Electronics
Open- and closed-loop control

Closed-loop control

Brightness control with CASSY

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.
Brightness control

Experiment description

This experiment realizes a brightness control for a light bulb using variable series resistors. A PI controller is used here. A PI controller determines the system deviation $w-x$ from the measured value $x = R_{A1}$ (resistance of an LDR) and the reference variable $w$ (set value of the LDR resistance).

Together with the base load $y_0$, this gives us the manipulated variable $y = y_0 + K_P (w-x) + K_I \int (w-x) \, dt$ for the PI controller. The proportional-action coefficient $K_P$ and the integral-action coefficient $K_I$ as control parameters can be optimized so that after a deviation (e.g. an additional series resistor, a change in the reference variable $w$ or the base load $y_0$) the system returns to a system deviation $w-x$ of about 0 as soon as possible.

If only a P-controller is used ($K_I = 0$), a residual system deviation $w-x$ occurs which does not disappear until an I-component is applied.

Equipment list

1. Sensor-CASSY 524 010 or 524 013
2. CASSY Lab 2 524 220
3. Current source box 524 031
4. Plug-in board DIN A4 576 74
5. Lamp socket E10, side 579 05
6. Set of 10 lamps 3.8 V/0.07 A 505 10
7. Toggle-switch, single-pole 579 13
8. Photoresistor LDR05 578 02
9. STE resistor 10 $\Omega$, 2 W 577 20
10. STE resistor 20 $\Omega$, 2 W 577 13
11. STE resistor 47 $\Omega$, 2 W 577 28
12. STE resistor 100 $\Omega$, 2 W 577 32
2. Pairs of cables, 100 cm, red and blue 501 46
1. PC with Windows XP/Vista/7/8

Experiment setup (see drawing)

The voltage source S supplies the lamp via a 100 $\Omega$ protective resistor. The brightness of the lamp is measured using a light-dependent resistor together with the current source box at CASSY input A.

Additional series resistors can be switched on with the toggle switch to produce deviations. A closed toggle switch shorts the series resistor, and an open toggle switch leaves it in the circuit.

Carrying out the experiment

- Load settings
- Turn the potentiometer of the voltage source S all the way to the right.
The lamp lights up already, as a base load $y_0$ of 0.5 has been set. This means that PWM output S is operating at a duty factor of 50%.

Change the base load $y_0$ as you like, by setting the corresponding parameter value in the Settings $y_0$ (right mouse button).

Enter the measured resistance as the reference variable $w$ by moving the pointer of the display instrument with the mouse or changing the value of the parameter in the Settings $w$ (right mouse button).

Start the control with $\square$ and stop it at the appropriate time with $\square$.

During control, a deviation can be applied, e.g. by switching a series resistor or changing the reference variable or base load.

You can optimize your controller by varying the proportional-action ($K_P$) and integral-action ($K_I$) coefficients; set the corresponding values in Settings $K_P$ or $K_I$ (right mouse button).

**Evaluation**

The recorded curves clearly illustrate the quality of the controller. The black line represents the reference variable $w$ (set value). The red curve represents the controlled variable $x$ (measured value) and should converge with the black curve quickly following a deviation. The blue curve represents the manipulated variable $y$ and thus corresponds to the lamp voltage.

**Empirically optimizing the PI brightness controller**

Set negative values for $K_P$ and $K_I$, as the measured resistance value of the sensor box becomes less the greater the voltage at the voltage source S is.

- Set $K_I$ to 0, and increase $K_P$ in moderate steps (e.g. by -0.1) until the control loop oscillates.
- Reduce $K_P$ again until the oscillations die out. A residual system deviation is created.
- Increase $K_I$ in moderate steps (e.g. by $10 \times K_P$) until the system oscillates again.
- Reduce $K_I$ again until the oscillations die out. Note that the controller becomes slower, the lower $K_I$ becomes.

In this example, we have used $K_P = 0.5$ and $K_I = 5 \text{/s}$.

**Automatically varying the reference variable**

The reference variable $w$ (set value) can be varied not only manually, but automatically as well. We can do this, for example, by entering the formula $1 + 0.5 \times \sin(360 \times t / 20)$ in the Settings $w$. This results in control of a sinusoidal resistance curve of the LDR between 0.5 kΩ and 1.5 kΩ with a period of 20 s.