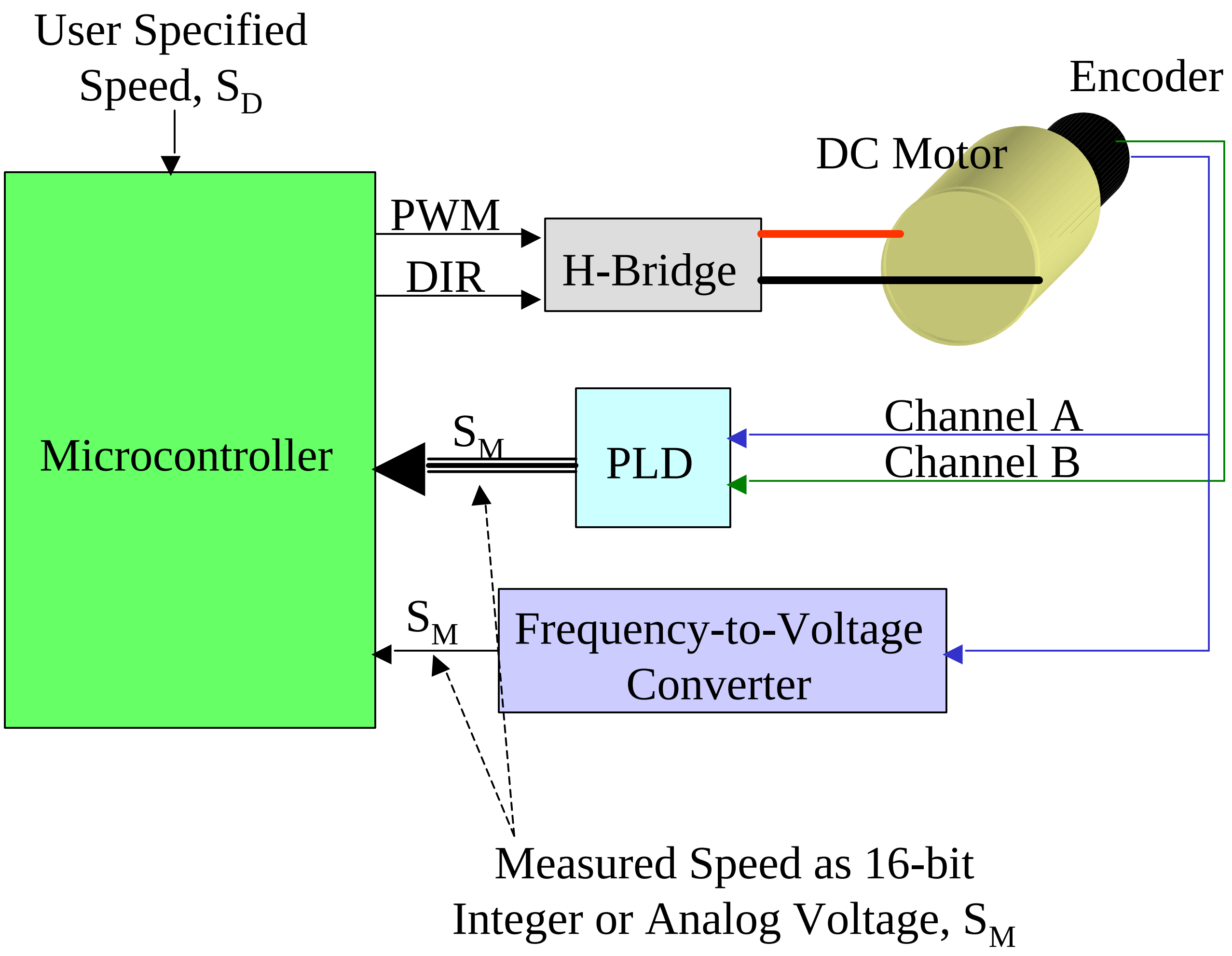
DC Motor Speed Control

- useful for maintaining robot’s speed in the presence of uncertainty (ramps, battery voltage variations, robot weight variations, ...)
- objective is to vary PWM duty cycle such that motor moves at a specified (desired) speed
- simple proportional type control is presented

DC Motor Speed Control



User Specified Speed, S_D

Encoder

DC Motor

PWM

DIR

H-Bridge

Microcontroller

S_M

PLD

Channel A

Channel B

S_M

Frequency-to-Voltage Converter

Measured Speed as 16-bit Integer or Analog Voltage, S_M

DC Motor Speed Control

- simplest to leave speed measurements in microcontroller units as opposed to converting them to rpm or rad/sec
- start simple - try to relate PWM duty cycle to measured motor speed S_M by generating PWM signal for many duty cycles and recording the resulting measured motor speed S_M

Duty Cycle	S_M
0	0
10	2
20	15
30	28
40	43
⋮	⋮

- determine constant K relating duty cycle and measured speed such that

duty cycle = K S_M (K ≈ 1, for example)

- given K and desired speed S_D (in same units as S_M), the appropriate duty cycle to apply can be found from

duty cycle = K S_D ⟸ Open-Loop Control

DC Motor Speed Control

- open-loop speed control is great for motor system that never changes
- our motor system is likely to vary
  - – battery voltage will drop as robot operates
  - – load will increase/decrease with ramps and robot weight
  - ⇒ need a mechanism to adjust speed based upon what speed robot is actually moving (too slow → speed up, too fast → slow down)
  - ⇒ need feedback (closed-loop) control
- simple closed-loop control approach - add proportional feedback control to open-loop control

$$\text{duty cycle} = \underbrace{K\,S_D}_{\text{predicted duty cycle}} + \underbrace{K_P(S_D - S_M)}_{\text{duty cycle adjustment}}$$

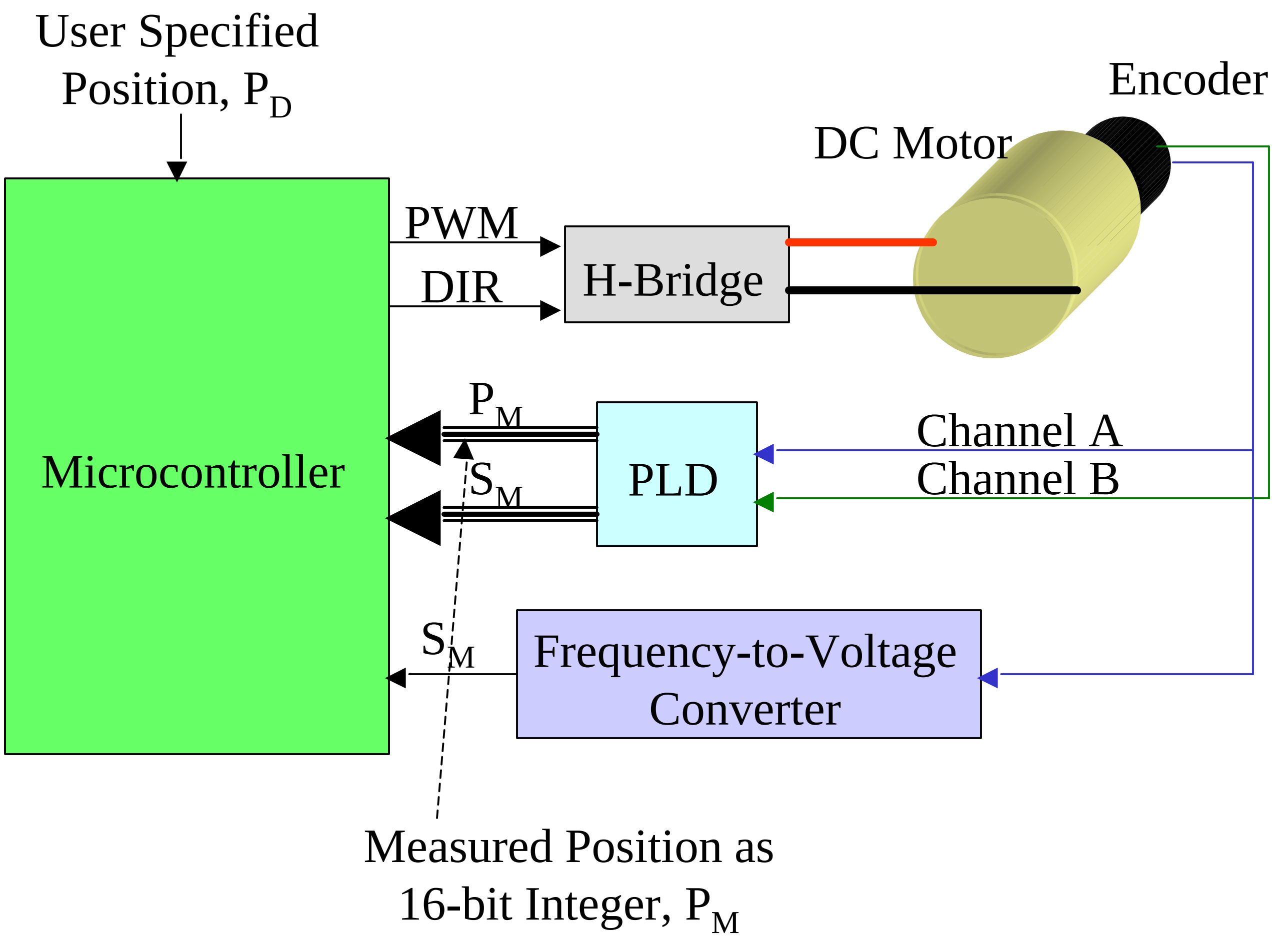
- K found by relating motor speed to duty cycle, K_P found experimentally

→ note: K, K_P need to be determined for each motor independently

DC Motor Position Control

- useful for fixed distance movements such as rotating robot 180° to exit a room after checking for candle
- objective is to vary PWM duty cycle such that motor rotates specified angle
- simple scheme utilizing previous closed-loop motor speed control is presented

DC Motor Position Control

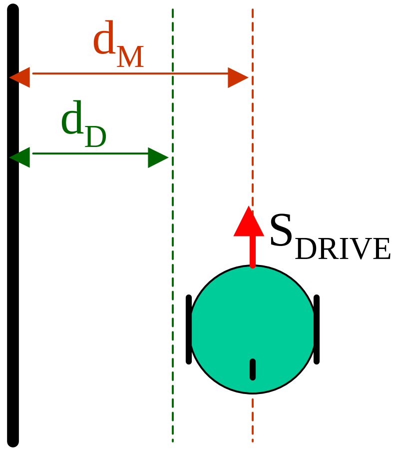


DC Motor Position Control

- simple position monitoring scheme
- to rotate “close to” a desired amount P_D:
  - → send a speed S_D to closed-loop speed controller
  - → stop motor ($S_D = 0$) when measured motor position P_M reaches P_D
  - → dependent on friction (or braking) to stop motion
- robot drive system will typically have a fair amount of friction, so motion will stop close to P_D
- more advanced and accurate closed-loop position controllers can be implemented to specify duty cycle directly

Wall-Following Control

- useful for moving along a wall at a constant speed S_{DRIVE} and keeping a specified fixed distance d_D away from it
- differential drive is assumed, but can easily be extended to other wheeled robot designs
- "outer-loop" approach presented is built around "inner-loop" closed-loop speed controller



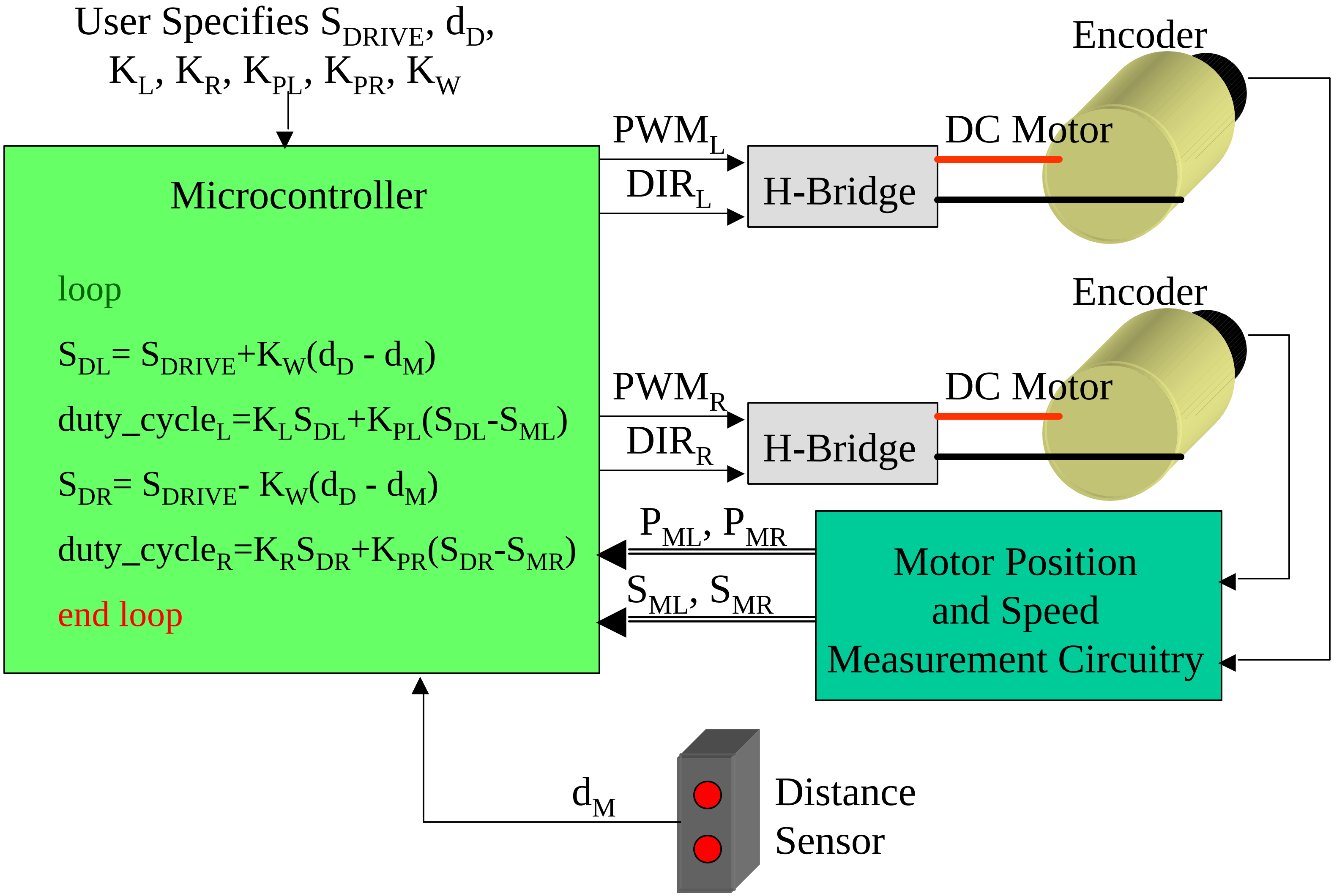
- left motor speed S_{DL} and right motor speed S_{DR} are determined from the measured distance to the wall d_M via (for left wall-following):

$$S_{DL} = S_{DRIVE} + K_W(d_D - d_M)$$

$$S_{DR} = S_{DRIVE} - K_W(d_D - d_M)$$

- constant gain K_W determined experimentally

Wall-Following Control



User Specifies S_{DRIVE}, d_D, K_L, K_R, K_{PL}, K_{PR}, K_W

Microcontroller

```
loop
    $S_{DL}= S_{DRIVE}+K_W(d_D - d_M)$
    $duty\_cycle_L=K_L S_{DL}+K_{PL}(S_{DL}-S_{ML})$
    $S_{DR}= S_{DRIVE}- K_W(d_D - d_M)$
    $duty\_cycle_R=K_R S_{DR}+K_{PR}(S_{DR}-S_{MR})$
end loop
```

PWM_L

DIR_L

H-Bridge

DC Motor

Encoder

PWM_R

DIR_R

H-Bridge

DC Motor

Encoder

P_{ML}, P_{MR}

S_{ML}, S_{MR}

Motor Position and Speed Measurement Circuitry

d_M

Distance Sensor