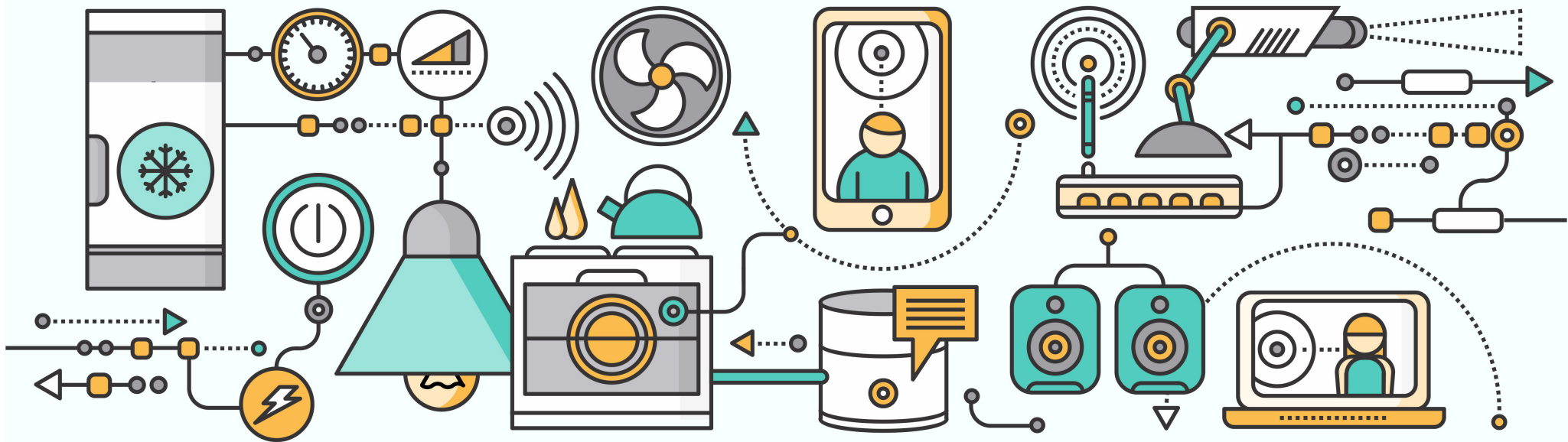# ENME 441
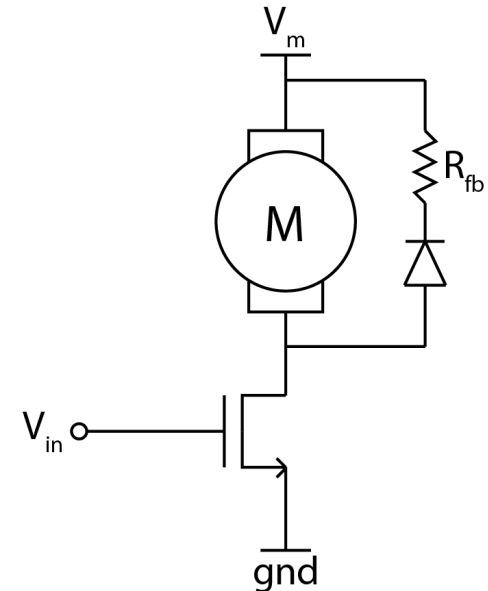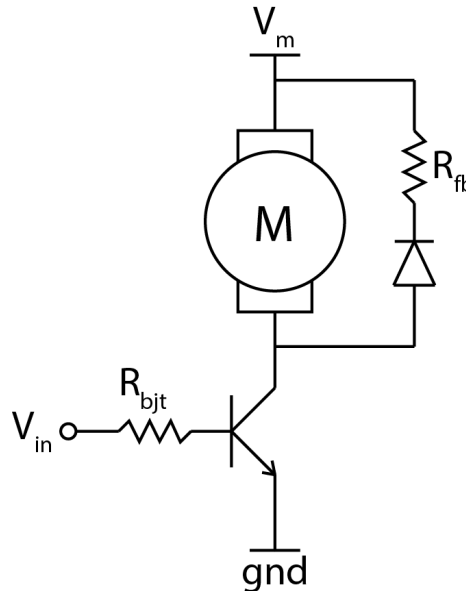# Mechatronics and the Internet of Things
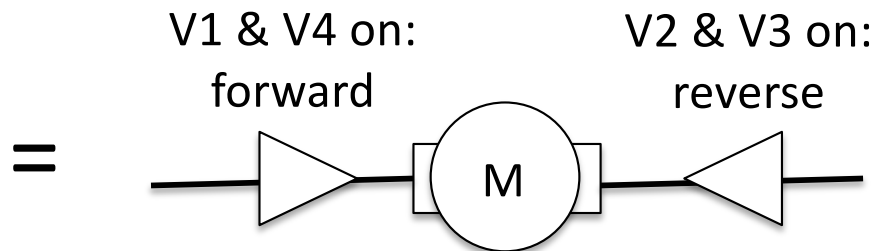

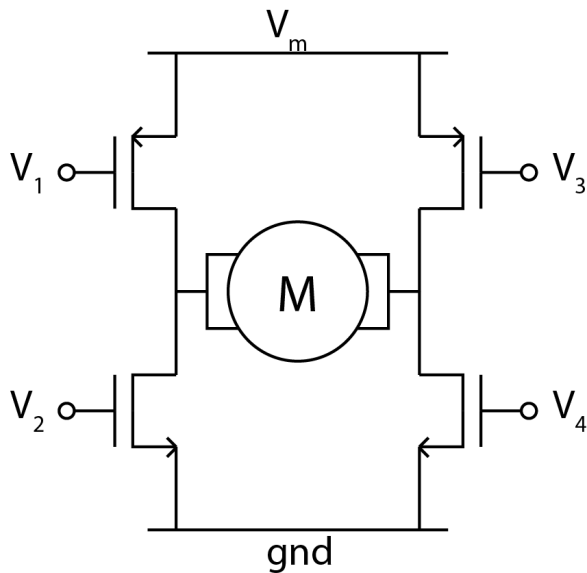**Motor Control (DC, Servo, Stepper)**

DC Motors

Forward drive using <u>BJT or CMOS</u> transistors for low-voltage PWM switching of motor current

V_m

M R_{fb}

R_{bjt}

V_{in}

gnd

V_m

M R_{fb}

V_{in}

gnd

H-bridge for bi-directional drive:

V_m

V_1 V_3

M

V_2 V_4

gnd

=

V1 & V4 on:
forward

M

V2 & V3 on:
reverse

L293D Dual H-Bridge

| 1,2EN | 1 | 16 | VCC1 | ← Vchip (5V) |

Pinout:
- 1,2EN — 1
- 1A — 2
- 1Y — 3
- gnd { 4, 5 }
- 2Y — 6
- 2A — 7
- Vmotor → VCC2 — 8 (4.5–36V)
- 16 — VCC1 ← Vchip (5V)
- 15 — 4A
- 14 — 4Y
- gnd { 13, 12 }
- 11 — 3Y
- 10 — 3A
- 9 — 3,4EN
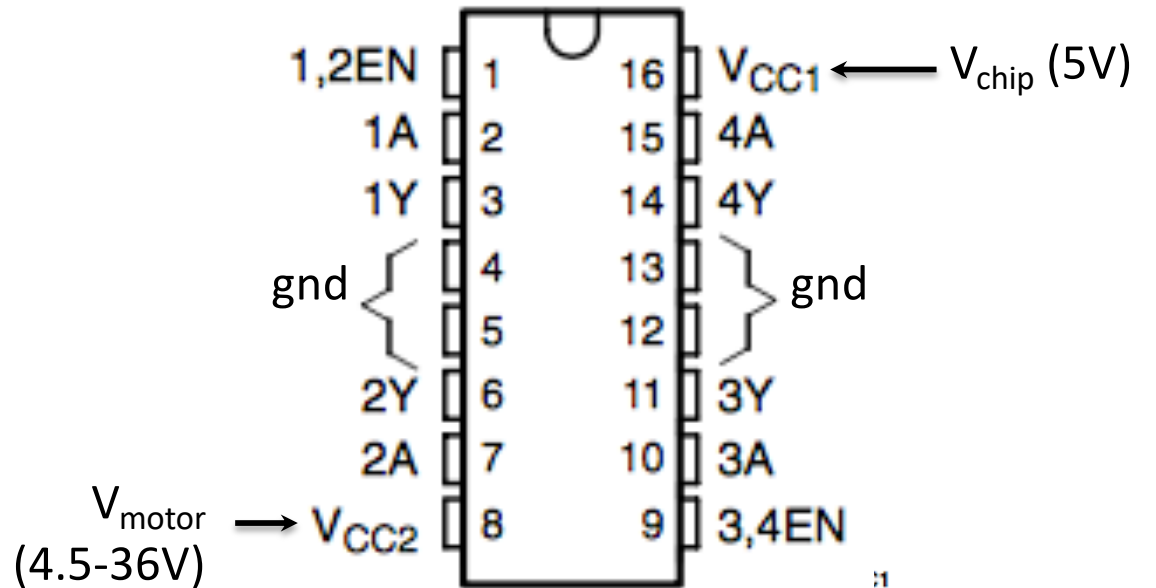
FUNCTION TABLE
(each driver)

| INPUTS† | | OUTPUT |
A	EN	Y
H	H	H
L	H	L
X	L	Z

H = high level, L = low level, X = irrelevant,
Z = high impedance (off)

Single drive

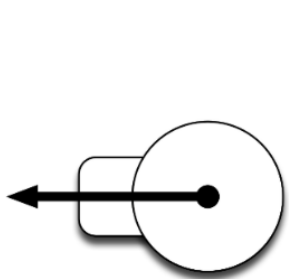Dual drive

1A — 2 — ▷ — 3 — 1Y
1,2EN — 1
2A — 7 — ▷ — 6 — 2Y

3A — 10 — ▷ — 11 — 3Y
3,4EN — 9
4A — 15 — ▷ — 14 — 4Y
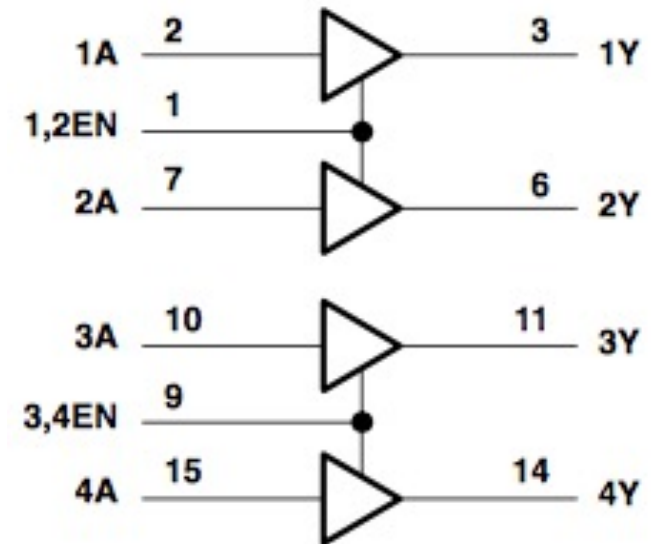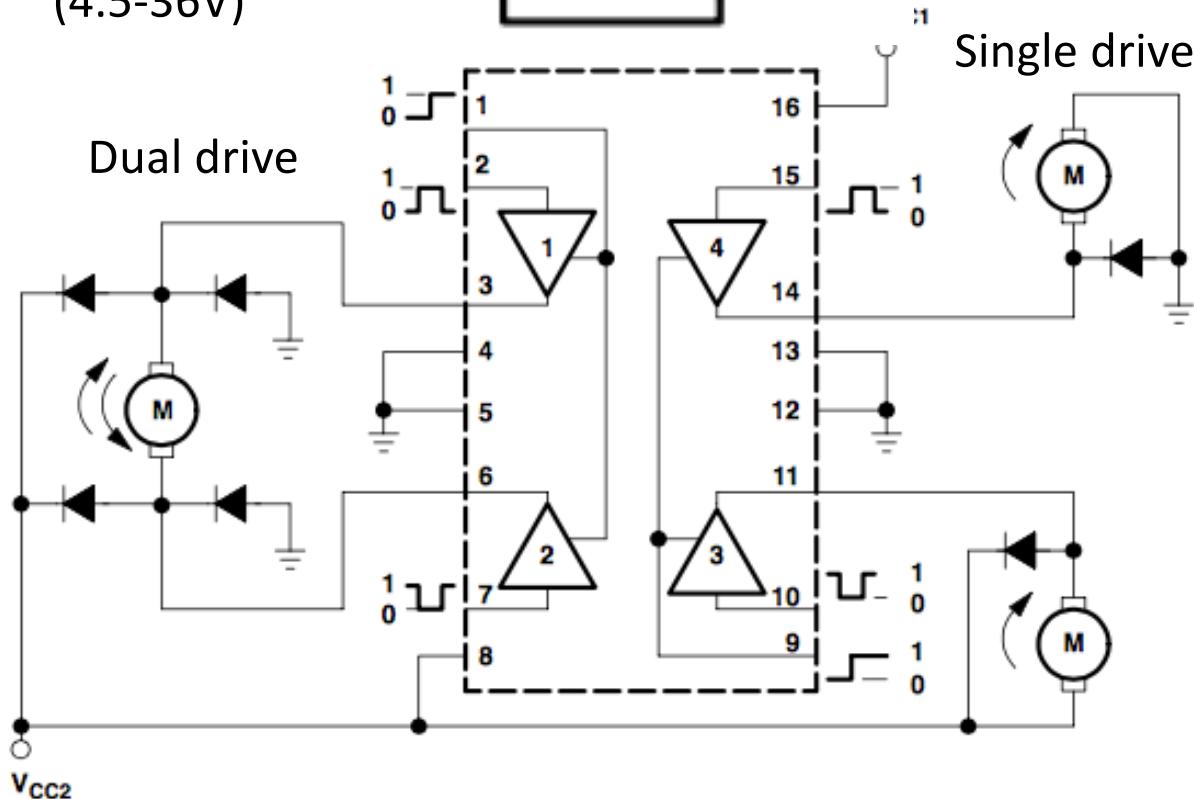
L293D: 600 mA per branch
L293: 1A per branch
L293N: 2A per branch

VCC2

Unidirectional Drive:
- For a single motor in position 1 or 4:
  - 0 V → motor off
  - 3.3 V → motor on
- Opposite behavior for positions 2 and 3
- Use PWM to control motor speed
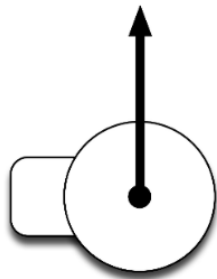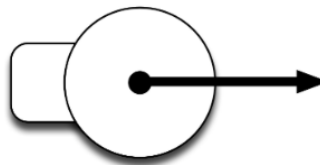
Servo Motors

Pinout:
- black/brown → gnd
- red → 5V
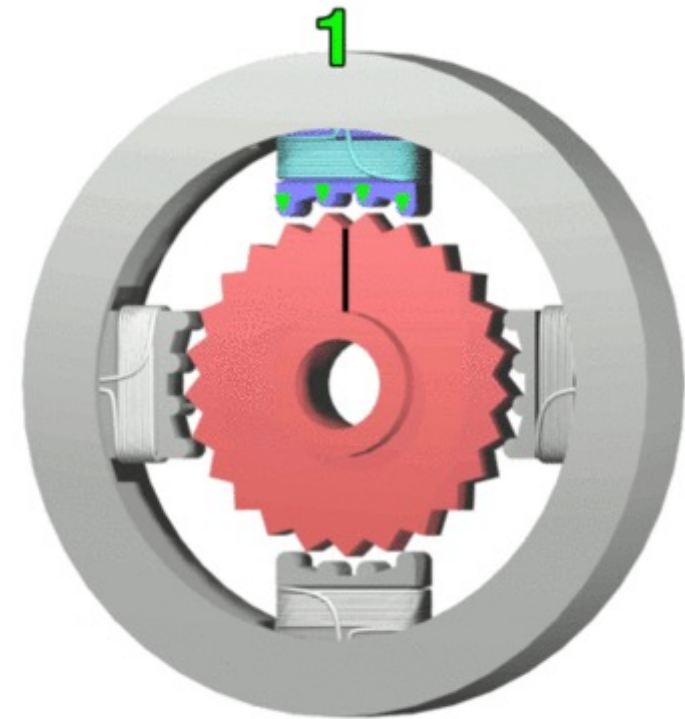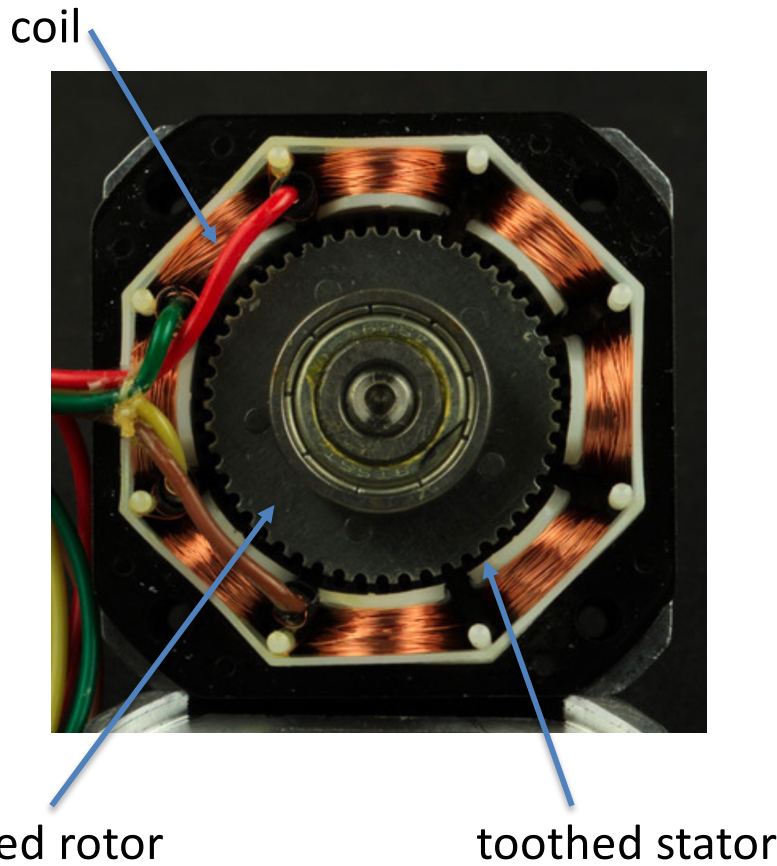- orange/white → PWM input

1 ms ON
19 ms OFF

1.5 ms ON
18.5 ms OFF

2 ms ON
18 ms OFF

- 20 ms period
- 1 ms ON = 5% duty cycle → full CCW
- 2 ms ON = 10% duty cycle → full CW

Servo motor codes: servo.py, servo_thread.py, servo_class.py

Stepper Motors

coil

toothed rotor

toothed stator

1

4-phase unipolar stepper motor
https://en.wikipedia.org/wiki/Stepper_motor

Advantages
Precise positioning & speed control
High torque @ low speeds (opposite of DC motors)

Disadvantages
Low efficiency & max speed
No integrated feedback (as in servo motors)

BYJ48 Stepper Motor

Motor specifications:

- 5 wire (unipolar) motor
- Rated Voltage: 5 V
- Input Resistance: 200 Ω
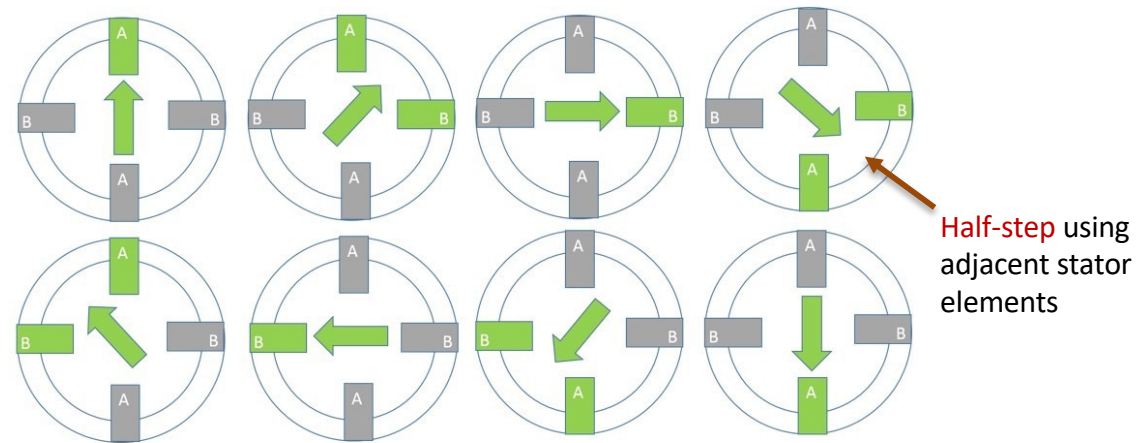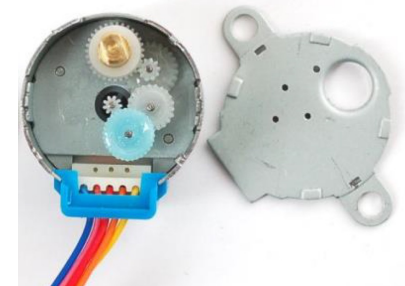- No-load frequency: >600 Hz
- Max. torque: 34 mN*m

Half-step using adjacent stator elements

Image shows a 4-phase unipolar motor <u>operating with half-steps</u> with 1 cycle per revolution – our motors use **8 cycles per revolution**
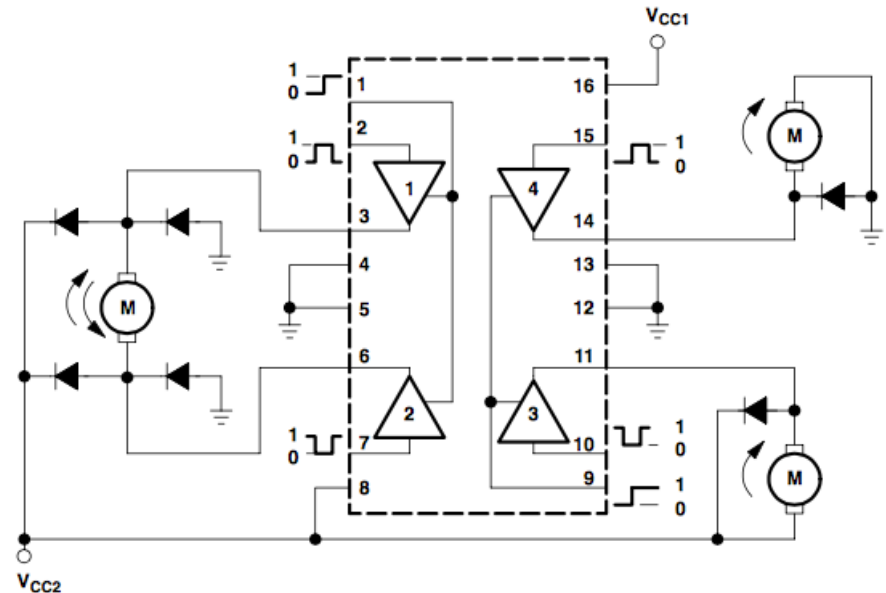
Operation:

- 2 half-steps per phase
- 4 phases per cycle
- 8 cycles per revolution (internal shaft)
- 1:64 gearbox (internal → external shaft)
  - → 2 x 4 x 8 x 64 = **4096** half-steps per output shaft rotation
- Output angle change per half-step: $360^o/\textbf{4096} = 0.0879^o$

Stepper Motor Driver Options

GPIO pins
IN1
IN2
IN3
IN4
IN5
IN6
IN7

5-12V   2PH64011A

gnd   5V
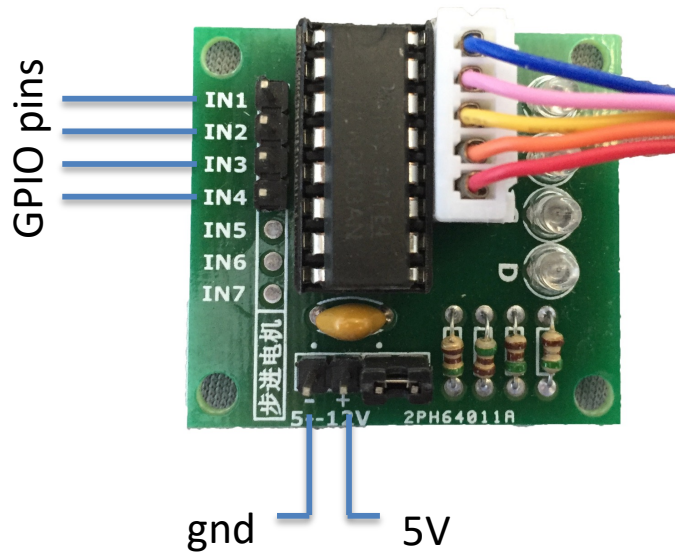
Darlington array
(50 V @ 0.5 A for ULN2003)

V_{CC1}

M

M

V_{CC2}

M

H-bridge
(35 V @ 2 A for L298N)
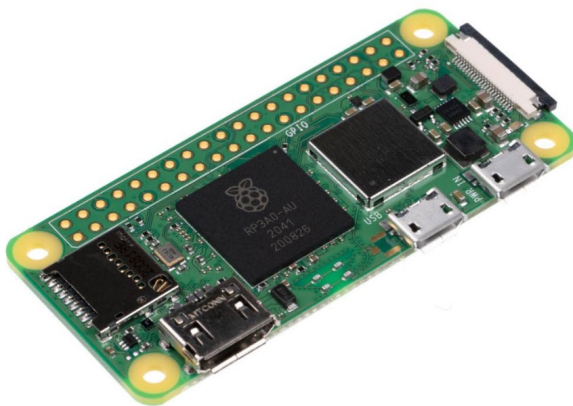
Drive directly from Pi Zero
(3.3 V @ 16 mA)

Q_B	1	16	V_{CC}
Q_C	2	15	Q_A
Q_D	3	14	SER
Q_E	4	13	$\overline{OE}$
Q_F	5	12	RCLK
Q_G	6	11	SRCLK
Q_H	7	10	$\overline{SRCLR}$
GND	8	9	$Q_{H'}$
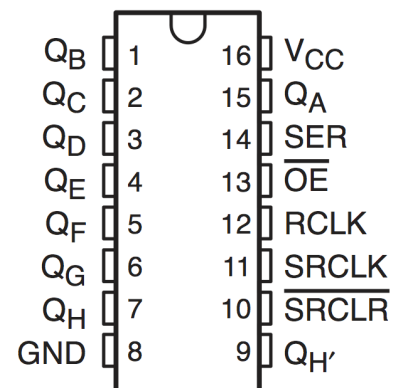
Shift register
(5 V @ 35 mA per line for SN74HC595)

Stepper Motor Driver Options

- The Red wire allows the current in each coil to be reversed by energizing the left or right side of the coil.
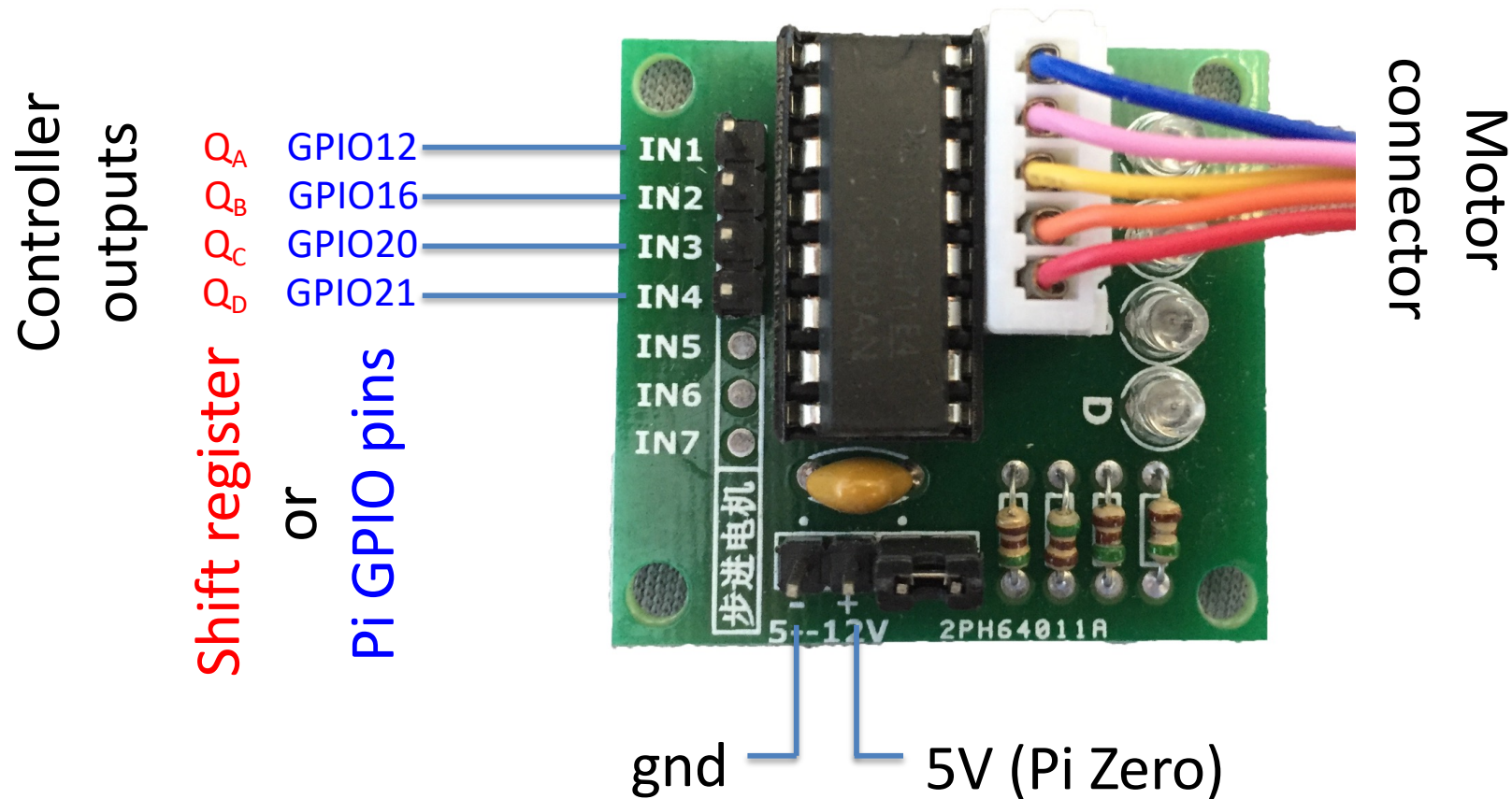- The L293D (H-bridge circuit) driver can reverse current → no need for the red wire, and the entire coil can be energized (<u>bipolar</u> operation)
- *However, because the red wire is common to all coils, we cannot use bipolar operation for our 5-wire motors*
- The ULN2003 (Darlington pair array) driver provides unidirectional amplification → the red wire is used, and only half of the coil is energized (<u>unipolar</u> operation)

Pink

Orange

Red1   Red2

Yellow   Blue

Bipolar operation – we cannot use this due to **shared red wire**

Pink

Orange

Red

Yellow   Blue

Unipolar operation
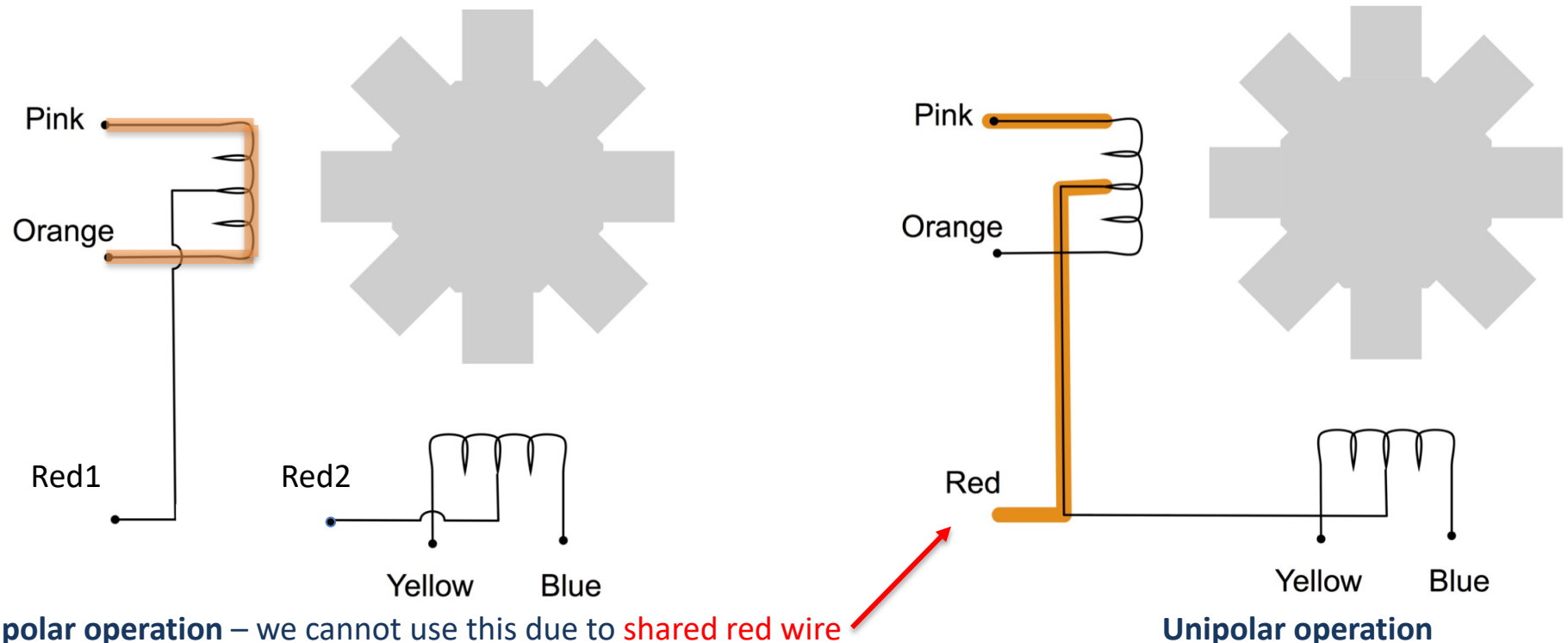
Stepper Motor Driver Board
(ULN2003 Darlington Array)

Controller outputs

Shift register or Pi GPIO pins

Q_A GPIO12 — IN1
Q_B GPIO16 — IN2
Q_C GPIO20 — IN3
Q_D GPIO21 — IN4

IN5
IN6
IN7

Motor connector

步进电机

5-12V

2PH64011A

gnd

5V (Pi Zero)

GPIO code: stepper.py