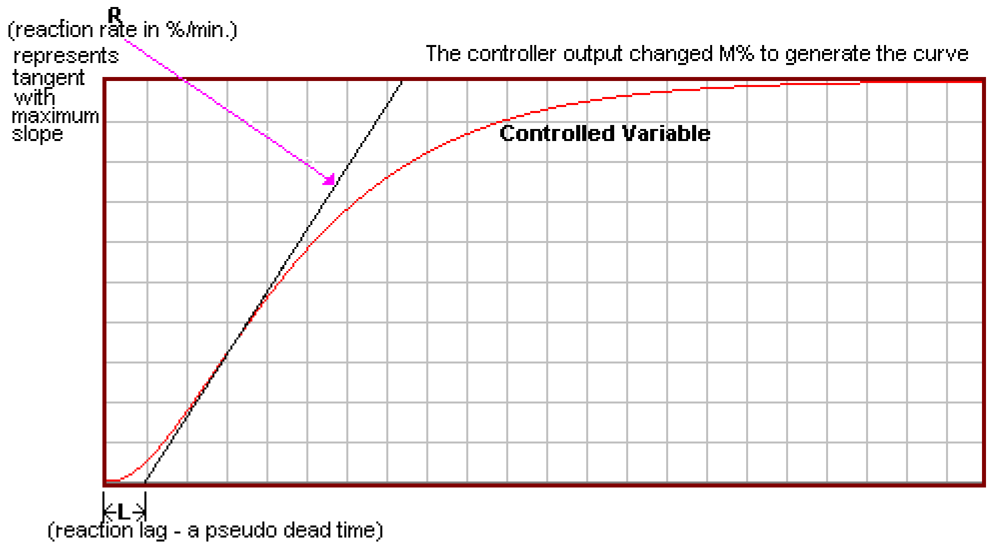
The Ziegler-Nichols open-loop tuning technique (ZNOL) essentially approximates the step response (process reaction curve) for any process as one having single time constant with dead time. The values of time constants and dead time are then used to produce a set of tuning constants that will result in a set point response that approximates quarter amplitude decay. As these results are based on Ziegler-Nichols empirical findings, they yield approximations to quarter decay. Best results are obtained when the ratio of dead time to time constant is between 0.1 and 1.

In generating the process reaction curve in an industrial process, what is done generally is to place the controller in manual and make a very small (< 5%) step change in the manipulated variable. The recording device should be marked at the instant the step change is made. The curve is then obtained and the data retrieved.




From the step response, the process characteristics are measured (the process is actually approximated as a single time constant process with dead time), and the tuning constants are calculated using the following equations:

$$PB = 83.3\ LR/M$$

$$I_t = 2.0L$$

$$D_t = 0.5L$$

Please note that these techniques produce an approximation to QAD. You should not be too concerned about the degree of accuracy in the QAD response. If the QAD produces a 4:1 ratio to within 20% accuracy, you should be satisfied that the settings on the controller are adequate.

The reaction curve shown on the next page was generated with a large output change of 59%. The process is the small thermal chamber where the temperature sensor is tightly coupled to the cement resistor heater. In effect, what the system is controlling is the surface temperature of the cement resistor.

The calculations of the Ziegler Nichols Open Loop method is done graphically. The version of the formula used on the graph requires the the process gain, the time constant, and the effective dead time or reaction lag.

$$Controller\ Gain, Kc = \frac{1.2\tau}{KpL}$$

$$Integral\ Time, T_i = 2L$$

$$Derivative\ Time, T_d = 0.5L$$

$$Proportional\ Band, PB = \frac{100\%}{K_c}$$

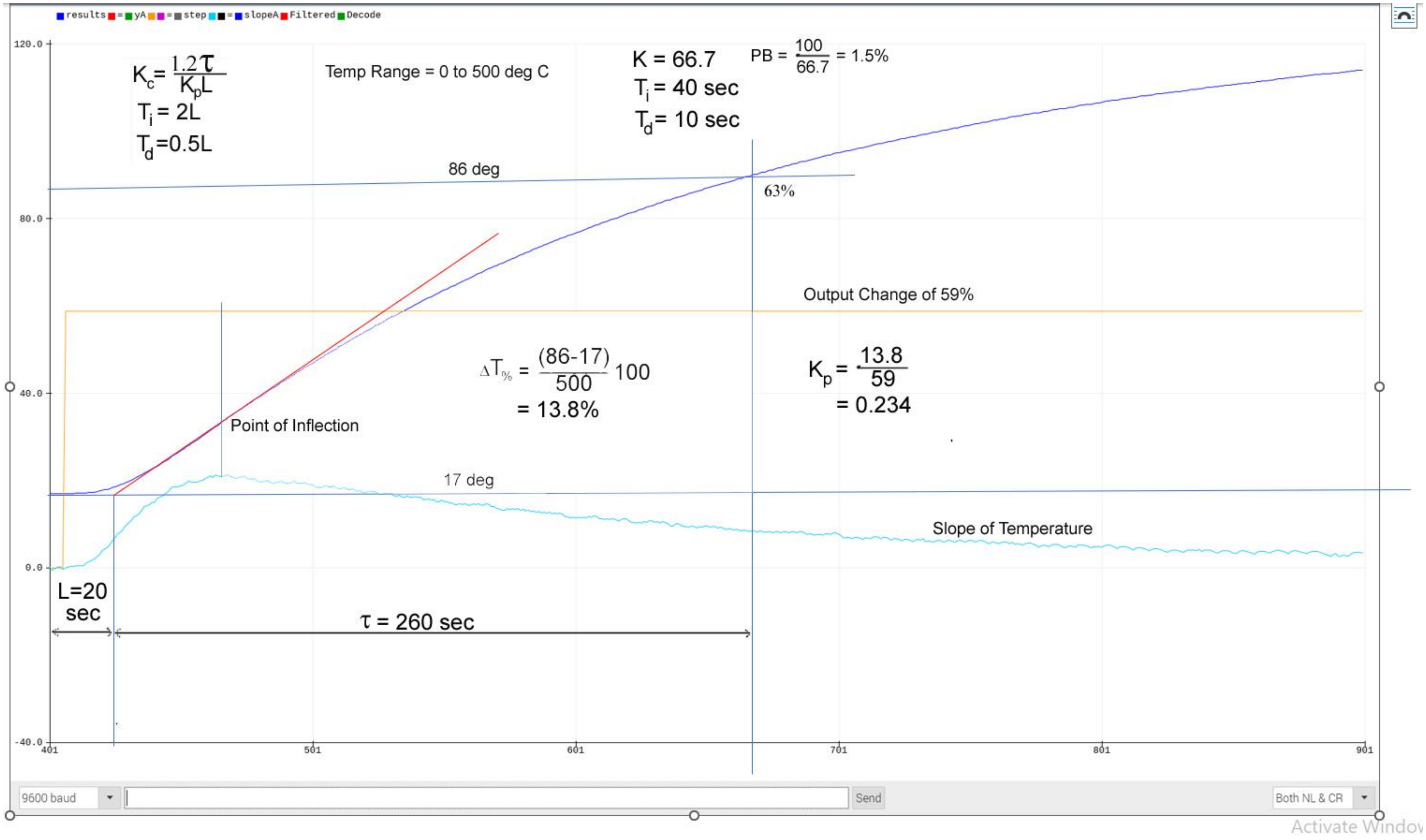
From the graphs:

PB = 1.5%

Ti = 40 sec

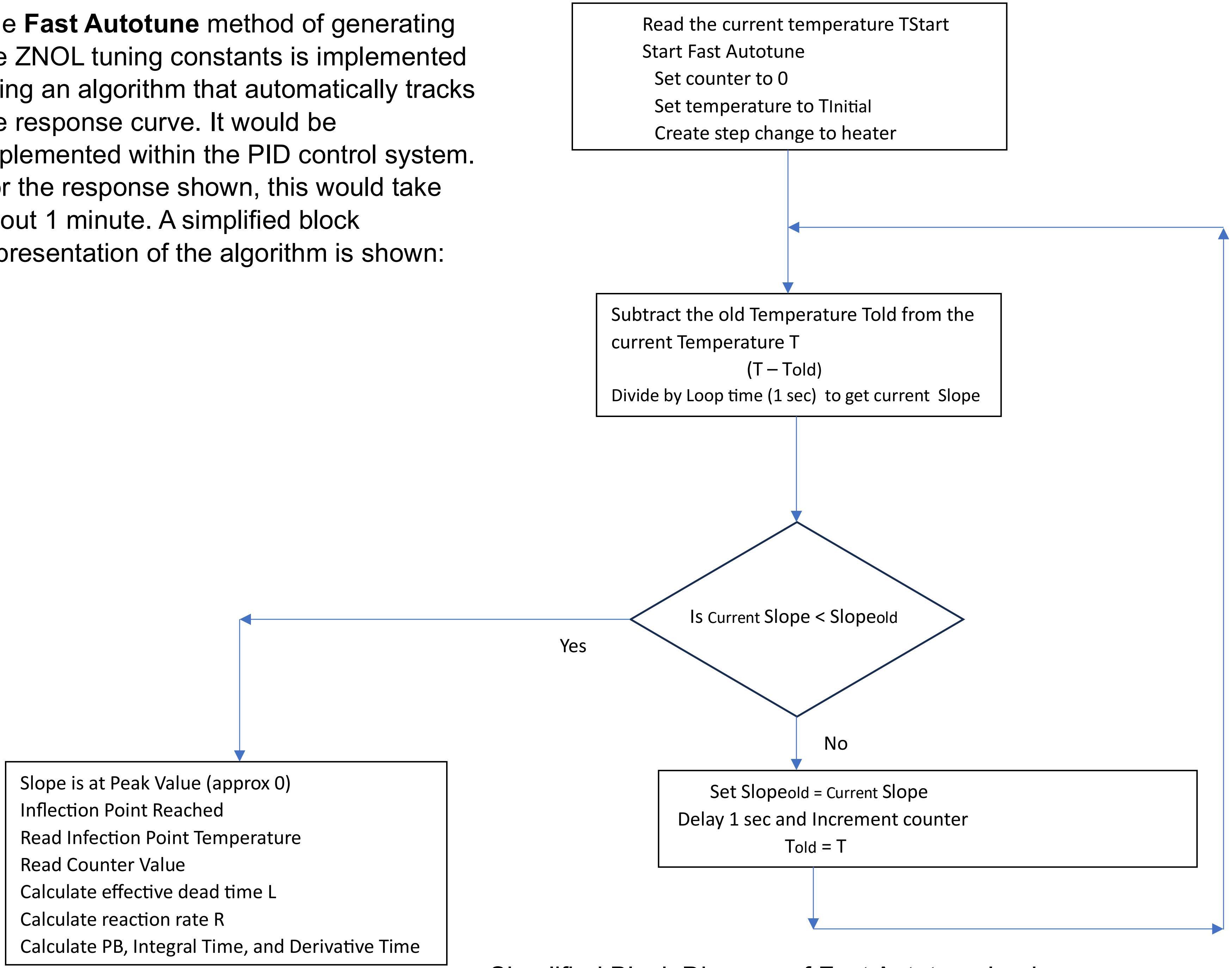
Td = 10 sec

The graphical method requires generation of a graph, with subsequent analysis. It also requires waiting until the response comes to steady state in order to calculate the process gain Kp. For the process graphed, waiting until steady state would require about 5 time constants or approximately **22 minutes**. Analysis and manual calculations would take significant additional time.




Graphical Method or Finding the ZNOL tuning Constants.

The **Fast Autotune** method of generating the ZNOL tuning constants is implemented using an algorithm that automatically tracks the response curve. It would be implemented within the PID control system. For the response shown, this would take about 1 minute. A simplified block representation of the algorithm is shown:




Simplified Block Diagram of Fast Autotune Logic

The graph on the next page shows the geometry behind the Fast Autotune method. A peak slope detector generates the point of inflection of the response curve. The slope at the inflection point generates the reaction rate R. In order to find the reaction lag (effective dead time TD), TR must be calculated. This is done using the slope and the value of the temperature difference at the inflection point. This information is then available to calculate the ZNOL tuning constants

The following calculations are based on the actual response automatically tracked and shown in the graph on the previous page.

R is reaction rate in %/min,

L is the effective dead time in sec

T1 is in seconds

R = (**60***peakSlope/**50**)/**500***100 **=** 0.24*peakSlope in %/min, where **50** is amplification factor, peakSlope is in deg/sec, **60** converts to minutes, **500** is temperature range, **100** converts to %

$T_R$=(yA_Peak-yA_Start)/(peakSlope/**50.0**)

$T_D$= $T_T$-$T_R$ = L

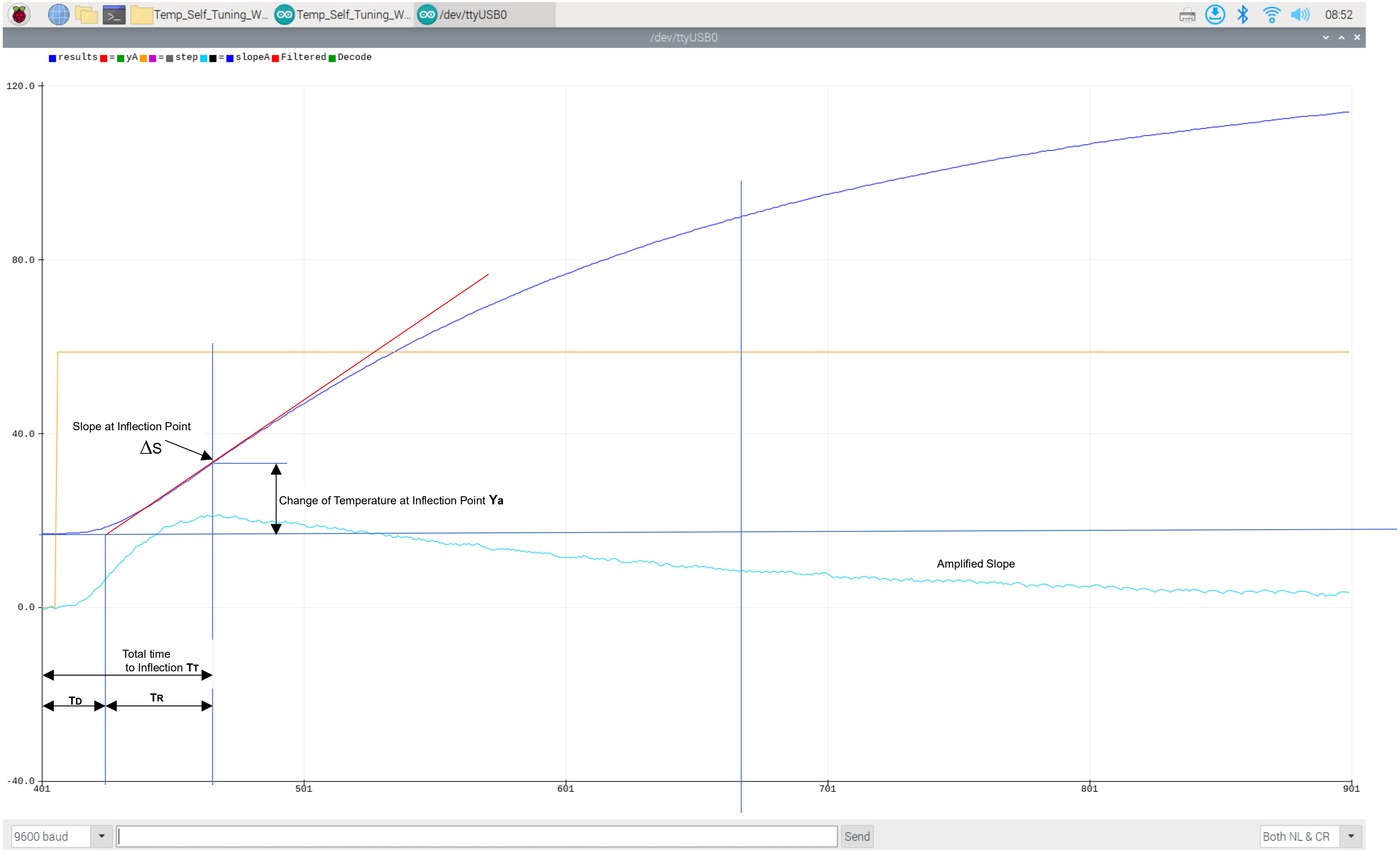
Mstep = step size in % of output change causing the response

## Ziegler Nichols Open Loop (ZNOL) Formulas

PB = 83.3*(L/**60**)*R/Mstep = 1.38833*L*R/Mstep

I = 2.0*L

D = 0.5*L



Temp_Self_Tuning_W...
Temp_Self_Tuning_W...
/dev/ttyUSB0
08:52
/dev/ttyUSB0
results = yA = step = slopeA Filtered Decode
120.0
80.0
40.0
0.0
-40.0
401
501
601
701
801
901
Slope at Inflection Point
ΔS
Change of Temperature at Inflection Point Ya
Amplified Slope
Total time
to Inflection TT
TD
TR
9600 baud
Send
Both NL & CR