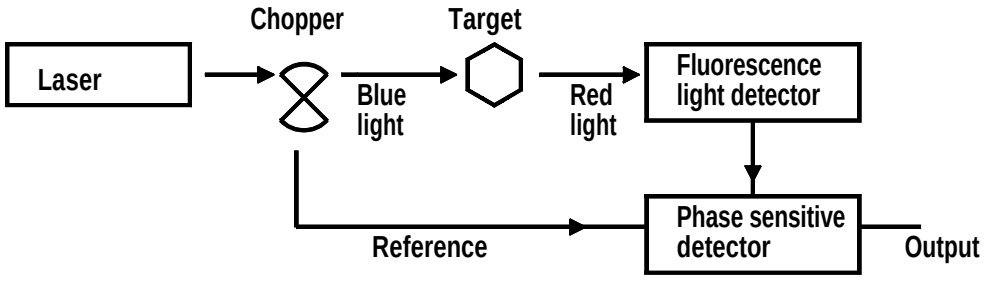
To measure amplitude of an AC waveform use a diode rectifier

However, if there is noise present as well as signal then the noise will also be rectified and contribute to the output.

A simple rectifier can not distinguish between signal and noise



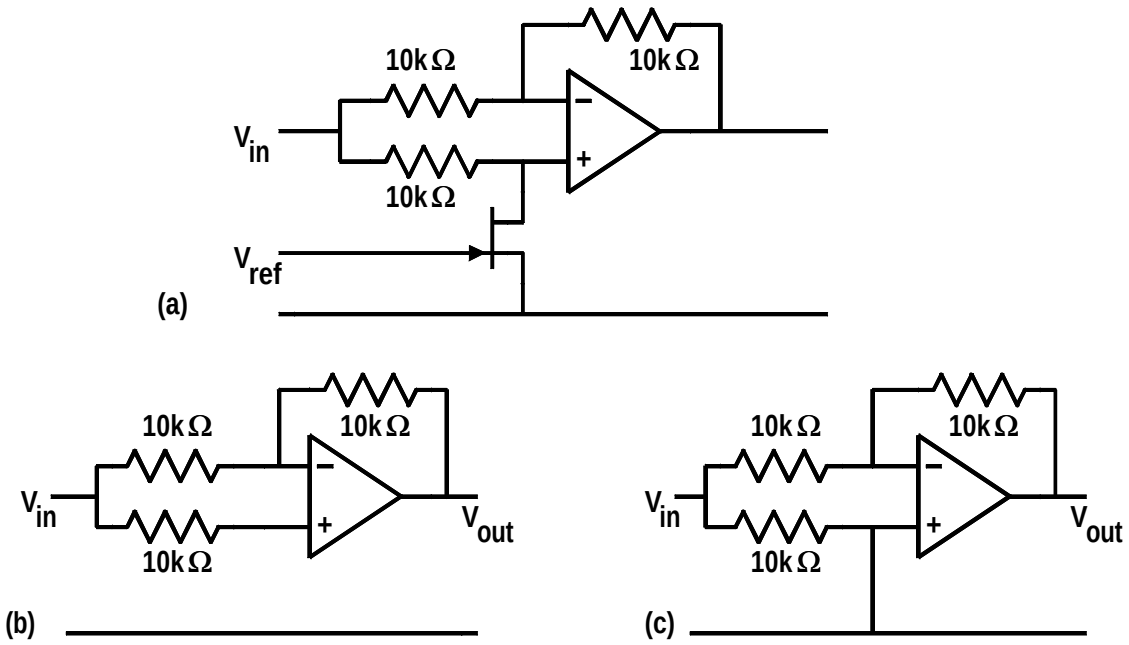
Chopper and phase sensitive detector configuration.



Laser beam is chopped at frequency F_R by a rotating chopper blade.

Weak fluorescence in a target material
Fluorescence light detected by a photodetector.

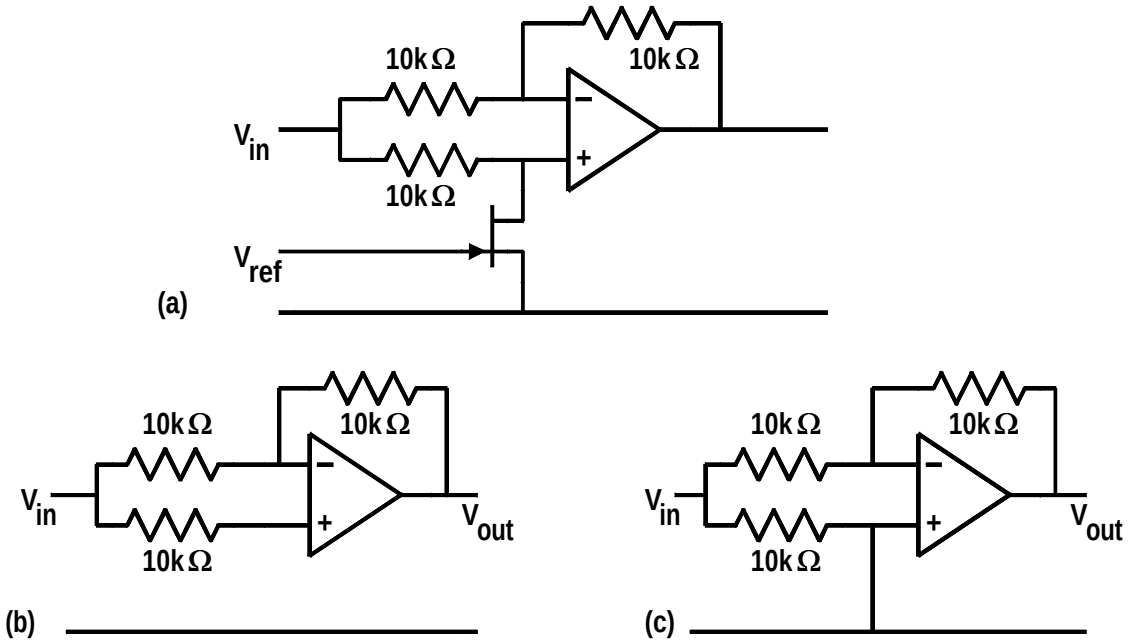
Photodetector may be noisy
The fluorescence signal will be at a frequency F_R because this is the frequency at which the exciting laser light is modulated.
Use this information.



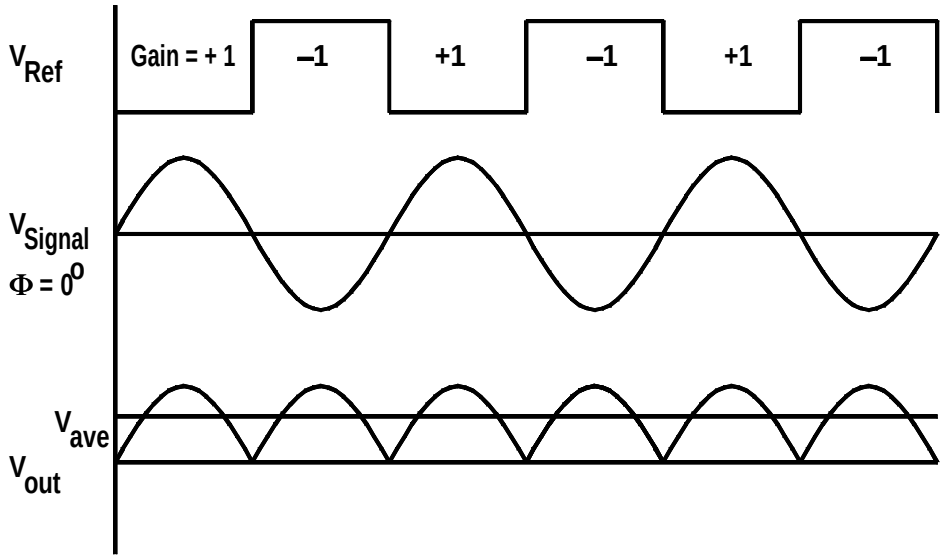
Basic phase sensitive detector circuit

A reference square wave signal from $0V$ to $-5V$ is available from the chopper

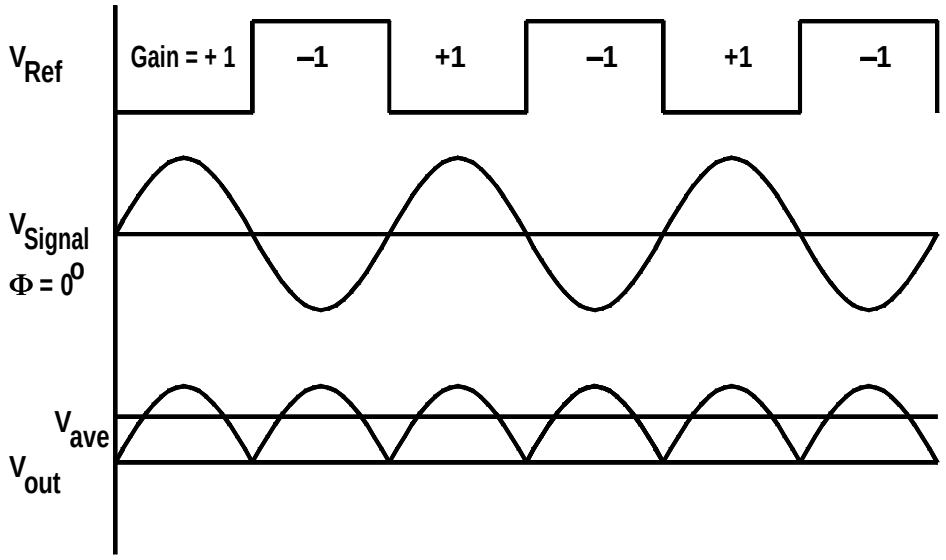
Reference is synchronized with the signal to be detected. This signal is applied to the gate of the FET.



The circuit for the phase sensitive detector is therefore an amplifier which is switched between a gain of $+1$ and -1 by the application of the reference square wave.



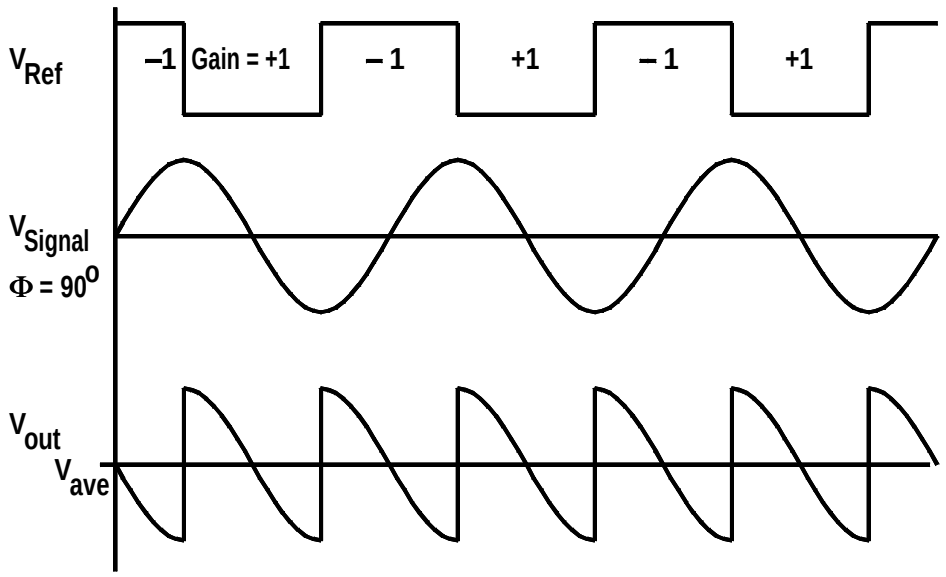
Reference and signal in phase.



Reference and signal in phase.

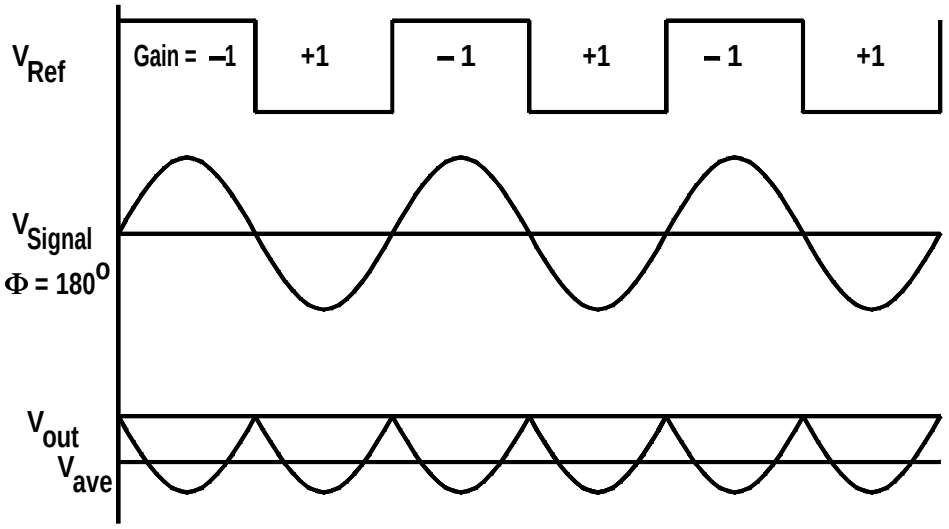
Input signal at the same frequency as the reference and is in phase with the reference, that is $\phi = 0$.

Signal is correlated with reference
Noise is uncorrelated with reference



Reference and signal 90^o out of phase.

When the phase difference is 90^o it can be seen that the output averages to zero.



Signal and reference 180^o out of phase.

The output voltage now averages to a negative value.

Output goes from full positive output to full negative output as the relative phase of the reference and the signal varies from 0^o to 180^o.

Panel control to vary phase angle.

A maximum can be obtained.

The commercial implementation of combined amplifiers and phase sensitive detectors are usually called Lock in Amplifiers

These systems are capable of measuring voltage signals down to levels of nanovolts ($10^{-9}V$)