The PID (proportional–integral–derivative) controller maintains the output to the process plant such that there is zero error $e(t)$ between process variable $y(t)$ and set point $u(t)$ or desired output by a closed loop or feedback loop mechanism. Feedback signal $y(t)$ from the process plant is compared with the set point or reference signal $u(t)$ and the corresponding difference or error signal $e(t)$ is fed to the PID algorithm. According to the P,I,D settings, the controller attempts to minimize the error over time by adjustment of a control variable $u(t)$ and hence produces combined and controlled output which is applied to the plant control devices.

**Proportional control**
- Makes a correction term proportional to the error.

**Integral control**
- Makes a correction term that integrates the error with respect to time.

**Derivative control**
- Makes a correction term that differentiates the error with respect to time.

Total Correction = $Pe(t) + I \int e(t) dt + D \frac{de}{dt}$,  
( where: $e(t)$ is the error signal with respect to time, P, I, and D are constants).

The combined operation of proportional, integral and derivative controls helps the unit to automatically compensate for changes in the system to which it is attached and provide accurate and stable control and is best used in systems which react quickly to changes added to the process variables like pressure, speed, temperature, flow, etc.

**Example:** For constant annealing of samples in a Furnace the temperature of the furnace (Plant/process) has to be controlled such that the final temperature (Set point) remains steady throughout the annealing process. For this purpose a PID Controller is utilized. The Furnace receives controlled power from the PID. The thermocouple (sensor) measuring the temperature of the furnace is connected back to the PID controller. As the power supply (from the PID) to the furnace varies, the temperature of the furnace also varies.

The behavior of the three basic control of PID are:

**P- Controller:**
Proportional controls are designed to eliminate the cycling associated with on-off control. A proportional controller decreases the average power supplied to the heater as the temperature approaches set point. This has the effect of slowing down the heater so that it will not overshoot the set point, but will approach the set point and maintain a stable temperature. This proportioning action can be accomplished by turning the output on and off for short time intervals. This "time proportioning" varies the ratio of "on" time to "off" time to control the temperature. The proportioning action occurs within a "proportional band" around the set point temperature. Outside this band, the controller functions as an on-off unit, with the output either fully on (below the band) or fully off (above the band). However, within the band, the output is turned on and off in the ratio of the measurement difference from the set point. At the set point (the midpoint of the proportional band), the output on:off ratio is 1:1; that is, the on-time and off-time are equal. If the temperature is further from the set point, the on- and off-times vary in proportion to the temperature difference. If the temperature is below set point, the output will be on longer; if the temperature is too high, the output will be off longer.

Proportional Controller gives output which is proportional to current error $e(t)$. It compares desired or set point with actual value or feedback process value. The resulting error is multiplied with proportional constant to get the output. If the error value is zero, then this controller output is zero.

**PI-Controller**
Due to limitation of p-controller where there always exists an offset between the process variable and set point, I-controller is needed, which provides necessary action to eliminate the steady state error. It integrates the error over a period of time until error value reaches to zero. It holds the value to final control device at which error becomes zero.

Integral control decreases its output when negative error takes place. It limits the speed of response and affects stability of the system. Speed of the response is increased by decreasing integral gain Ki.

**PID-Controller**
I-controller doesn’t have the capability to predict the future behavior of error. So it reacts normally once the set point is changed. D-controller overcomes this problem by anticipating future behavior of the error. Its output depends on rate of change of error with respect to time, multiplied by derivative constant. It gives the kick start for the output thereby increasing system response.