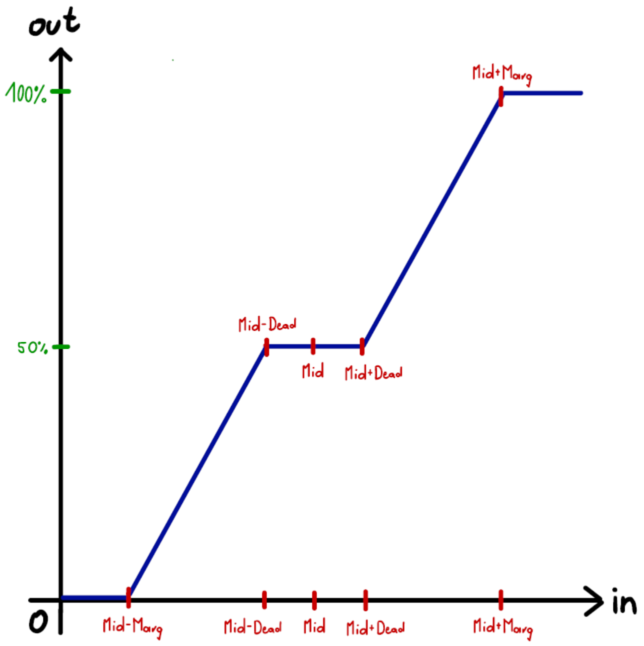
4D-Joystick – Calibration calculation

1. Introduction

The calibration-data are global attributes of the system and not related to different model-configurations. For every input channel (x, y, z and w on 4D-Joystick) and every output channel (x, y, z, and w on remote-unit) the three following values are stored:

- **Midpoint**
  The analogue value when the joysticks is in middle position.
- **Margin**
  The maximum movement from midpoint to one of the endpoints. Therefore, every channel theoretically has two margins (an upper and a lower one). However, only the bigger of both ones is stored. Value can be from 1 to 2047 and is automatically determined during calibration.
- **Inversion**
  Stores if the channel is inverted.



Additionally, every input channel can have a deadzone. Unlike the other calibration-data, the deadzone is related to the model-configuration and not to the systemwide configuration.
The deadzone is an area around the midpoint of an analogue input, where output value keeps constant at the midpoint-value. It can be a value between 0 and 255.

2. Calculation

To reduce calculation-time for the analogue channels and their calibration-data, a simple formula with constant parameters is calculated. The calculation is done in three steps.
First of all, the input channel is normalized. This means that the values are modified in a way to use the full scale (12bit, 0-4095) for the maximum movement of the joystick (from bottom/left to top/right).
Then the same is done for output channel, but in the other direction. The full-scale input-value is modified in a way, that it depicts the maximum movement of the output joystick.
Finally the two calculation are combined to get a single formula. At runtime, the parameters for this formula are calculated when a configuration is loaded and can then be used for calculation of the analogue channels at every communication-cycle. This method is more efficient then calculating every step in every communication-cycle.

The formula for the output channel is a simple linear equation. However, the calculation for the input channel is more complex. This is mainly caused by the additional deadzone-parameter. For this reason, the calculation is separated into three linear equations which are related to different areas of the input-values.

2.1 Parameters

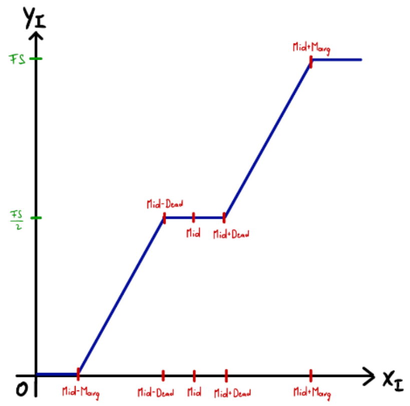
mid_I ... Midpoint of input channel
$marg_I$ ... Margin of input channel
$dead_I$ ... Deadzone of input channel
x_I ... Analogue input value
y_I ... Normalized value from input

mid_O ... Midpoint of output channel
$marg_O$ ... Margin of output channel
x_O ... Normalized value for output calculation
y_O ... Analogue output value
FS ... Full scale value ($2^{12} = 4096$)

2.2 Input Channel

As mentioned before, the calculation is separated into three different areas.

Lower area	Deadzone	Upper area
$x_I < (mid_I - dead_I)$	$(mid_I - dead_I) \geq x_I$ and $(mid_I + dead_I) \leq x_I$	$x_I > (mid_I + dead_I)$
$y_I = k_I * x_I + d_{I,L}$ $k_I = \frac{FS}{2\,(marg_I - dead_I)}$ $d_{I,L} = -k_I * (mid_I - marg_I)$	$y_I = \frac{FS}{2}$	$y_I = k_I * x_I + d_{I,H}$ $k_I = \frac{FS}{2\,(marg_I - dead_I)}$ $d_{I,H} = -k_I * (mid_I + dead_I) + \frac{FS}{2}$



2.3 Output Channel

The calculation for the output channel is a linear equation:

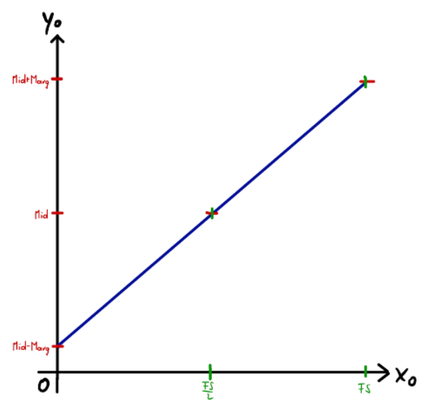
$$y_O = k_O * x_O + d_O$$

$$k_O = \frac{2 * marg_O}{FS}$$

$$d_O = mid_O - marg_O$$

2.4 Combination of input and output channel

Finally, both calculations are combined:



$$x_O = y_I$$

$$y_O = k_O * y_I + d_O$$

$$y_O = k_O * (k_I * x_I + d_{I,(L/H)}) + d_O$$

$$y_O = k_O * k_I * x_I + k_O * d_{I,(L/H)} + d_O$$

$$y_O = k * x_I + d_{(L/H)}$$

$$k = k_O * k_I = \frac{2 * marg_O}{FS} * \frac{FS}{2\,(marg_I - dead_I)} = \frac{marg_O}{marg_I - dead_I}$$

$$d_{(L/H)} = k_O * d_{I,(L/H)} + d_O$$

Lower area	Deadzone	Upper area
$x_I < (mid_I - dead_I)$	$(mid_I - dead_I) \geq x_I$ and $(mid_I + dead_I) \leq x_I$	$x_I > (mid_I + dead_I)$
$d_L = -k_O * k_I * (mid_I - marg_I) + d_O$ $d_L = -k * (mid_I - marg_I) + mid_O - marg_O$ $k = \frac{marg_O}{marg_I - dead_I}$ $y_O = k * x_I + d_L$	$y_I = \frac{FS}{2}$ $y_O = k_O * y_I + d_O$ $y_O = mid_O$	$d_H = -k_O * k_I * (mid_I + dead_I) + k_O \frac{FS}{2} + d_O$ $d_H = -k * (mid_I + dead_I) + marg_O + mid_O - marg_O$ $d_H = -k * (mid_I + dead_I) + mid_O$ $k = \frac{marg_O}{marg_I - dead_I}$ $y_O = k * x_I + d_H$