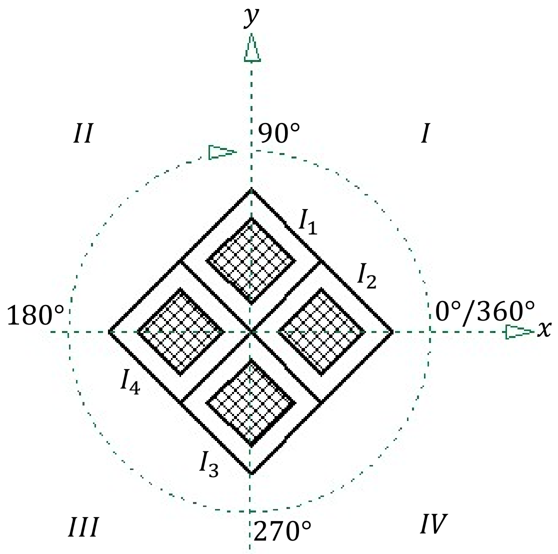
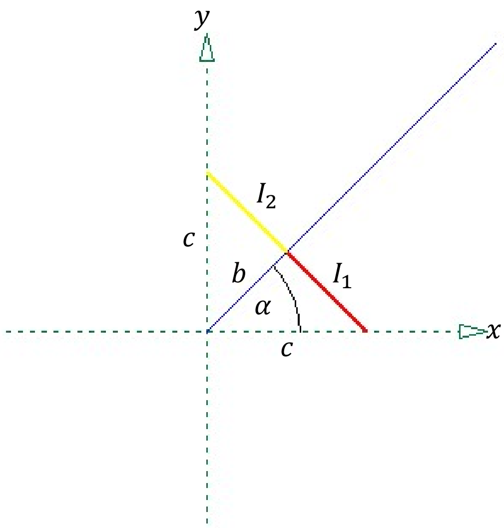
4 pixel camera sensor - angle of incidence computation

The four pin photodiodes are arranged as shown below and divided into 4 quadrants. Half of the photo sensitive surfaces of photodiode 1 and 2 belong to quadrant 1, half of the photo sensitive surfaces of photodiode 1 and 4 belong to quadrant 2, and so on. A simple algorithm determinates in a first step, in which quadrant the largest amount of light is detected. Then the angle of incidence is computed.





Let I_1 to I_4 be the measured intensity of light, which is linear to the output voltages of the op amp stages. The MCU will map input voltages between 0 and 5 volts into integer values between 0 and 1023, so I_1 to I_4 will have according values. We can now interpret these values geometrically as shown above. The sum of I_1 and I_2 can be interpreted as the length of the hypotenuse of an isosceles triangle with the side length c. If $I_1 = 0$, the angle of detected light source α will be 0°, if $I_2 = 0$, α will be 90°, if $I_1 = I_2$, α will be 45°, etc.
We are starting to compute the angle of detected light source α_1 for quadrant 1:

$$2 \cdot c^2 = (I_1 + I_2)^2$$

$$c^2 = \frac{(I_1 + I_2)^2}{2}$$

$$c = \sqrt{\frac{(I_1 + I_2)^2}{2}}$$

$$c = \frac{I_1 + I_2}{\sqrt{2}}$$

$$b^2 = {I_1}^2 + \frac{(I_1 + I_2)^2}{2} - 2 \cdot I_1 \cdot \frac{I_1 + I_2}{\sqrt{2}} \cdot \cos(45°)$$

$$\cos 45\,° = \frac{1}{\sqrt{2}}$$

$$b^2 = I_1{}^2 + \frac{(I_1 + I_2)^2}{2} - I_1 \cdot (I_1 + I_2)$$

$$b^2 = I_1{}^2 + \frac{I_1{}^2 + 2 \cdot I_1 \cdot I_2 + I_2{}^2}{2} - I_1 \cdot (I_1 + I_2)$$

$$b^2 = I_1{}^2 + \frac{I_1{}^2 + 2 \cdot I_1 \cdot I_2 + I_2{}^2}{2} - I_1{}^2 - I_1 \cdot I_2$$

$$b^2 = \frac{I_1{}^2 + 2 \cdot I_1 \cdot I_2 + I_2{}^2}{2} - I_1 \cdot I_2$$

$$b^2 = \frac{I_1{}^2 + I_2{}^2}{2}$$

$$b = \sqrt{\frac{I_1{}^2 + I_2{}^2}{2}}$$

$$\frac{I_1}{\sin(\alpha_1)} = \frac{\sqrt{\frac{I_1{}^2 + I_2{}^2}{2}}}{\sin(45°)}$$

$$\sin 45\,° = \frac{1}{\sqrt{2}}$$

$$\frac{I_1}{\sin(\alpha_1)} = \sqrt{2} \cdot \sqrt{\frac{I_1{}^2 + I_2{}^2}{2}}$$

$$\frac{I_1}{\sin(\alpha_1)} = \sqrt{I_1{}^2 + I_2{}^2}$$

$$\sin(\alpha_1) = \frac{I_1}{\sqrt{I_1{}^2 + I_2{}^2}}$$

$$\boldsymbol{\alpha_1} = \mathbf{arcsin}\left(\frac{\boldsymbol{I_1}}{\sqrt{\boldsymbol{I_1}^{\mathbf{2}} + \boldsymbol{I_2}^{\mathbf{2}}}}\right)$$

Analog for the other 3 quadrants:

$$\boldsymbol{\alpha_2} = \mathbf{arcsin}\left(\frac{\boldsymbol{I_4}}{\sqrt{\boldsymbol{I_1}^2 + \boldsymbol{I_4}^2}}\right) + \mathbf{90°}$$

$$\boldsymbol{\alpha_3} = \mathbf{arcsin}\left(\frac{\boldsymbol{I_3}}{\sqrt{\boldsymbol{I_3}^2 + \boldsymbol{I_4}^2}}\right) + \mathbf{180°}$$

$$\boldsymbol{\alpha_4} = \mathbf{arcsin}\left(\frac{\boldsymbol{I_2}}{\sqrt{\boldsymbol{I_2}^2 + \boldsymbol{I_3}^2}}\right) + \mathbf{270°}$$