Flight Surface Deflection Controller (FSDC).

Flight Control System (FLCS).

Valery Burkin. Flight Labs GmbH, 2011.

The main function of a Flight Surface Deflection Controller (FSDC) is to process flight stick input signal according to the current flight condition assuring the aircraft allways stays in the bounds of its optimal performance envelope with no regard on what command is given.

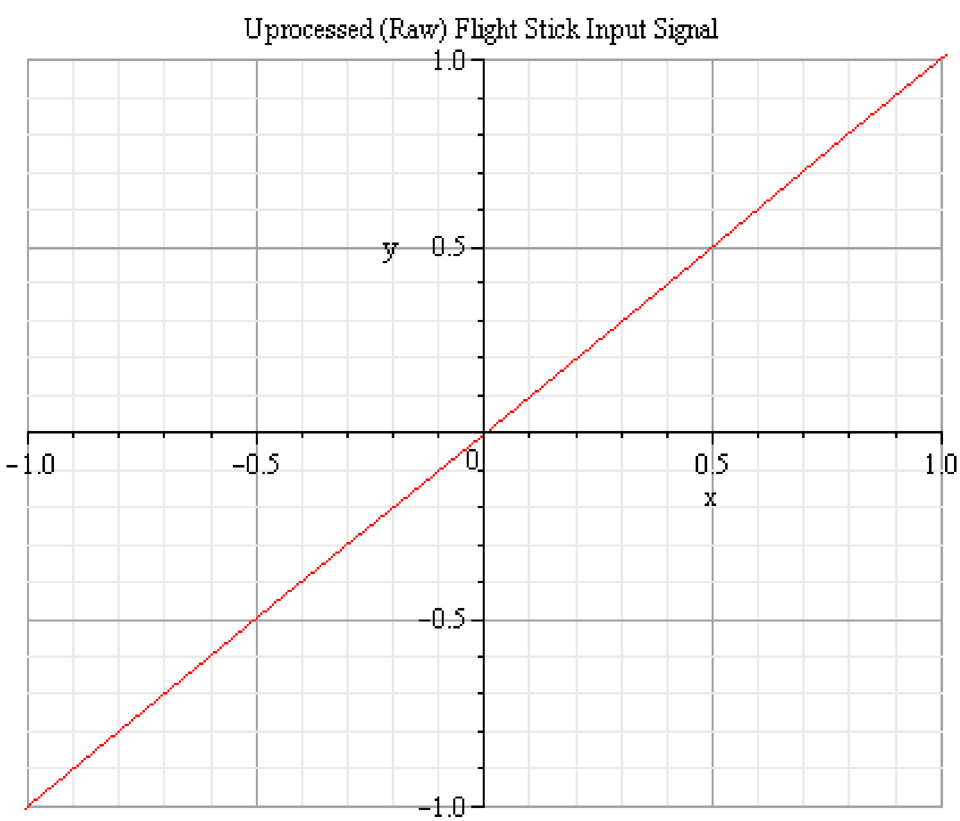
In order to avoid sharp gains in the pitch, yaw and bank angles the input signal is smoothed via general polynomial function.

$$X_{out} = f(G, \alpha) \left(\sum_{n=0}^{N} A_n X_{\mathbf{in}}^{2n+1} \right)$$

where $f(G, \alpha)$ is a gain function of some airborne parameters, which define the limiting factor e.g. at high speed or high AoA conditions.

Unprocessed (Raw) flight stick input command is mostly a straight line :

$$Y(x) = k \cdot x; \quad k = 1;$$
$$plot(x, x = -1..1)$$

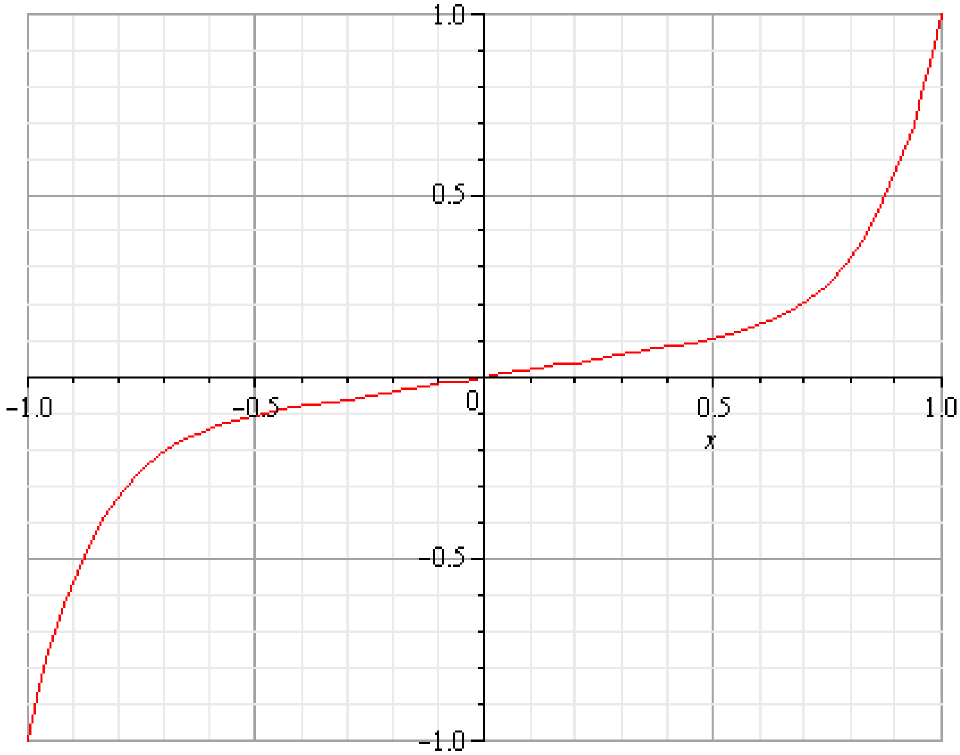


Applying the polynomial function assures the signal is smoothed and no sharp gains are present around 0:

$$\boldsymbol{A}_{\boldsymbol{x}} \cdot x^7 + \left(1 - \boldsymbol{A}_{\boldsymbol{x}}\right) \cdot x$$

$$plot\left(0.8 \cdot x^7 + (1 - 0.8) \cdot x, x = -1..1\right)$$

Smoothed, but unlimited input signal



Applying the gain function of current G and AoA parameters would strech down the signal so that the limiting factor at high speed condition would be G and that of the low speed condition would be AoA :

$$f(G, \alpha) = \frac{1}{\left(1 + \left(\boldsymbol{c}_{\boldsymbol{G}} \cdot G\right)^2\right)} \cdot \frac{1}{\left(1 + \left(\boldsymbol{c}_{\alpha} \cdot \alpha\right)^2\right)}$$

where $\boldsymbol{c}_{\boldsymbol{G}}$ and $\boldsymbol{c}_{\alpha}$ are constant factors for G and AoA respectively.

The complete input signal controller function is defined as the following :

$$Y\left(G, \alpha, x_i\right) = \frac{1}{\left(1 + \left(\boldsymbol{c}_{\boldsymbol{G}} \cdot G\right)^2\right)} \cdot \frac{1}{\left(1 + \left(\boldsymbol{c}_{\alpha} \cdot \alpha\right)^2\right)} \cdot \left(\boldsymbol{A}_{\boldsymbol{i}} \cdot x_i^7 + \left(1 - \boldsymbol{A}_{\boldsymbol{i}}\right) \cdot x_i\right);$$

All constants are controller specific and normally defined as vectors for pitch, yaw and roll respectively, $\boldsymbol{A}_{\boldsymbol{i}} = \left(\boldsymbol{A}_{pitch}, \boldsymbol{A}_{yaw}, \boldsymbol{A}_{roll}\right)$.

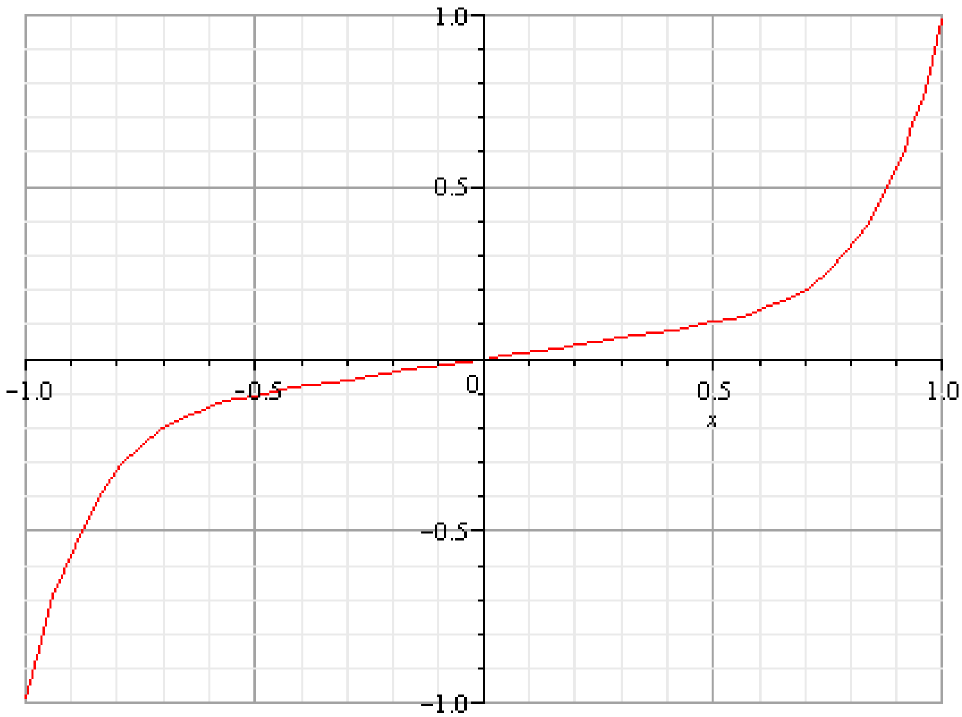
Lets consider a few examples of a pitch controller behavior with:

$$c_G = 0.12, \quad c_\alpha = 0.015 \text{ and } A_x = 0.8;$$

☐ An example of level flight (normal condition). $G = 1$, $\alpha = 2$ degrees and $A_x = 0.8$.

$$plot\left(\frac{1}{\left(1+(1\cdot\mathbf{0.12})^2\right)}\cdot\frac{1}{\left(1+(2\cdot\mathbf{0.015})^2\right)}\cdot\left(\mathbf{0.8}\cdot x^7+(1-\mathbf{0.8})\cdot x\right),\ x=-1..1\right);$$

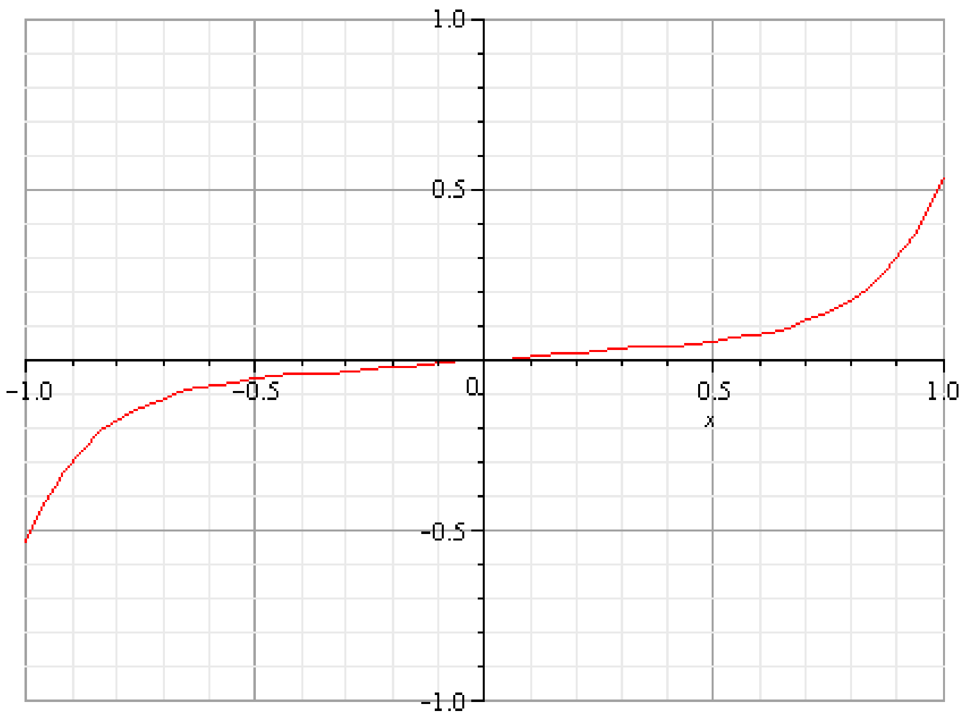
Processed Pitch input signal for $G = 1$, $\alpha = 2$ degrees and $A_x = 0.8$



☐ An example of high G load. $G = 7.5$, $\alpha = 12$ degrees and $\boldsymbol{A_x} = 0.8$.

$$plot\left(\frac{1}{\left(1+\left(7.5\cdot\mathbf{0.12}\right)^2\right)}\cdot\frac{1}{\left(1+\left(12\cdot\mathbf{0.015}\right)^2\right)}\cdot\left(\mathbf{0.8}\cdot x^7 + \left(1-\mathbf{0.8}\right)\cdot x\right),\ x=-1..1\right);$$

Processed Pitch input signal for $G = 7.5$, $\alpha = 12$, $A_x = 0.8$



☐ An example of near critical AoA (near stall condition). $G = 2.7$, $\alpha = 44$ degrees and $\boldsymbol{A_x} = 0.8$.

$$plot\left(\frac{1}{\left(1+\left(2.7\cdot\mathbf{0.12}\right)^2\right)}\cdot\frac{1}{\left(1+\left(44\cdot\mathbf{0.015}\right)^2\right)}\cdot\left(\mathbf{0.8}\cdot x^7 + \left(1-\mathbf{0.8}\right)\cdot x\right),\ x=-1..1\right);$$

Processed Pitch input signal for $G = 2.7$, $\alpha = 44$, $A_x = 0.8$