WORKSHEET

U5.4 The integral term

Feedback control · University · about 30 min

Name _____ Class _____ Date _____

What this lesson is about

Removing the error that P leaves behind, and the windup that comes with it.

- In code
- Windup
- Choosing Ki

Questions

7 marks in all

1. A PI controller has settled exactly on target. Which term is supplying the command? [1 mark]

- ☐ **A** The integral term
- ☐ **B** The proportional term
- ☐ **C** Both equally
- ☐ **D** Neither, the command is zero

2. A constant 4 cm error is held for five ticks. What does this print? [1 mark]

```
KP, KI, DT = 1.6, 0.5, 0.1
integral = 0.0
for tick in range(5):
    error = 4.0
    integral += error * DT
    print(round(KP * error + KI * integral, 2))
```

3. Using the lesson's rule of thumb, how many seconds does the integral take to contribute as much as the proportional term when Kp = 1.6 and Ki = 0.5? Give one decimal place. [1 mark]

4. Which of these are the standard defences against integral windup given in the lesson? [1 mark]

Tick every answer that is true.

- ☐ **A** Clamp the integral to a sensible range
- ☐ **B** Stop integrating while the output is saturated
- ☐ **C** Subtract the clipped amount, scaled, from the integral
- ☐ **D** Raise Kp so the error shrinks faster
- ☐ **E** Filter the error before integrating it

5. An obstacle holds the robot at 40 cm while the target is 25 cm. Ten seconds later it is removed and the robot charges far past the target. Why? [1 mark]

- ☐ **A** The integral grew the whole time and must be unwound by an error in the other direction
- ☐ **B** Kp is too high
- ☐ **C** The D term amplified the removal of the obstacle
- ☐ **D** The sensor was biased by the obstacle

6. The error is in cm, the command in percent, and time in seconds. What are the units of Ki? [1 mark]

7. The robot sails slowly past the target, turns round, and sails past again with large, slow swings. Which gain is the likely cause? [1 mark]

- ☐ **A** Ki too large
- ☐ **B** Kd too large
- ☐ **C** Kp too small
- ☐ **D** The dead band too small

The task: no offset left

Settle exactly 25 cm from the wall, within 3 cm, from fourteen seconds onwards. Proportional control alone at a gentle gain will not do it: at `Kp = 1.5` it stops about 8 cm short, because this drive does nothing below about 15 percent. Plot `error` and `i term`.

```
from bugbot import *
connect()

KP, KI = 1.5, 0.8
TARGET = 25.0
DT = 0.1
integral = 0.0
```

Plan your program here, then type it in and press Run.

Do it on the robot

www.bugbotlab.com/learn/u5-4-integral/

The simulator checks it and tells you when it passes. Nothing to install, no account.

Challenges

1. Set `Ki = 0` and report the offset the robot settles at.
2. Remove the clamp and hold the robot back by hand for a few seconds. Describe the result.
3. Plot the P term and the I term separately and watch which one is carrying the command at the end.
