

# Configuration lt\_mk2\_linked\_leds

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config version : 1.0
chamber model : Light Tunnel Mk2

changelog
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1.0: Initial version
    
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## Description

This configuration exposes all variables of the Light Tunnel Mk2, excluding the camera. The motor control parameters (`mot*_enabled`, `mot*_steps` and `mot*_max`) are kept fixed to ensure accurate positioning of the polarizers. The IR and UV LEDs (`led*_ir`, `led*_uv`) placed above each light sensor only turn on when the sensor is taking a measurement, eliminating their effect on the readings of the other light sensors. Furthermore, the chamber sets the values of `led_2_uv` and `led_3_uv` as a clamped linear transformation of `ir_1` and `ir_2`, i.e.,

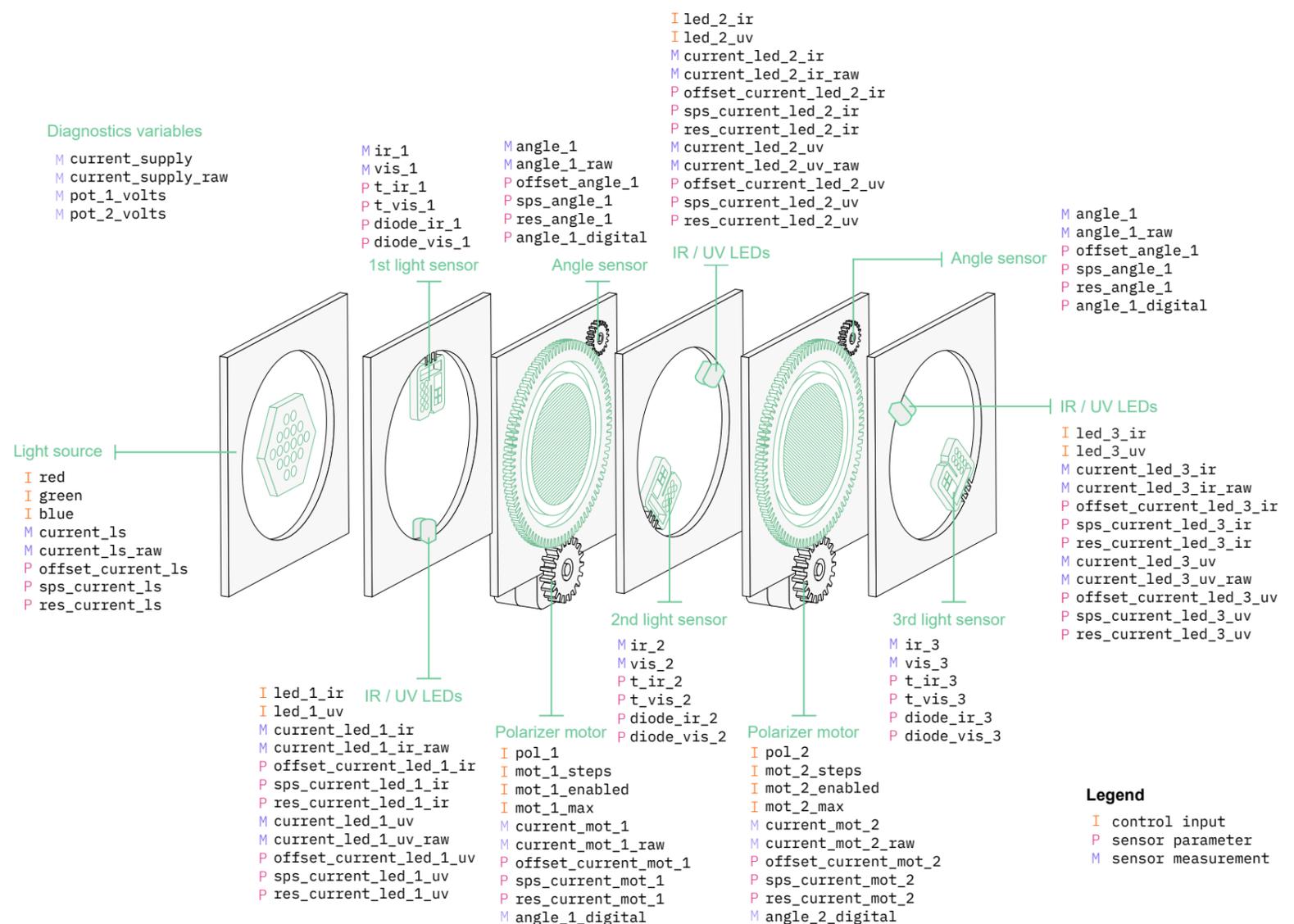
$$\text{led\_2\_uv} \leftarrow \text{clamp}[f_2(\text{ir\_1})] \text{ where } f_2 := \text{slope\_f2} \times \text{ir\_1} + \text{intercept\_f2}, \tag{1}$$

$$\text{led\_3\_uv} \leftarrow \text{clamp}[f_3(\text{ir\_2})] \text{ where } f_3 := \text{slope\_f3} \times \text{ir\_2} + \text{intercept\_f3}, \tag{2}$$

and where  $\text{clamp}[x] := \max(0, \min(4095, x))$  clamps the output of  $f_i$  to  $[0, 4095]$ . The parameters `slope_f2`, `slope_f3`, `intercept_f2` and `intercept_f3` behave as additional manipulable chamber variables (see the variables table for their default value).

## Chamber Diagram

See the variables table for a detailed description of each variable.



## Variables Table

Variable	Settable	Values	Default	Description
<code>timestamp</code>	No	float	–	The timestamp of the measurement, in seconds with respect to the system wall-clock.
<code>counter</code>	No	$\{i \in \mathbb{Z} : i \geq 0\}$	–	Measurement counter.
<code>flag</code>	Yes	float	0	User-defined flag.
<code>intervention</code>	No	$\{0,1\}$	–	Intervention flag. Has a value of 1 if this is the first measurement after a SET instruction, and 0 otherwise.
<code>slope_f2</code>	Yes	float	0.0624	Slope of the clamped linear transformation in (1). Setting it to 0 disables the causal effect <code>ir_1</code> $\rightarrow$ <code>led_2_uv</code> .
<code>intercept_f2</code>	Yes	float	0	Intercept of the clamped linear transformation in (2).
<code>slope_f3</code>	Yes	float	0.0624	Slope of the clamped linear transformation in (2). Setting it to 0 disables the causal effect <code>ir_2</code> $\rightarrow$ <code>led_3_uv</code> .
<code>intercept_f3</code>	Yes	float	0	Intercept of the clamped linear transformation in (2).
<code>red</code>	Yes	$\{0, \dots, 255\}$	0	The brightness setting of the red LEDs on the main light source. Higher values correspond to higher brightness.
<code>green</code>	Yes	$\{0, \dots, 255\}$	0	The brightness setting of the green LEDs on the main light source. Higher values correspond to higher brightness.
<code>blue</code>	Yes	$\{0, \dots, 255\}$	0	The brightness setting of the blue LEDs on the main light source. Higher values correspond to higher brightness.
<code>current_ls</code>	No	float	–	The measurement of electric current drawn by the light source, in Amperes.
<code>current_ls_raw</code>	No	$\{-32768, \dots, 32767\}$	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_ls</code> .
<code>offset_current_ls</code>	Yes	$\{0, \dots, 4095\}$	0	The reference voltage (offset) of the ADC producing the <code>current_ls</code> and <code>current_ls_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_ls}}{4095}.$ Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_ls</code> result in lower values of <code>current_ls_raw</code> .
<code>sps_current_ls</code>	Yes	$\{0, \dots, 7\}$	7	The data rate of the ADC producing the <code>current_ls</code> and <code>current_ls_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_ls</code>	Yes	$\{0, \dots, 5\}$	0	The resolution of the ADC producing the <code>current_ls</code> and <code>current_ls_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range $\{-32768, 32767\}$ . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at $-32768$ or $32767$ , if the input voltage exceeds the set range.
<code>pol_1</code>	Yes	float $\in [-270, 270]$	0	The set position of the first polarizer, in degrees. The actual angle of the polarizer may slightly deviate from this setting due to the imperfect coupling of the mechanical pieces and the resolution of the motor (see <code>mot_1_steps</code> ).
<code>mot_1_steps</code>	No	$\{3200, 1600, 800, 400, 200\}$	3200	The steps-per-revolution of the stepper motor controlling the first polarizer. Higher values mean a higher motor resolution, i.e., more precise positioning. At low current levels <code>mot_1_max</code> and/or step values below 800, the motor may lose torque and start missing steps, resulting in a mismatch between the set position <code>pol_1</code> and the actual polarizer angle.
<code>mot_1_enabled</code>	No	$\{0,1\}$	1	Enables (1) or disables (0) the motor of the first polarizer. If the motor is disabled (0), setting <code>pol_1</code> will have no effect on the actual position of the polarizer.

Table 1: Description of the variables produced by the chamber configuration `lt_mk2_linked_leds`. Settable variables can be manipulated by calling `.set(<variable>, <value>)`. “float” corresponds to a 32-bit float.

Variable	Settable	Values	Default	Description
<code>mot_1_max</code>	No	<code>{0, ..., 4095}</code>	3000	Regulates the maximum current drawn by the motor controlling the first polarizer. At low current levels and/or <code>mot_1_steps</code> values below 800, the motor may lose torque and start missing steps, resulting in a mismatch between the set position <code>pol_1</code> and the actual polarizer angle.
<code>current_mot_1</code>	No	float	–	The measurement (in Amperes) of the electric current drawn by the motor controlling the first polarizer.
<code>current_mot_1_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_mot_1</code> .
<code>offset_current_mot_1</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_mot_1</code> and <code>current_mot_1_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_mot\_1}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_mot_1</code> result in lower values of <code>current_mot_1_raw</code>.</p>
<code>sps_current_mot_1</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>current_mot_1</code> and <code>current_mot_1_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_mot_1</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>current_mot_1</code> and <code>current_mot_1_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>angle_1</code>	No	float	–	The position (in degrees) of the first polarizer as measured by the analog angle sensor.
<code>angle_1_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated angle measurement for the first polarizer, i.e., the raw ADC output corresponding to <code>angle_1</code> .
<code>offset_angle_1</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>angle_1</code> and <code>angle_1_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_angle\_1}}{4095}.$
<code>sps_angle_1</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>angle_1</code> and <code>angle_1_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_angle_1</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>angle_1</code> and <code>angle_1_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>angle_1_digital</code>	No	$\mathbb{Z}$	–	The position (in degrees) of the first polarizer as measured by the rotary encoder.
<code>pol_2</code>	Yes	float $\in [-270, 270]$	0	The set position of the second polarizer, in degrees. The actual angle of the polarizer may slightly deviate from this setting due to the imperfect coupling of the mechanical pieces and the resolution of the motor (see <code>mot_2_steps</code> ).
<code>mot_2_steps</code>	No	<code>{3200, 1600, 800, 400, 200}</code>	3200	The steps-per-revolution of the stepper motor controlling the second polarizer. Higher values mean a higher motor resolution, i.e., more precise positioning. At low current levels <code>mot_2_max</code> and/or step values below 800, the motor may lose torque and start missing steps, resulting in a mismatch between the set position <code>pol_2</code> and the actual polarizer angle.
<code>mot_2_enabled</code>	No	<code>{0,1}</code>	1	Enables (1) or disables (0) the motor of the second polarizer. If the motor is disabled (0), setting <code>pol_2</code> will have no effect on the actual position of the polarizer.

Table 1: Description of the variables produced by the chamber configuration `lt_mk2_linked_leds`. Settable variables can be manipulated by calling `.set(<variable>, <value>)`. “float” corresponds to a 32-bit float.

Variable	Settable	Values	Default	Description
<code>mot_2_max</code>	No	<code>{0, ..., 4095}</code>	3000	Regulates the maximum current drawn by the motor controlling the second polarizer. At low current levels and/or <code>mot_2_steps</code> values below 800, the motor may lose torque and start missing steps, resulting in a mismatch between the set position <code>pol_2</code> and the actual polarizer angle.
<code>current_mot_2</code>	No	float	–	The measurement (in Amperes) of the electric current drawn by the motor controlling the second polarizer.
<code>current_mot_2_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_mot_2</code> .
<code>offset_current_mot_2</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_mot_2</code> and <code>current_mot_2_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_mot\_2}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_mot_2</code> result in lower values of <code>current_mot_2_raw</code>.</p>
<code>sps_current_mot_2</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>current_mot_2</code> and <code>current_mot_2_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_mot_2</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>current_mot_2</code> and <code>current_mot_2_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>angle_2</code>	No	float	–	The position (in degrees) of the second polarizer as measured by the analog angle sensor.
<code>angle_2_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated angle measurement for the second polarizer, i.e., the raw ADC output corresponding to <code>angle_2</code> .
<code>offset_angle_2</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>angle_2</code> and <code>angle_2_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_angle\_2}}{4095}.$
<code>sps_angle_2</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>angle_2</code> and <code>angle_2_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_angle_2</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>angle_2</code> and <code>angle_2_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>angle_2_digital</code>	No	$\mathbb{Z}$	–	The position (in degrees) of the second polarizer as measured by the rotary encoder.
<code>ir_1</code>	No	<code>{0, ..., 65535}</code>	–	The uncalibrated infrared intensity measurement produced by the first light sensor, placed in front of both polarizers (wrt. the light source).
<code>vis_1</code>	No	<code>{0, ..., 65535}</code>	–	The uncalibrated visible-light intensity measurement produced by the first light sensor, placed in front of both polarizers (wrt. the light source).
<code>ir_2</code>	No	<code>{0, ..., 65535}</code>	–	The uncalibrated infrared intensity measurement produced by the second light sensor, placed between the two polarizers.
<code>vis_2</code>	No	<code>{0, ..., 65535}</code>	–	The uncalibrated visible-light intensity measurement produced by the second light sensor, placed between the two polarizers.
<code>ir_3</code>	No	<code>{0, ..., 65535}</code>	–	The uncalibrated infrared intensity measurement produced by the third light sensor, placed after both polarizers (wrt. the light source).

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Variable	Settable	Values	Default	Description
<code>vis_3</code>	No	{0, ..., 65535}	–	The uncalibrated visible-light intensity measurement produced by the third light sensor, placed after both polarizers (wrt. the light source).
<code>t_ir_1</code>	Yes	{0,1,2,3}	3	The exposure time of the first sensor during an infrared intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>t_vis_1</code>	Yes	{0,1,2,3}	3	The exposure time of the first sensor during a visible-light intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>t_ir_2</code>	Yes	{0,1,2,3}	3	The exposure time of the second sensor during an infrared intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>t_vis_2</code>	Yes	{0,1,2,3}	3	The exposure time of the second sensor during a visible-light intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>t_ir_3</code>	Yes	{0,1,2,3}	3	The exposure time of the third sensor during an infrared intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>t_vis_3</code>	Yes	{0,1,2,3}	3	The exposure time of the third sensor during a visible-light intensity measurement. Higher values correspond to longer exposure, increasing the sensitivity of the sensor.
<code>diode_ir_1</code>	Yes	{0,1,2}	2	The photodiode used by the first light sensor when taking an infrared measurement, corresponding to the small (0), medium (1) and large (2) photodiodes. Larger values increase the sensitivity of the sensor.
<code>diode_vis_1</code>	Yes	{0,1}	1	The photodiode used by the first light sensor when taking a visible-light measurement, corresponding to the small (0) and medium (1) photodiodes. Larger values increase the sensitivity of the sensor.
<code>diode_ir_2</code>	Yes	{0,1,2}	2	The photodiode used by the second light sensor when taking an infrared measurement, corresponding to the small (0), medium (1) and large (2) photodiodes. Larger values increase the sensitivity of the sensor.
<code>diode_vis_2</code>	Yes	{0,1}	1	The photodiode used by the second light sensor when taking a visible-light measurement, corresponding to the small (0) and medium (1) photodiodes. Larger values increase the sensitivity of the sensor.
<code>diode_ir_3</code>	Yes	{0,1,2}	2	The photodiode used by the third light sensor when taking an infrared measurement, corresponding to the small (0), medium (1) and large (2) photodiodes. Larger values increase the sensitivity of the sensor.
<code>diode_vis_3</code>	Yes	{0,1}	1	The photodiode used by the third light sensor when taking a visible-light measurement, corresponding to the small (0) and medium (1) photodiodes. Larger values increase the sensitivity of the sensor.
<code>led_1_ir</code>	Yes	{0, ..., 4095}	0	The brightness setting of the infrared (IR) LED above the first light-intensity sensor. Higher values correspond to higher brightness.
<code>led_1_uv</code>	Yes	{0, ..., 4095}	0	The brightness setting of the ultraviolet (UV) LED above the first light-intensity sensor. Higher values correspond to higher brightness.
<code>led_2_ir</code>	Yes	{0, ..., 4095}	0	The brightness setting of the infrared (IR) LED above the second light-intensity sensor. Higher values correspond to higher brightness.
<code>led_2_uv</code>	No	{0, ..., 4095}	0	The brightness setting of the ultraviolet (UV) LED above the second light-intensity sensor. Higher values correspond to higher brightness. In each measurement cycle, the chamber first measures <code>ir_1</code> and then sets <code>led_2_uv</code> following (1), before proceeding to measure <code>ir_2</code> , <code>current_led_2_uv</code> and <code>current_led_2_uv_raw</code> .
<code>led_3_ir</code>	Yes	{0, ..., 4095}	0	The brightness setting of the infrared (IR) LED above the third light-intensity sensor. Higher values correspond to higher brightness.
<code>led_3_uv</code>	No	{0, ..., 4095}	0	The brightness setting of the ultraviolet (UV) LED above the third light-intensity sensor. Higher values correspond to higher brightness. In each measurement cycle, the chamber first measures <code>ir_2</code> and then sets <code>led_3_uv</code> following (2), before proceeding to measure <code>ir_3</code> , <code>current_led_3_uv</code> and <code>current_led_3_uv_raw</code> .
<code>current_led_1_ir</code>	No	float	–	Measurement (in Amperes) of the current drawn by the IR LED above the first sensor.

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Variable	Settable	Values	Default	Description
<code>current_led_1_ir_raw</code>	No	<code>{-32768,...,32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_1_ir</code> .
<code>offset_current_led_1_ir</code>	Yes	<code>{0,...,4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_led_1_ir</code> and <code>current_led_1_ir_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_led\_1\_ir}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_1_ir</code> result in lower values of <code>current_led_1_ir_raw</code>.</p>
<code>sps_current_led_1_ir</code>	Yes	<code>{0,...,7}</code>	7	The data rate of the ADC producing the <code>current_led_1_ir</code> and <code>current_led_1_ir_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_led_1_ir</code>	Yes	<code>{0,...,5}</code>	0	The resolution of the ADC producing the <code>current_led_1_ir</code> and <code>current_led_1_ir_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768,32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>current_led_1_uv</code>	No	float	–	Measurement (in Amperes) of the current drawn by the UV LED above the first sensor.
<code>current_led_1_uv_raw</code>	No	<code>{-32768,...,32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_1_uv</code> .
<code>offset_current_led_1_uv</code>	Yes	<code>{0,...,4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_led_1_uv</code> and <code>current_led_1_uv_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_led\_1\_uv}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_1_uv</code> result in lower values of <code>current_led_1_uv_raw</code>.</p>
<code>sps_current_led_1_uv</code>	Yes	<code>{0,...,7}</code>	7	The data rate of the ADC producing the <code>current_led_1_uv</code> and <code>current_led_1_uv_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_led_1_uv</code>	Yes	<code>{0,...,5}</code>	0	The resolution of the ADC producing the <code>current_led_1_uv</code> and <code>current_led_1_uv_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768,32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code> , if the input voltage exceeds the set range.
<code>current_led_2_ir</code>	No	float	–	Measurement (in Amperes) of the current drawn by the IR LED above the second sensor.
<code>current_led_2_ir_raw</code>	No	<code>{-32768,...,32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_2_ir</code> .
<code>offset_current_led_2_ir</code>	Yes	<code>{0,...,4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_led_2_ir</code> and <code>current_led_2_ir_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_led\_2\_ir}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_2_ir</code> result in lower values of <code>current_led_2_ir_raw</code>.</p>
<code>sps_current_led_2_ir</code>	Yes	<code>{0,...,7}</code>	7	The data rate of the ADC producing the <code>current_led_2_ir</code> and <code>current_led_2_ir_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.

Table 1: Description of the variables produced by the chamber configuration `lt_mk2_linked_leds`. Settable variables can be manipulated by calling `.set(<variable>,<value>)`. “float” corresponds to a 32-bit float.

Variable	Settable	Values	Default	Description
<code>res_current_led_2_ir</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>current_led_2_ir</code> and <code>current_led_2_ir_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at $-32768$ or $32767$ , if the input voltage exceeds the set range.
<code>current_led_2_uv</code>	No	float	–	Measurement (in Amperes) of the current drawn by the UV LED above the second sensor.
<code>current_led_2_uv_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_2_uv</code> .
<code>offset_current_led_2_uv</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_led_2_uv</code> and <code>current_led_2_uv_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_led\_2\_uv}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_2_uv</code> result in lower values of <code>current_led_2_uv_raw</code>.</p>
<code>sps_current_led_2_uv</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>current_led_2_uv</code> and <code>current_led_2_uv_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_led_2_uv</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>current_led_2_uv</code> and <code>current_led_2_uv_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at $-32768$ or $32767$ , if the input voltage exceeds the set range.
<code>current_led_3_ir</code>	No	float	–	Measurement (in Amperes) of the current drawn by the IR LED above the third sensor.
<code>current_led_3_ir_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_3_ir</code> .
<code>offset_current_led_3_ir</code>	Yes	<code>{0, ..., 4095}</code>	0	The reference voltage (offset) of the ADC producing the <code>current_led_3_ir</code> and <code>current_led_3_ir_raw</code> measurements. The actual reference voltage (in Volts) is given by $5 \times \frac{\text{offset\_current\_led\_3\_ir}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_3_ir</code> result in lower values of <code>current_led_3_ir_raw</code>.</p>
<code>sps_current_led_3_ir</code>	Yes	<code>{0, ..., 7}</code>	7	The data rate of the ADC producing the <code>current_led_3_ir</code> and <code>current_led_3_ir_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.
<code>res_current_led_3_ir</code>	Yes	<code>{0, ..., 5}</code>	0	The resolution of the ADC producing the <code>current_led_3_ir</code> and <code>current_led_3_ir_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code> . The voltage ranges are, respectively, $\pm 6.144$ , $\pm 4.096$ , $\pm 2.048$ , $\pm 1.024$ , $\pm 0.512$ and $\pm 0.256$ Volts. The reading will saturate, i.e., clamp at $-32768$ or $32767$ , if the input voltage exceeds the set range.
<code>current_led_3_uv</code>	No	float	–	Measurement (in Amperes) of the current drawn by the UV LED above the third sensor.
<code>current_led_3_uv_raw</code>	No	<code>{-32768, ..., 32767}</code>	–	The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_led_3_uv</code> .

Table 1: Description of the variables produced by the chamber configuration `lt_mk2_linked_leds`. Settable variables can be manipulated by calling `.set(<variable>, <value>)`. “float” corresponds to a 32-bit float.

Variable	Settable	Values	Default	Description
<code>offset_current_led_3_uv</code>	Yes	<code>{0, ..., 4095}</code>	0	<p>The reference voltage (offset) of the ADC producing the <code>current_led_3_uv</code> and <code>current_led_3_uv_raw</code> measurements. The actual reference voltage (in Volts) is given by</p> $5 \times \frac{\text{offset\_current\_led\_3\_uv}}{4095}.$ <p>Because the signal from the current sensor is passed through an inverting amplifier, higher values of <code>offset_current_led_3_uv</code> result in lower values of <code>current_led_3_uv_raw</code>.</p>
<code>sps_current_led_3_uv</code>	Yes	<code>{0, ..., 7}</code>	7	<p>The data rate of the ADC producing the <code>current_led_3_uv</code> and <code>current_led_3_uv_raw</code> measurements. Lower values mean the ADC accumulates more readings to produce a single measurement, reducing noise but also lowering the measurement speed. The actual data rates are (respectively) 8, 16, 32, 64, 128, 250, 475 and 860 samples per second.</p>
<code>res_current_led_3_uv</code>	Yes	<code>{0, ..., 5}</code>	0	<p>The resolution of the ADC producing the <code>current_led_3_uv</code> and <code>current_led_3_uv_raw</code> measurements. Higher values mean a higher resolution, where a smaller voltage range is mapped to the ADC output range <code>{-32768, 32767}</code>. The voltage ranges are, respectively, <math>\pm 6.144</math>, <math>\pm 4.096</math>, <math>\pm 2.048</math>, <math>\pm 1.024</math>, <math>\pm 0.512</math> and <math>\pm 0.256</math> Volts. The reading will saturate, i.e., clamp at <code>-32768</code> or <code>32767</code>, if the input voltage exceeds the set range.</p>
<code>current_supply</code>	No	float	–	<p>The current drawn by the chamber and all its components, including the onboard computer and server. Used for diagnosis.</p>
<code>current_supply_raw</code>	No	<code>{0, ..., 1023}</code>	–	<p>The uncalibrated measurement, i.e., the raw ADC output, corresponding to the measurement <code>current_supply</code>.</p>
<code>pot_1_volts</code>	No	float	–	<p>The raw voltage (in volts) of the first angle sensor. Used for diagnosis.</p>
<code>pot_2_volts</code>	No	float	–	<p>The raw voltage (in volts) of the second angle sensor. Used for diagnosis.</p>

Table 1: Description of the variables produced by the chamber configuration `lt_mk2_linked_leds`. Settable variables can be manipulated by calling `.set(<variable>, <value>)`. “float” corresponds to a 32-bit float.

### Causal Ground Truth

The graph below can be interpreted as a causal ground truth, where an edge  $X \rightarrow Y$  signifies that an intervention on  $X$  will change the distribution of subsequent measurements of  $Y$ . This causal interpretation is formalized in Gamella et al. [2025, Appendix V]. Note that the absence of an edge between two variables does not preclude the existence of a causal effect between them. As with most real systems, effects between observed variables may exist beyond what we know or can validate through experimentation, e.g., due to a lack of statistical power. Furthermore, there may be confounding effects where unmeasured external variables simultaneously affect some of the variables in the chamber, such as ambient pressure or lighting conditions. For more details, we refer the reader to Gamella et al. [2025, Appendix V].

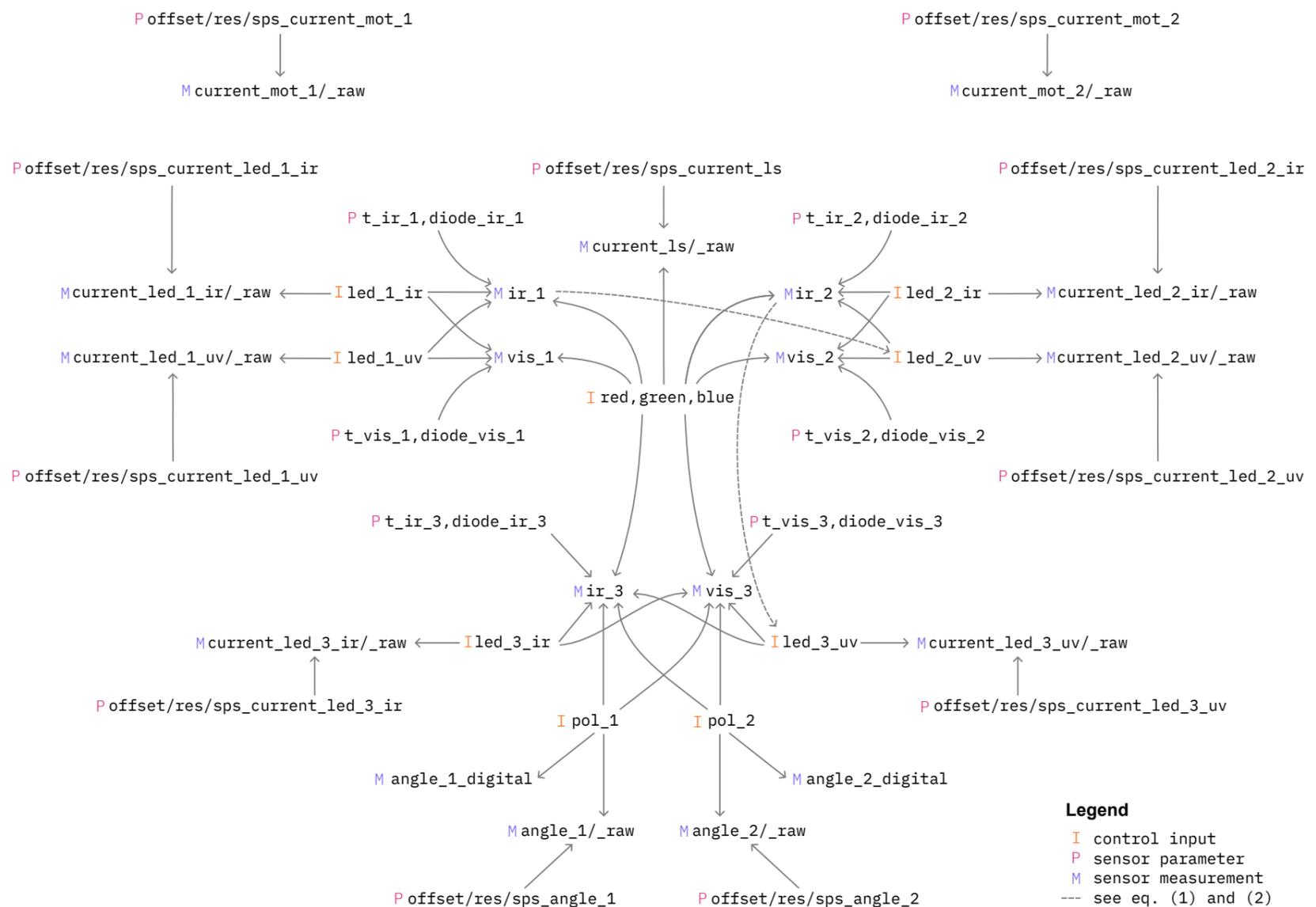


Figure 1: Graph representation of the known effects between the variables of the chamber. We use some shorthand notation to simplify the graph: node labels separated by a comma correspond to independent nodes with the same incident edges, e.g., a node var\_1, var\_2 corresponds to two separate nodes var\_1 and var\_2. Similarly, a node a/b/c\_var is shorthand notation for the separate nodes a\_var, b\_var, and c\_var.

### References

Juan L. Gamella, Jonas Peters, and Peter Bühlmann. Causal chambers as a real-world physical testbed for AI methodology. *Nature Machine Intelligence*, 2025. doi: 10.1038/s42256-024-00964-x.