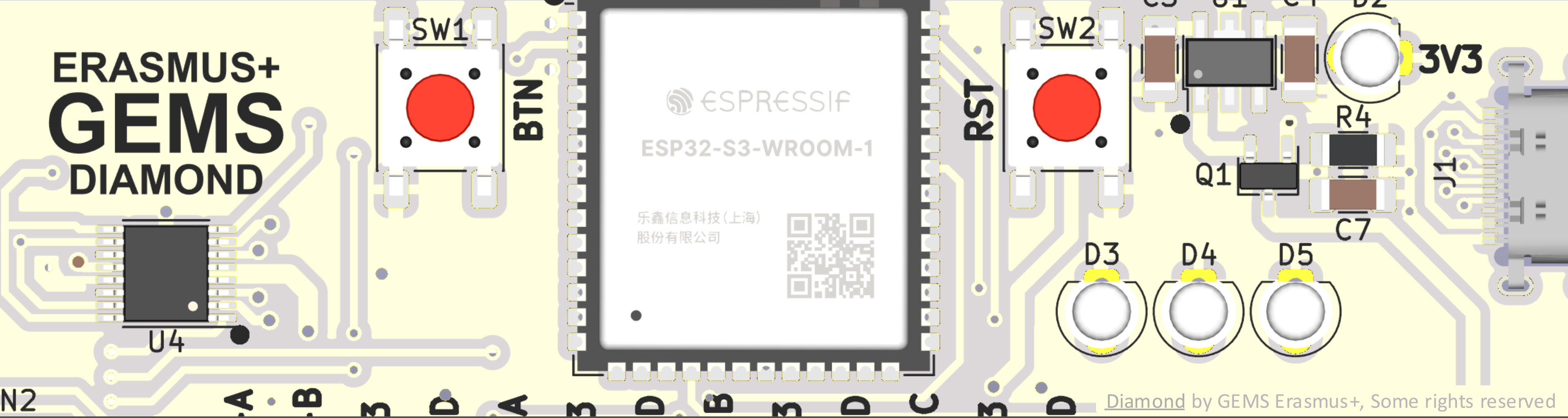
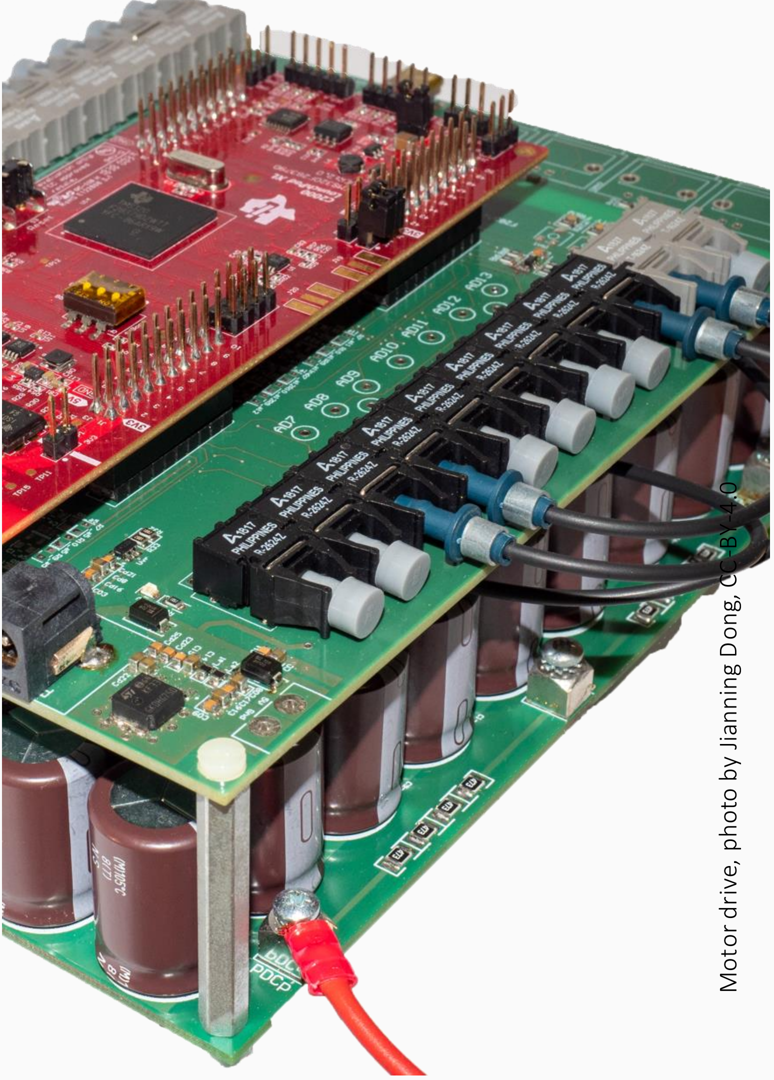


DC Motor Drives

Hardware overview and system architecture

Dr. Sachin Yadav



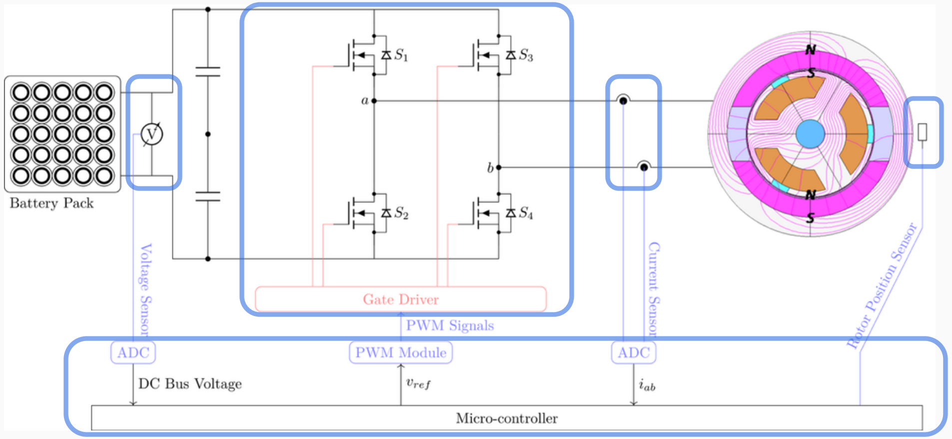
Motor drive, photo by Jianning Dong, CC-BY-4.0

Lecture Outline

1. DC drive system introduction
2. Hardware architecture
3. Feedback and sensing
4. Close-loop control

What is the system architecture of a DC drive system?

DC drive system overview



Power converter: power electronics, gate drivers etc. to enable a DC-DC conversion

DC bus voltage sensor: measure DC bus voltage to calculate duty cycle or for protection

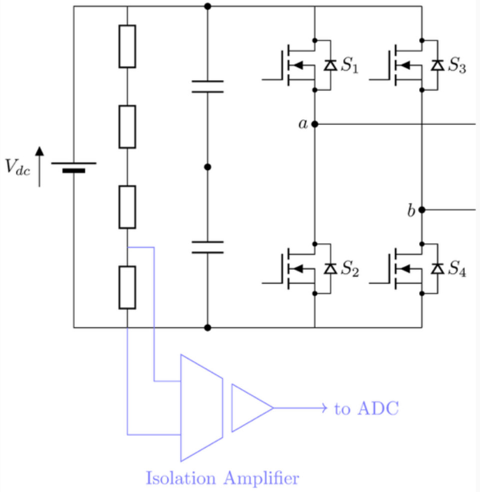
Armature current sensor: measure armature current for feedback control

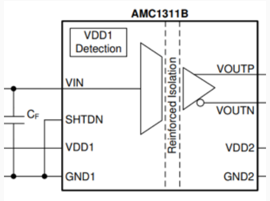
Rotor position sensor: measure the rotor speed and position for speed or position tracking

Control hardware: micro-controller (MCU), digital signal processor (DSP) or field-programmable gate array (FPGA) based hardware with pulse width modulation (PWM), analogue-digital conversion (ADC) and digital encoder/resolver interfaces etc.

How to sense the voltage, current and rotor position?

Voltage sensing hardware



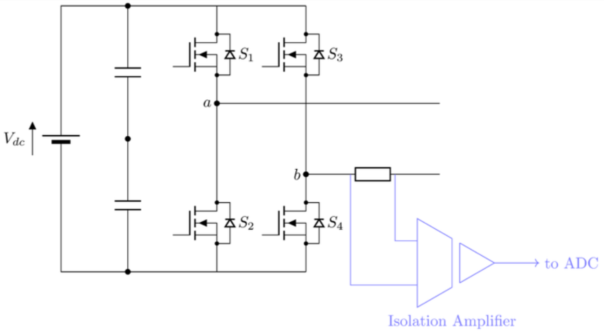


Source: Texas Instruments, https://www.ti.com/lit/ds/symlink/amc1311.pdf?ts=1755430089672

- Voltage divider with large resistance to turn high voltage to small signal;
- Isolation amplifier to isolate low voltage control circuit to high voltage power circuit.

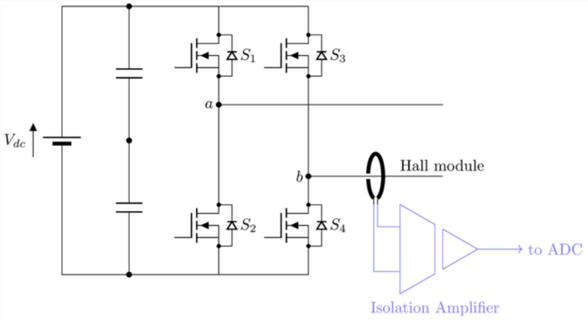
Current sensing hardware

Shunt resistor sensing



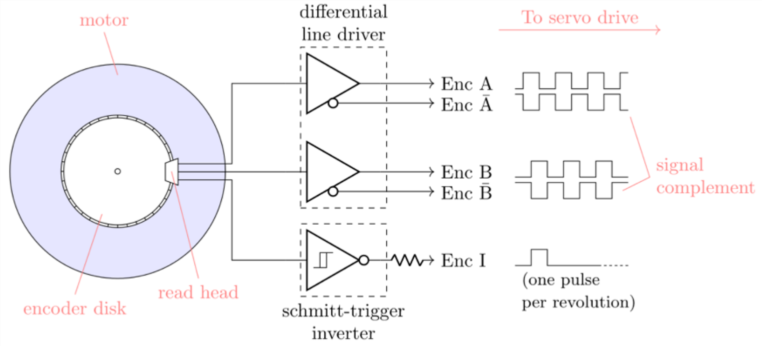
- Measure current via voltage drop across a small but precise in-line resistor
- Isolation amplifier needed
- Additional loss
- Immunity to magnetic interference
- High accuracy, small size

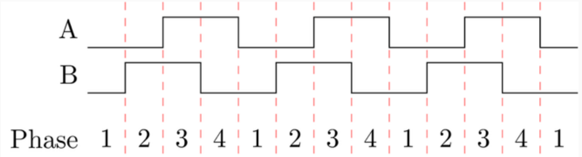
Hall effect based sensor

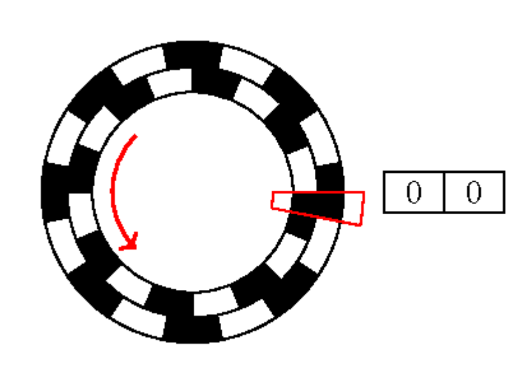


- Measure current based on hall effect: v_H proportional to magnetic field caused by current
- Vulnerable to magnetic interference
- Expensive for high accuracy
- No physical contact with main circuit: no isolation amplifier needed
- NO power dissipation

Rotor position sensing: quadrature encoder







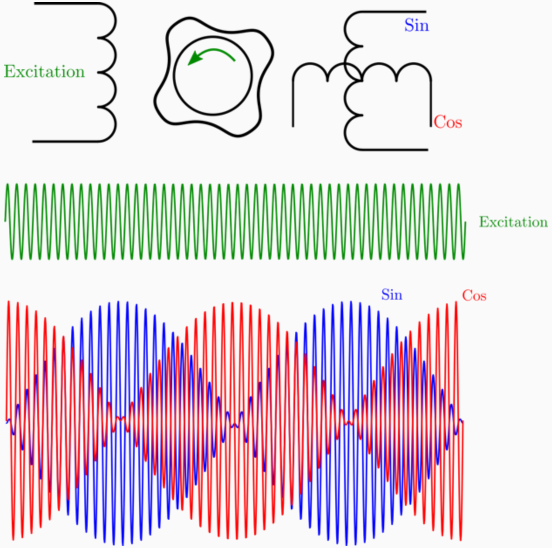
- Incremental couting at every rising/falling edge
- Index signal needed to know the absolute position (homing)

Rotor position sensing: advanced solutions

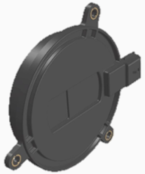
Variable reluctance resolver

Source: Tamagawa Seiki

- Three coils on teeth
  - Sin and Cos
  - Excitation

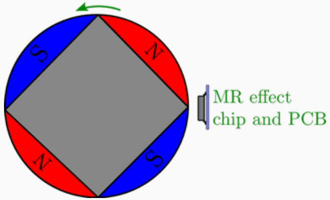


Magnetoresistive (MR) sensor



Source: Continental

- MR effect
  - Magnetic field controller resistance
  - Sine and cosine output

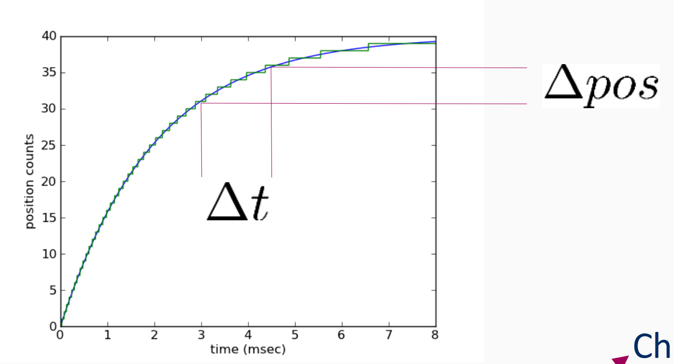


Other types of position sensors

- Brushless resolver (excitation by rotational transformer)
- Inductive position sensor
- Hall effect sensor

How to measure rotor speed from position sensors?

Measure speed from rotor positions



First order approximation $v = \frac{\mathrm{d}pos}{\mathrm{d}t} \approx \frac{\Delta pos}{\Delta t}$

Change in position

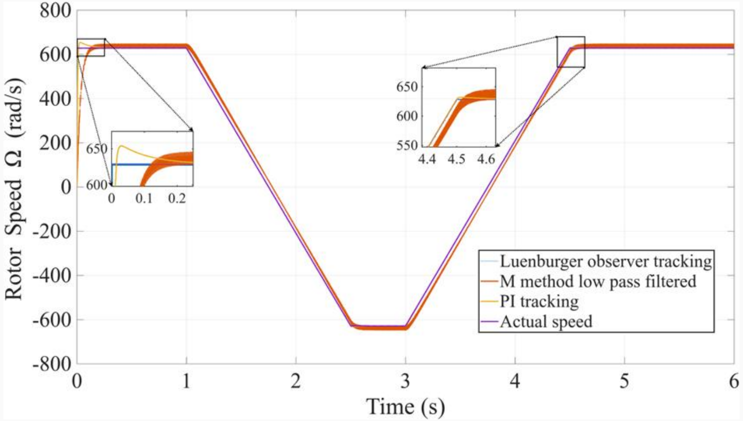
Change in time

- Fixed time increment (M method)
  - Δpos updated at fixed Δt
  - Speed resolution $1/\Delta t$
  - Suitable for moderate to high speed

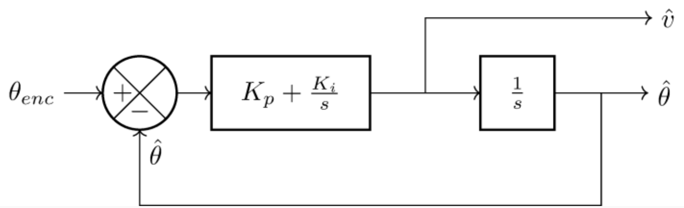
- Fixed change in position (T method)
  - Δt measured between a specific Δpos
  - Resolution based on speed
  - Zero speed not detectable
  - Suitable for low speed

Measure speed from rotor positions: tracking loop

- Problems first-order approximation
  - Time delay, limited bandwidth
  - None zero steady state error
  - Prone to noise



- Advanced solution: a tracking loop

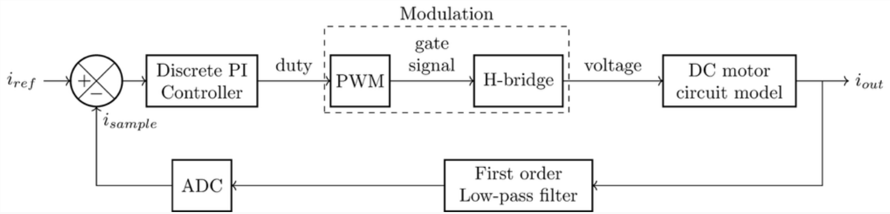


- Proportional-integral (PI) control loop or a Luenburger observer drives position estimation steady state error to 0.
- Integrate the estimated velocity to get the position.
- Optimal than M or T method for noise rejection and bandwidth.

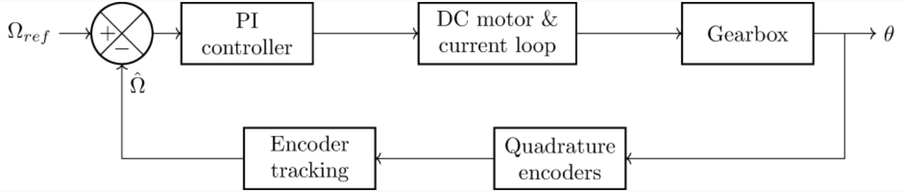
How to realize feedback control based on hardware components?

Feedback control of DC motor drive

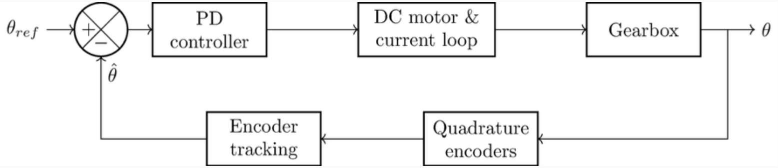
- Use sensor readings to approach reference values
  - Close-loop current control



  - Cascaded close-loop speed control

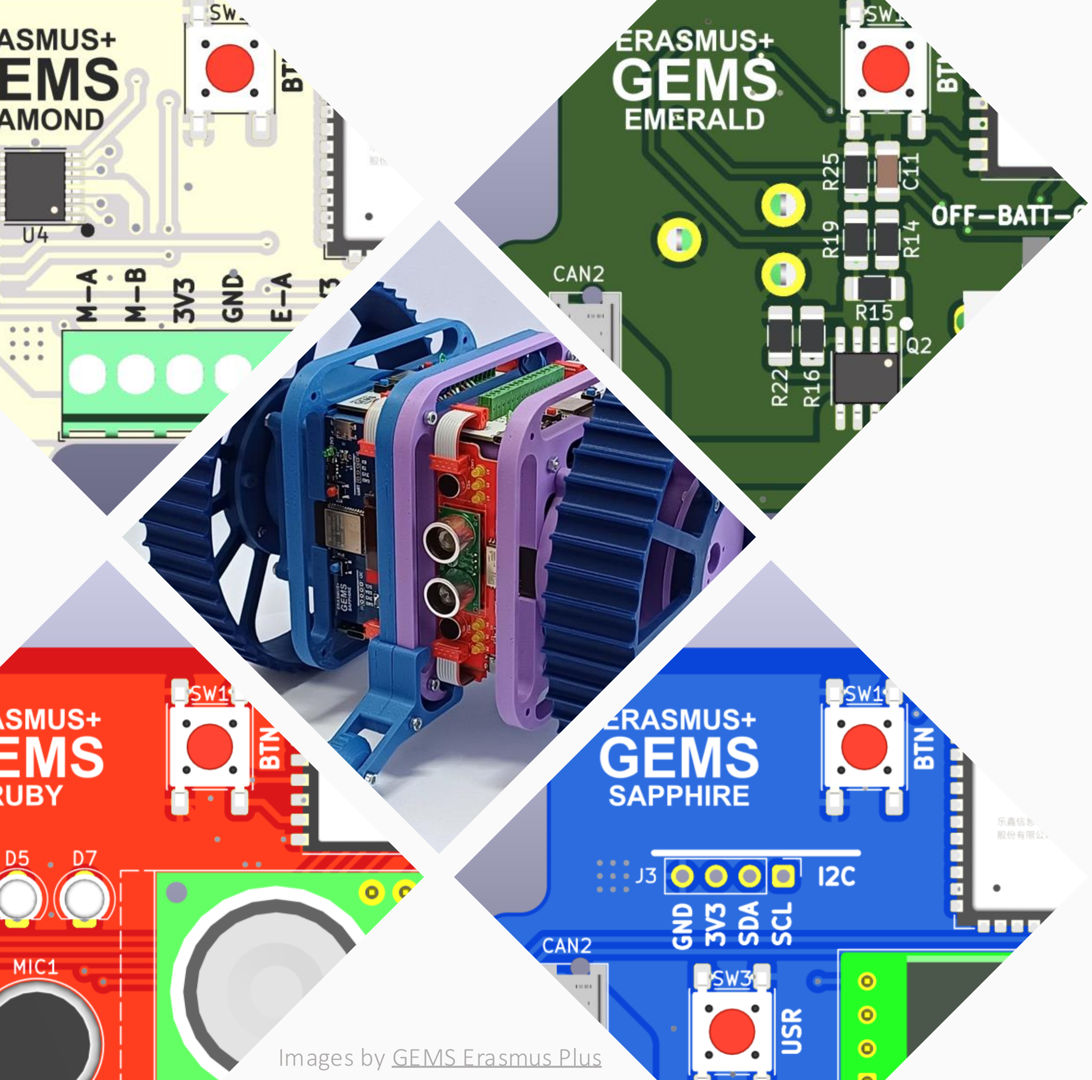


  - Cascaded close-loop position control



Conclusions

- DC motor drive consists hardware components: power converter, voltage/current sensors, position sensors and controller.
- Quadrature encoder measures incremental position change. Absolute position is measurable if a homing reference is used.
- A tracking loop can be used to estimate speed from position sensors.
- Various close loop controls are possible with feedback from sensors.



Images by GEMS Erasmus Plus

Thank you for watching!

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