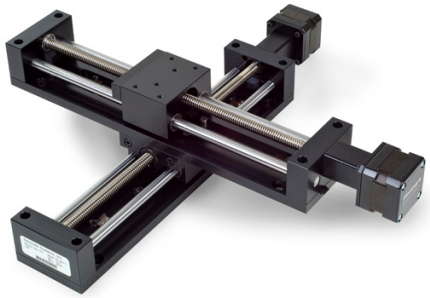
Steppers

IPD516

Stuff

- HW3 please finish this before Thursday.
  - 5% per day late after Thursday
- LED circuits finished by Monday 10/14
  - 5% per day late after Monday
- Stepper motors today
- Thursday @10AM
  - Quiz on stepper motors
- Thursday after quiz
  - Review of instruments
  - Bring full scale models.

What is a stepper motor, and why would you use one?



Stepper motor terms

- Permanent magnet (PM)
- Variable Reluctance (VR)
- Hybrid stepper motor
- Resolution (number of steps)
- Phase (2-phase, 3-phase, etc.)
- Bifilar wound / Monofilar wound
- Bipolar / Unipolar
- Holding torque

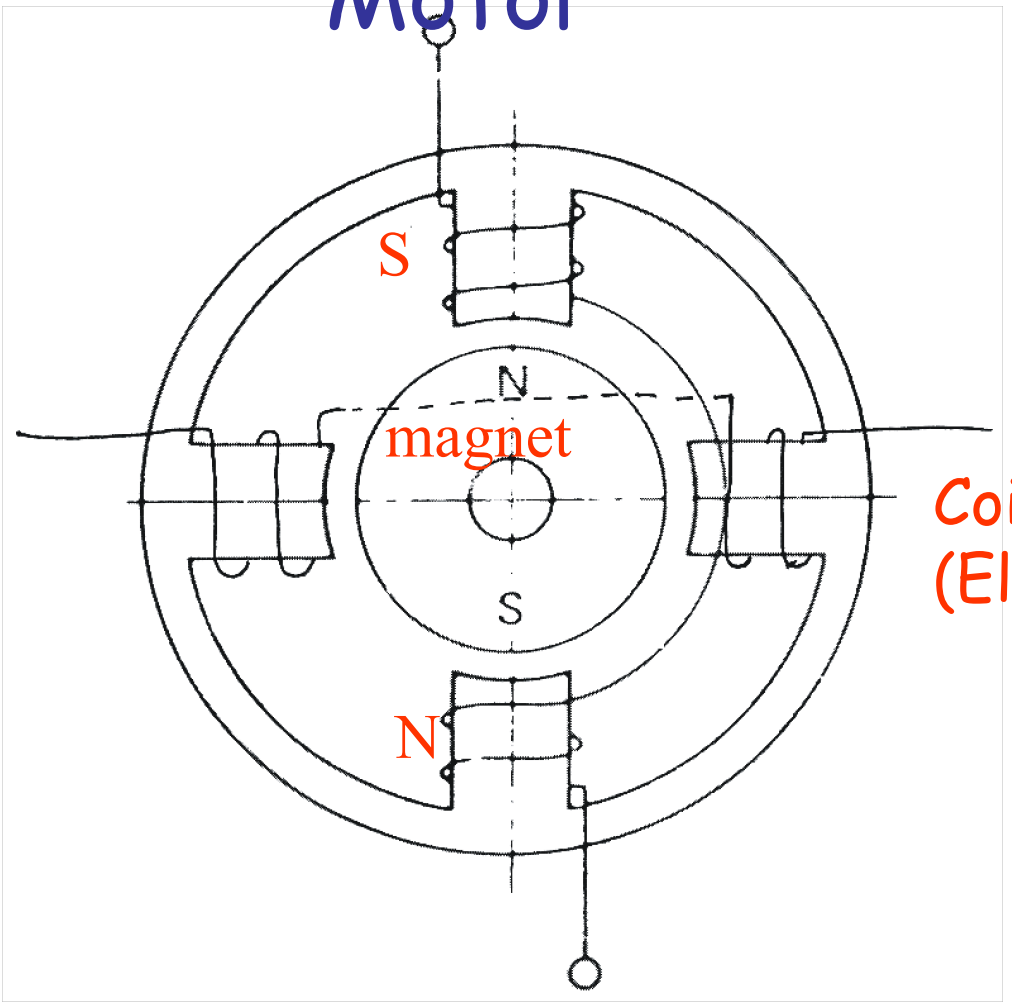
Nice overview http://www.cs.uiowa.edu/~jones/step

Quiz

(things you should know by the end of this lecture)

- You want to drive a stepper with more torque at low speed. Do you want to use bipolar or a unipolar?
- You want to minimize driver space and cost, what type of stepper should you use?
- Which style of stepping sequence gives you the highest torque?
- Which style of stepping sequence gives you the highest resolution?

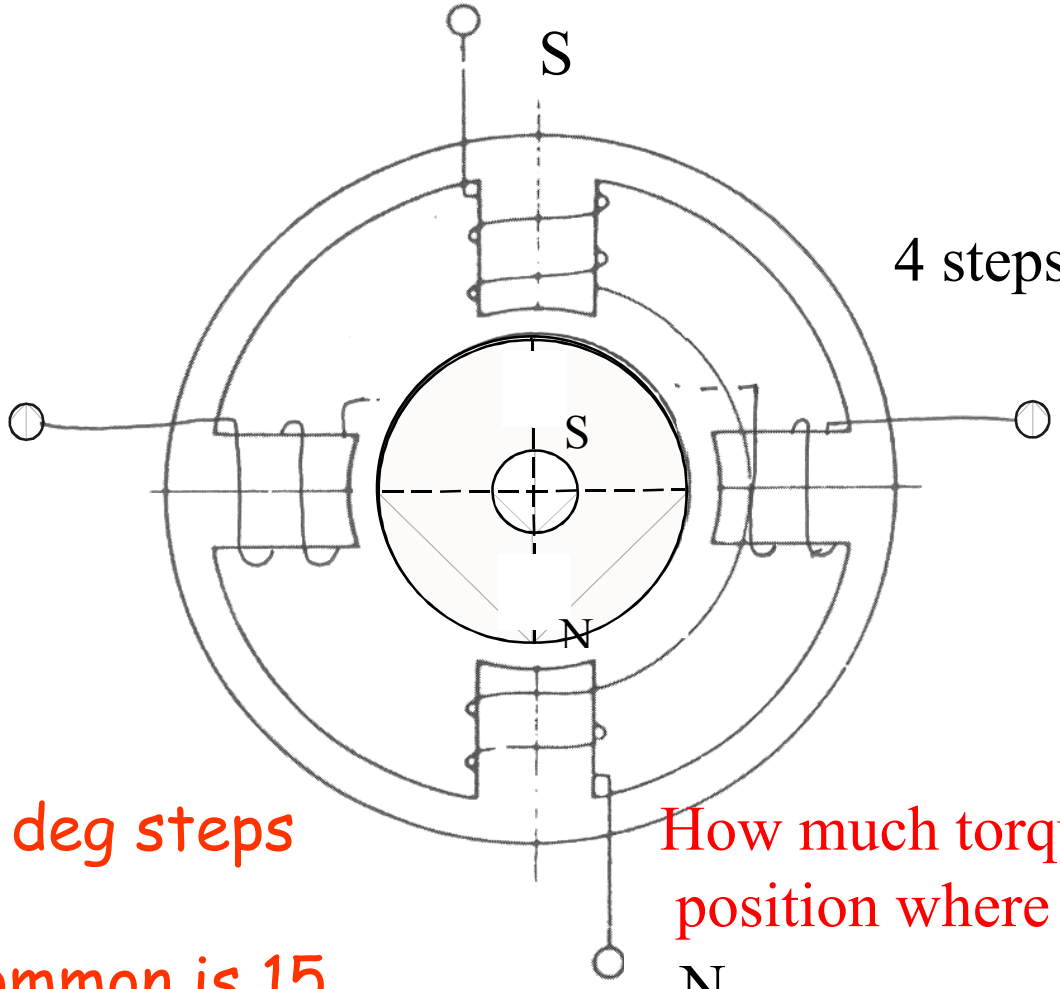
The Permanent Magnet (PM) Stepper Motor



Coils on outside
(Electromagnet)

Can do position control open loop

PM Stepper Operation



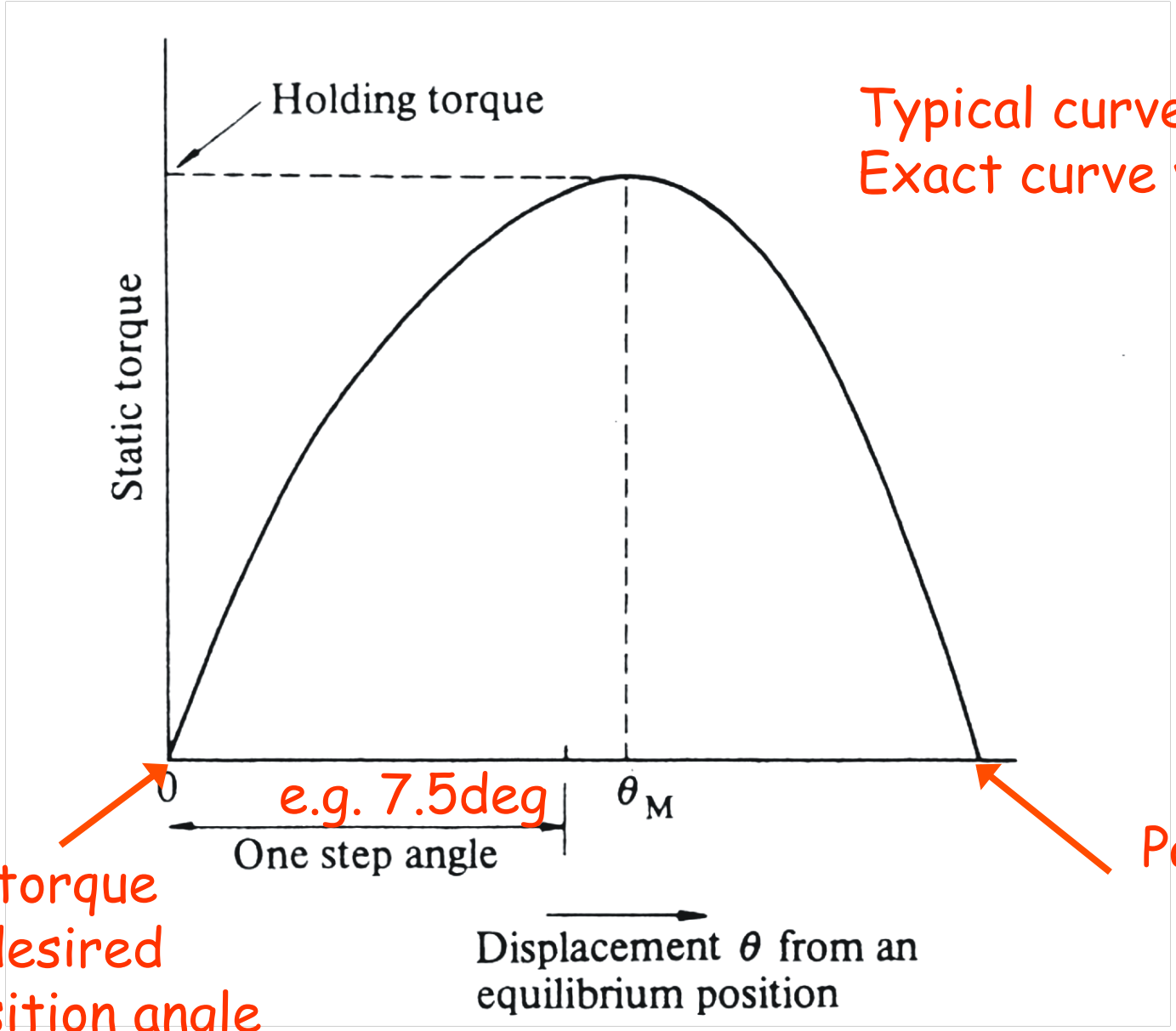
4 steps /cycle

These are 90 deg steps

Much more common is 15 deg and 7.5 deg (24 and 48 resolution)

How much torque at this position where rotor is aligned?

Torque v.s. Angular Displacement



Typical curve
Exact curve varies

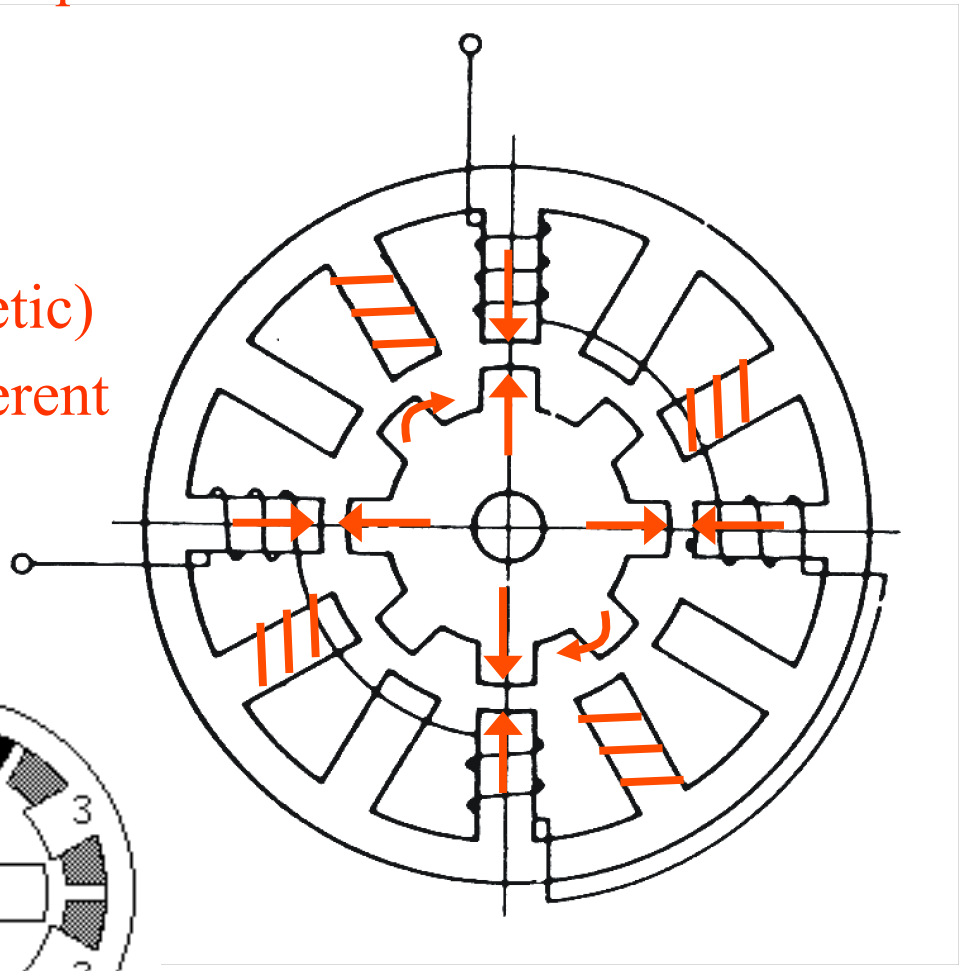
No torque at desired position angle

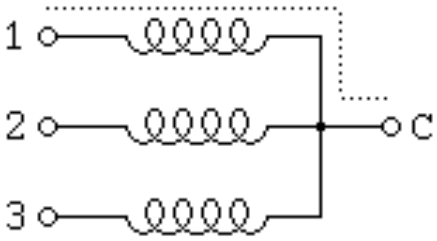
Past this point skip steps

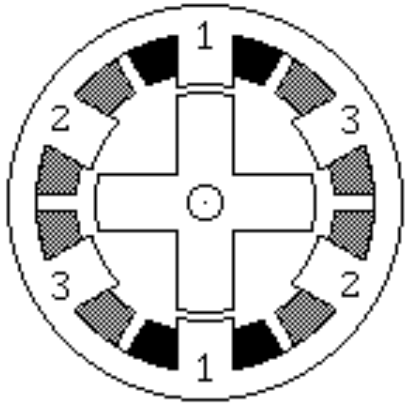
The Variable Reluctance (VR) Stepper Motor

Can make more teeth (higher resolution of steps)
All things being equal, more torque from PM
No detent torque from VR
Lower rotor inertia for VR

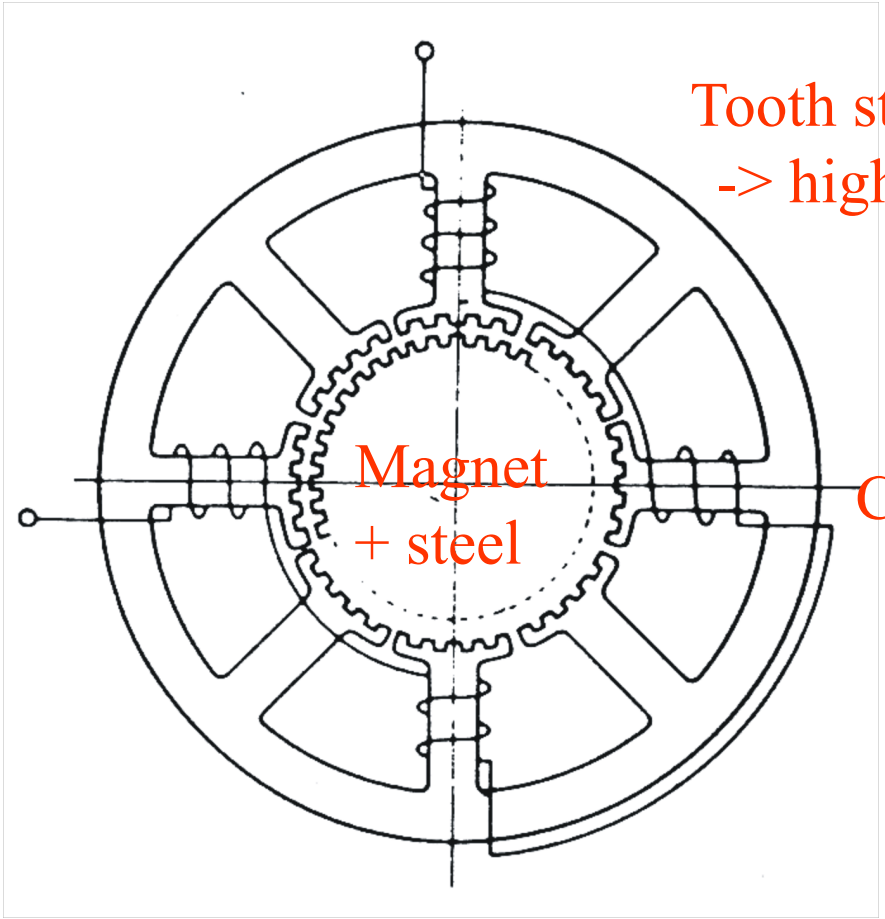
1) Soft iron rotor (not magnetic)
2) #teeth on rotor/stator different







The Hybrid Stepper Motor



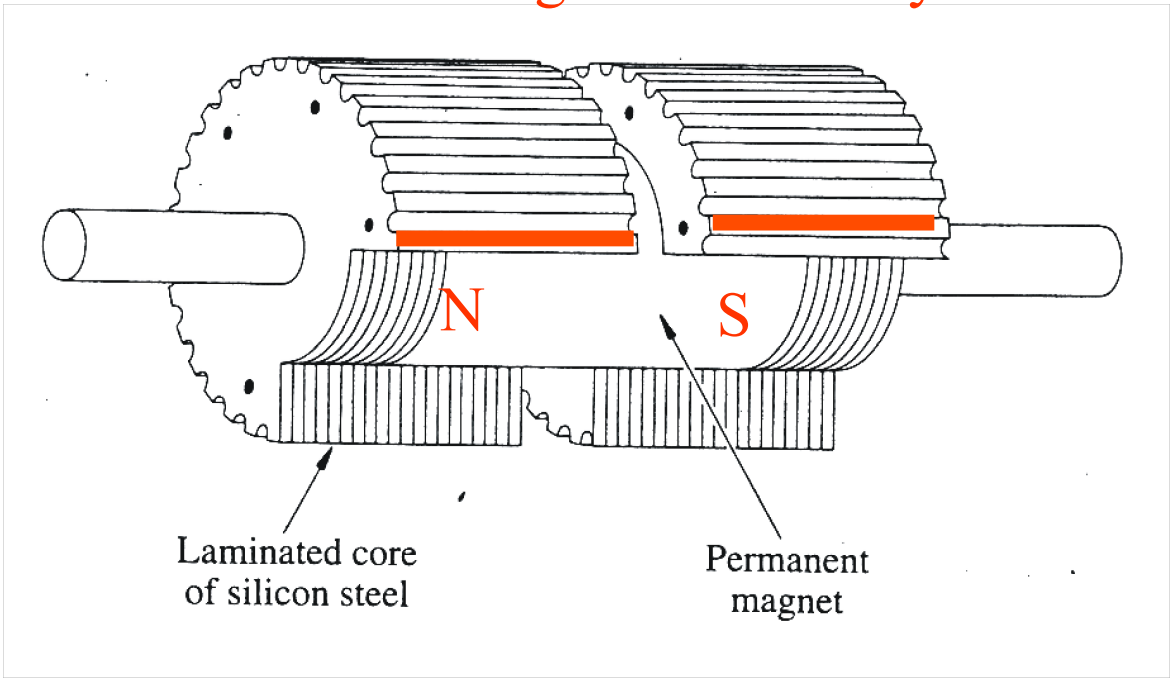
Tooth structure of VR
-> higher resolution

Coils on outside

PM rotor
-> higher torque
-> detent torque (even in absence of power)

The Hybrid Motor Rotor

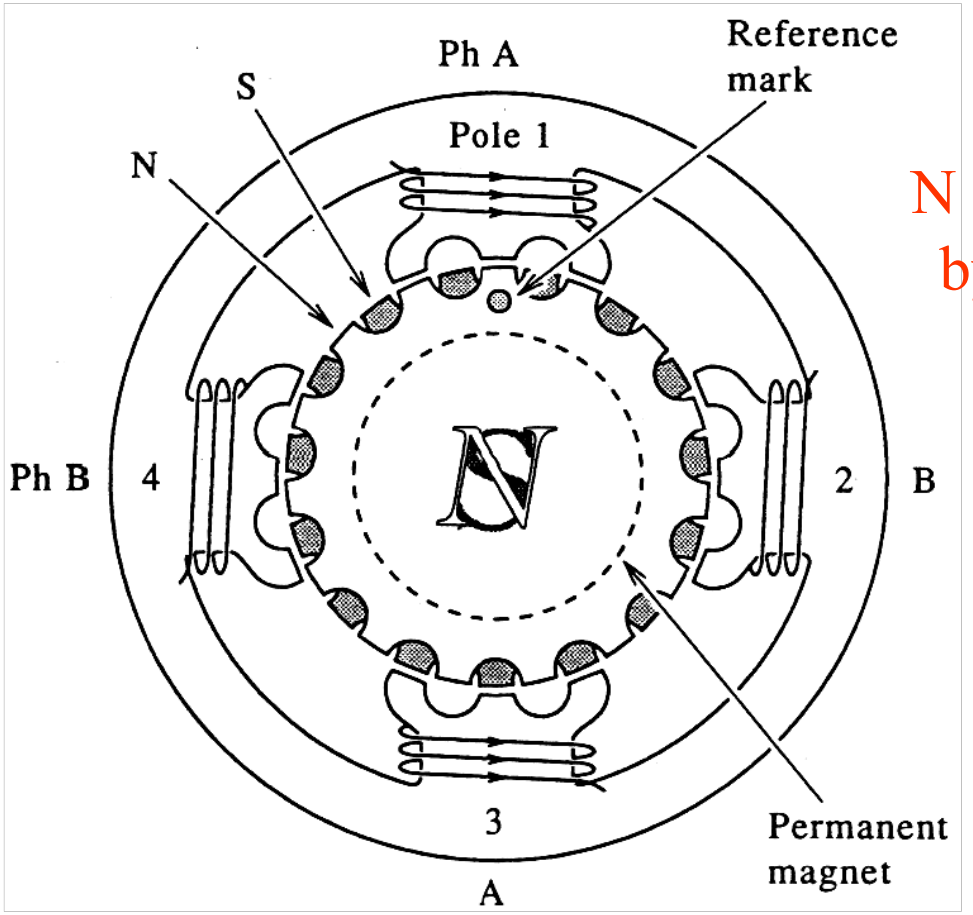
N teeth and S teeth aligned differently



Axially magnetized

Well suited for
Two phase

Offset Teeth in Hybrid Rotor



N and S are offset by ½ tooth pitch

Typically 1.8 deg/step (200 step/revolution)
Sometimes 0.9deg/step (400 steps/revolution)

Variations in Output Torque

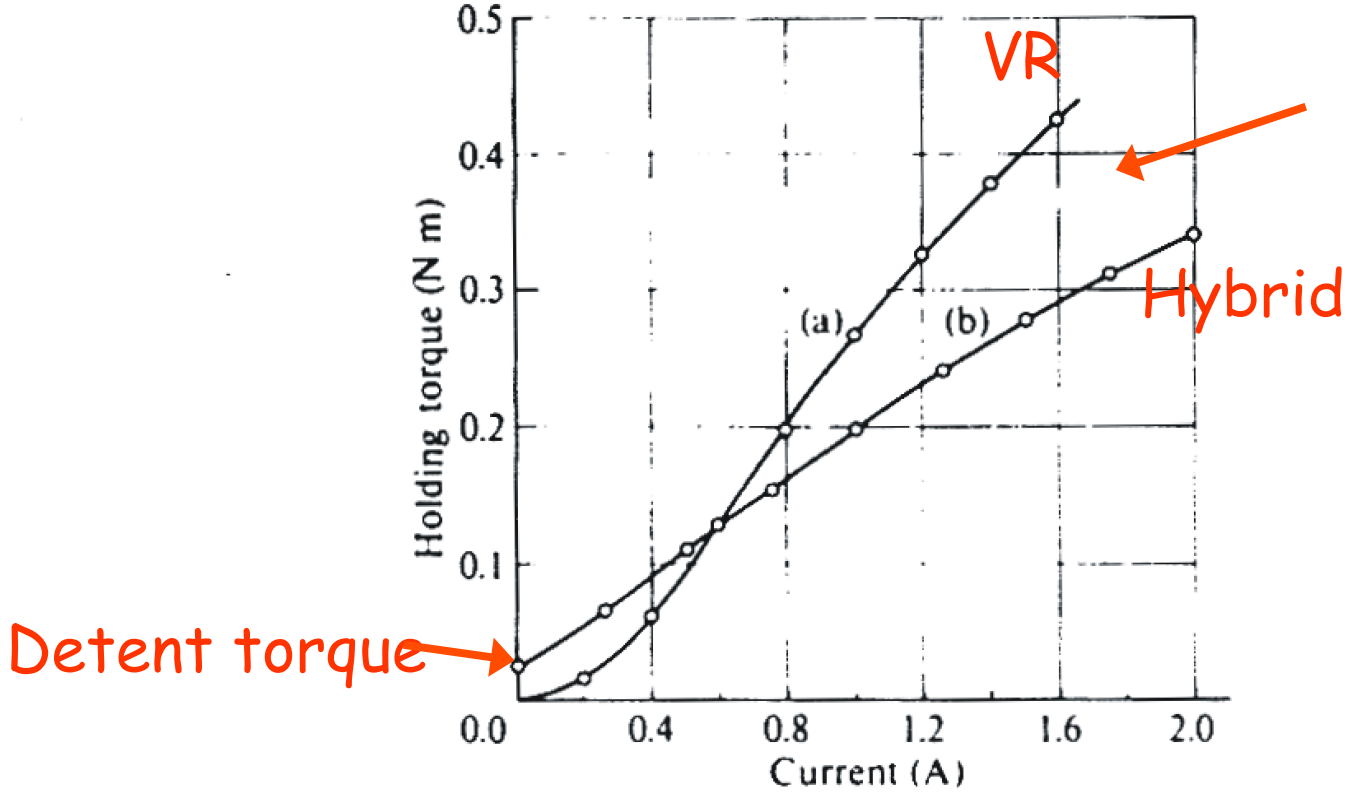


Fig. 2.74. Examples of *T/I* characteristics: (a) a 1.8° four-phase VR motor; and (b) a 1.8° four-phase hybrid motor. (After Ref. [17].)

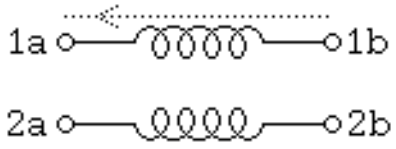
Buying steppers

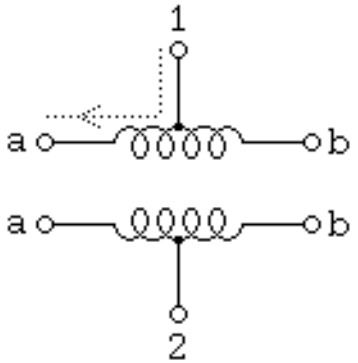
- Specs:
  - Dimensions
  - Current
  - Step angle/ resolution
  - Torque (usually)
  - Bipolar / unipolar (sometimes)
  - Phase (sometimes)
  - Power dissipation (W)

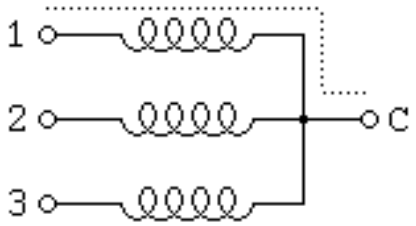
How do you tell what kind of stepper you have?

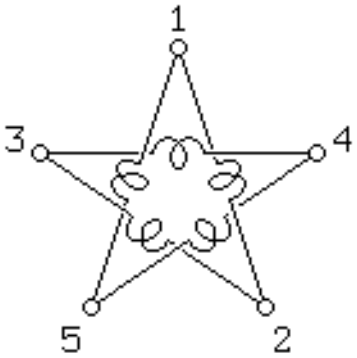
Number of wires

Connectivity of wires

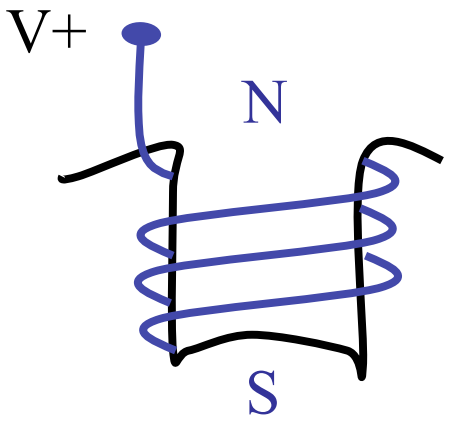




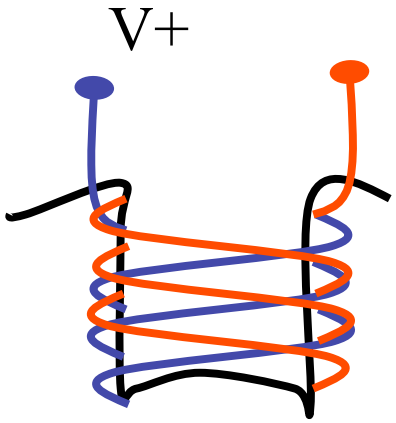




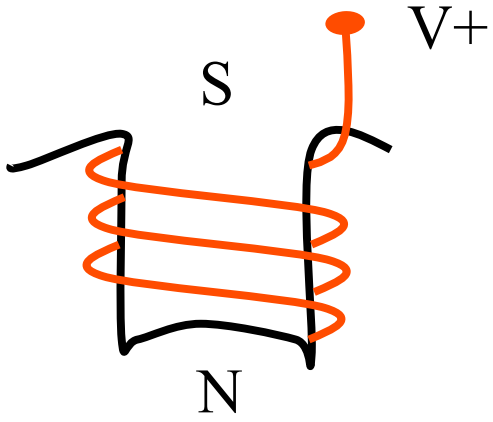
Winding Direction is Important



clockwise



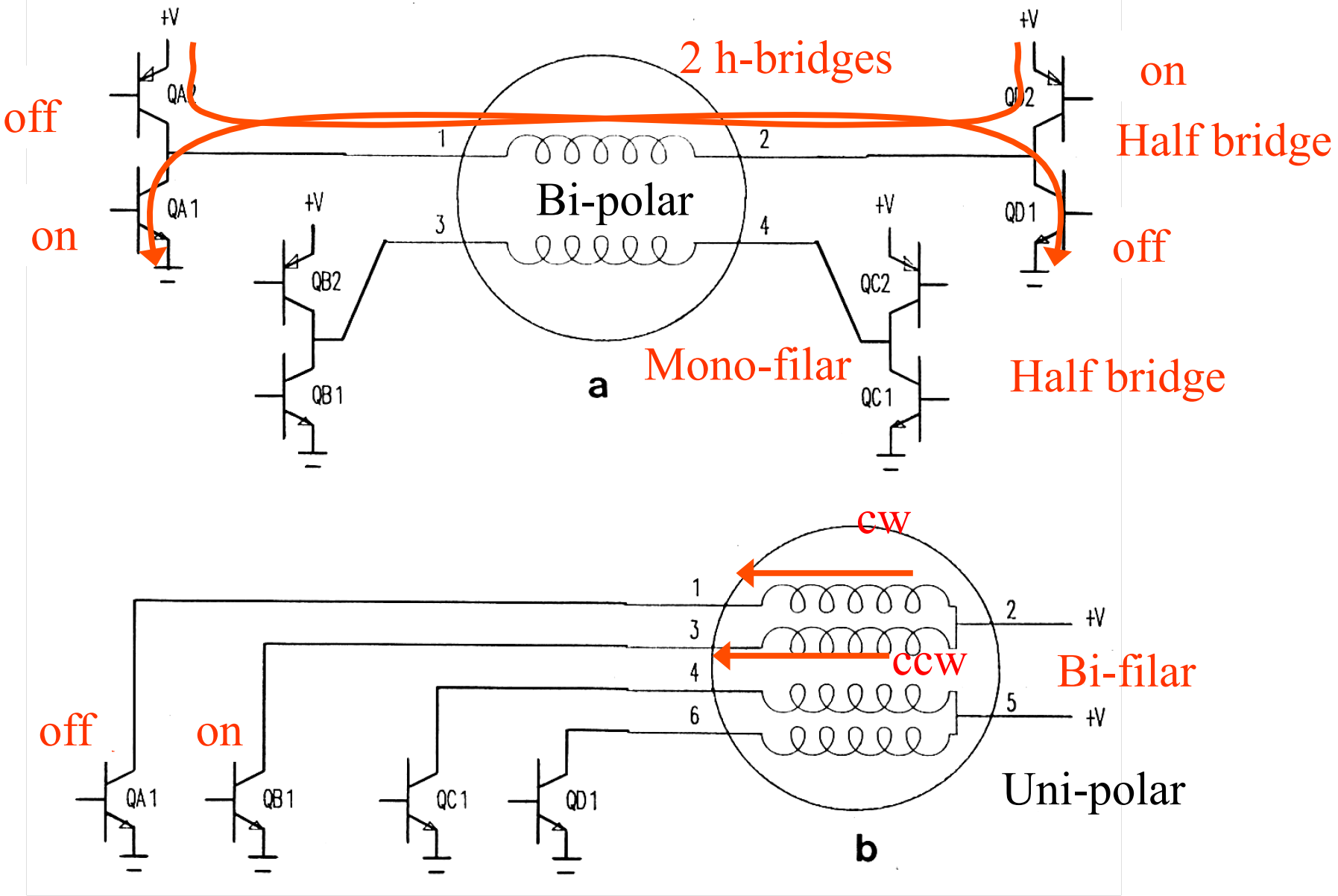
Bi-filar wound
(unipolar)



counterclockwise

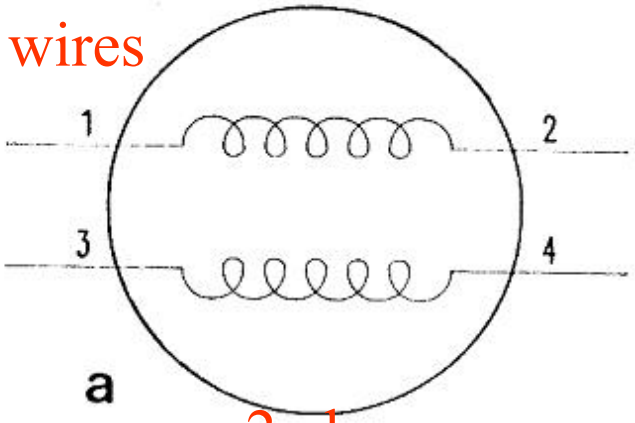
no h-bridge needed to
change direction

Driving Stepper Motors



Stepper Motor Wiring

4 wires



2 phase

6 wires

3 phase

8 wires

5 wires

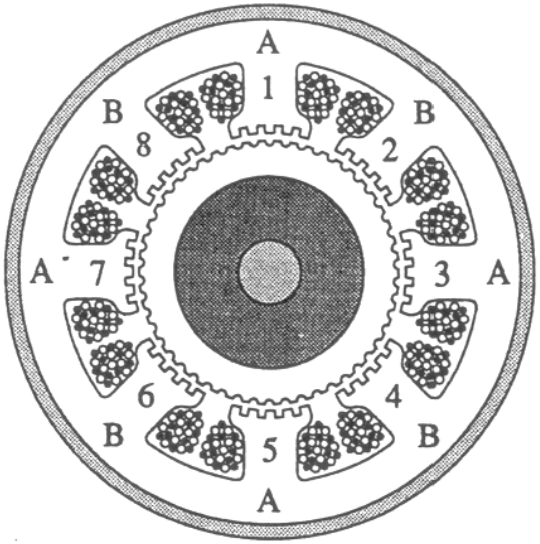
Bi-filar wound

2 phase

Ambiguous.
4phase or
2phase universal wound

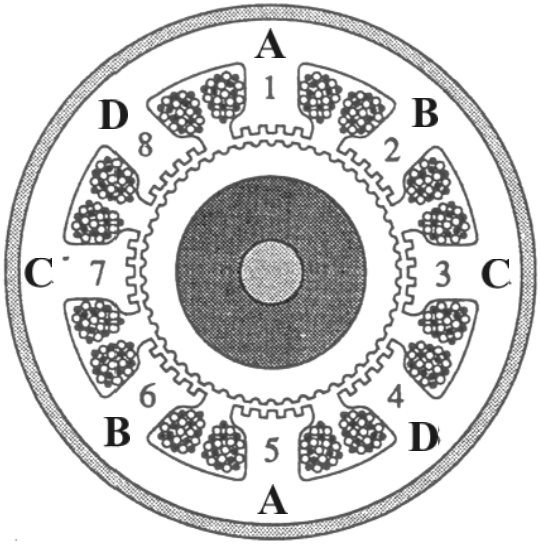
2 phase

2-Phase Universal Wound v.s. 4-Phase



a

8 wires brought out
2 phase (A and B)
(can hook use unipolar or bipolar drive)

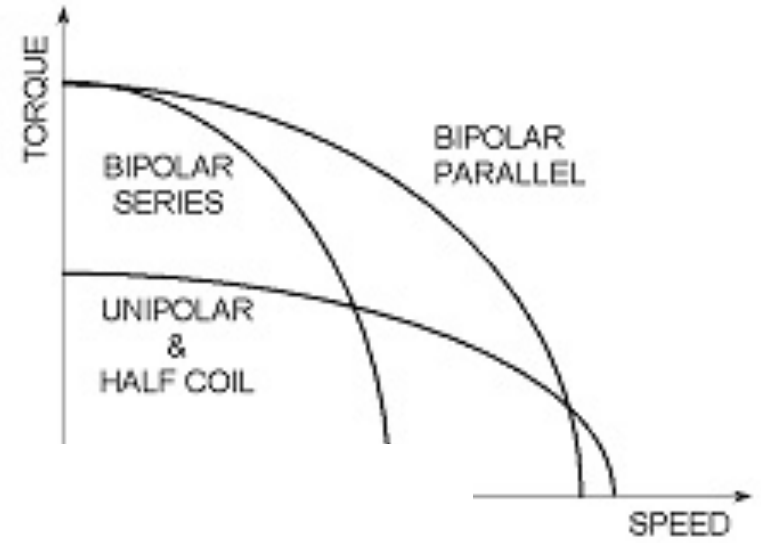


b

8 wires brought out
4 phase (four separate coils)

Driving universal winding as uni vs bi polar

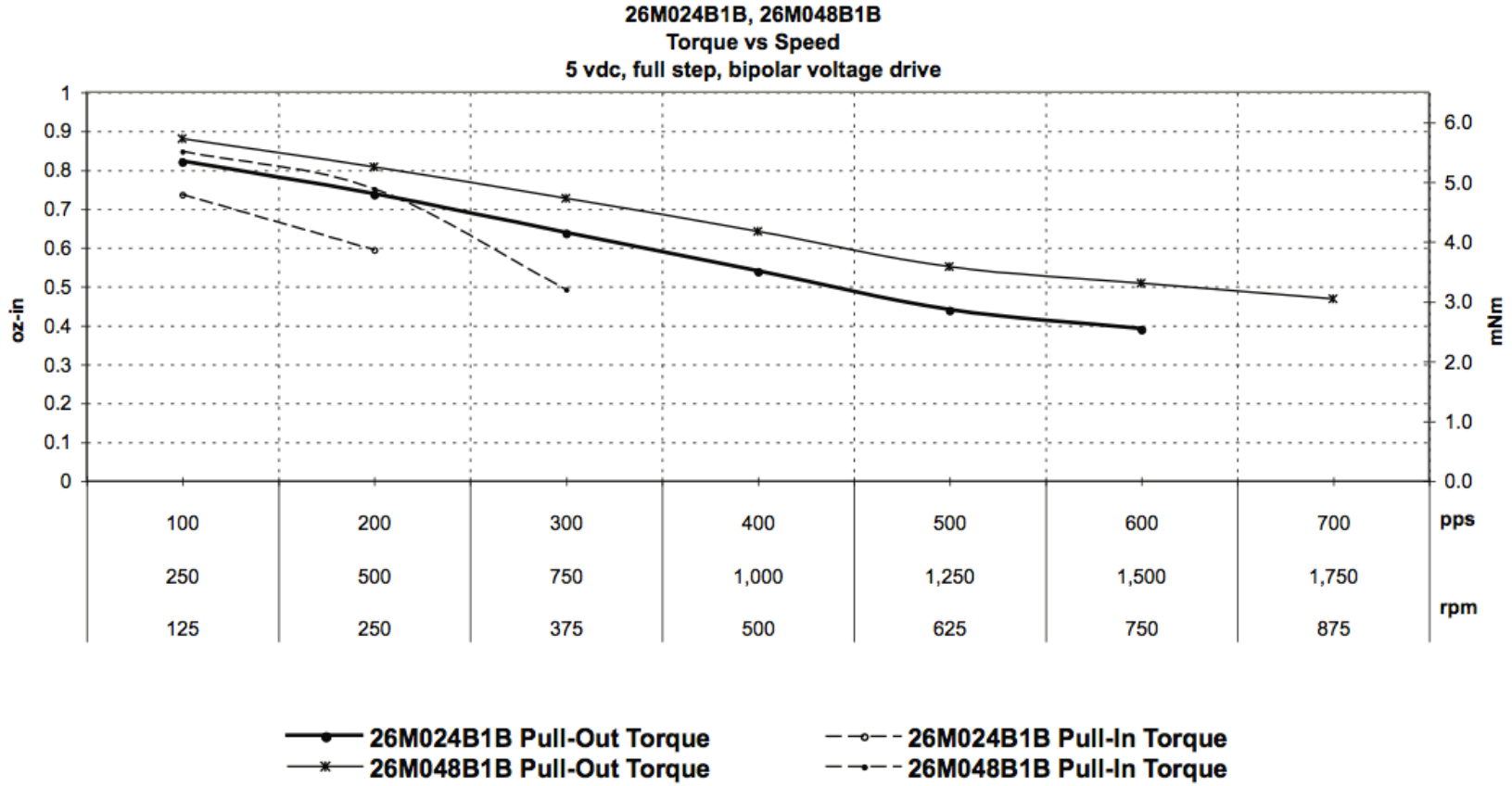
- Unipolar drives half the coils
- Bipolar can drive all coils at once
  - In series (2x's voltage, 1x current)
  - In parallel (1x voltage, 2x's current)



Wired series

Wired parallel

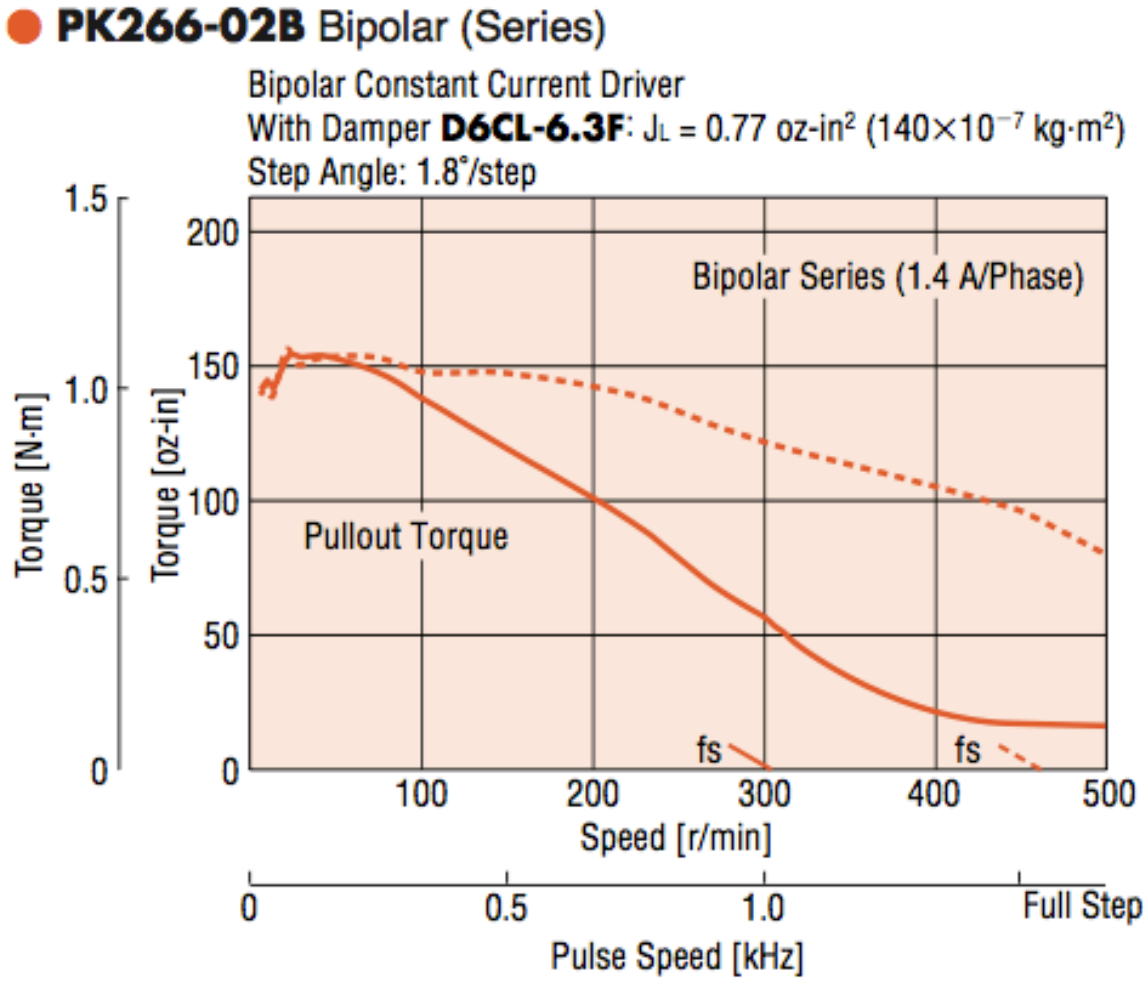
Torque specifications



Pull-In Torque: resistance torque applied from start that motor can still reach speed instantaneously.

Pull-Out Torque: load torque applied at speed, that doesn't result in stall or skipped steps.

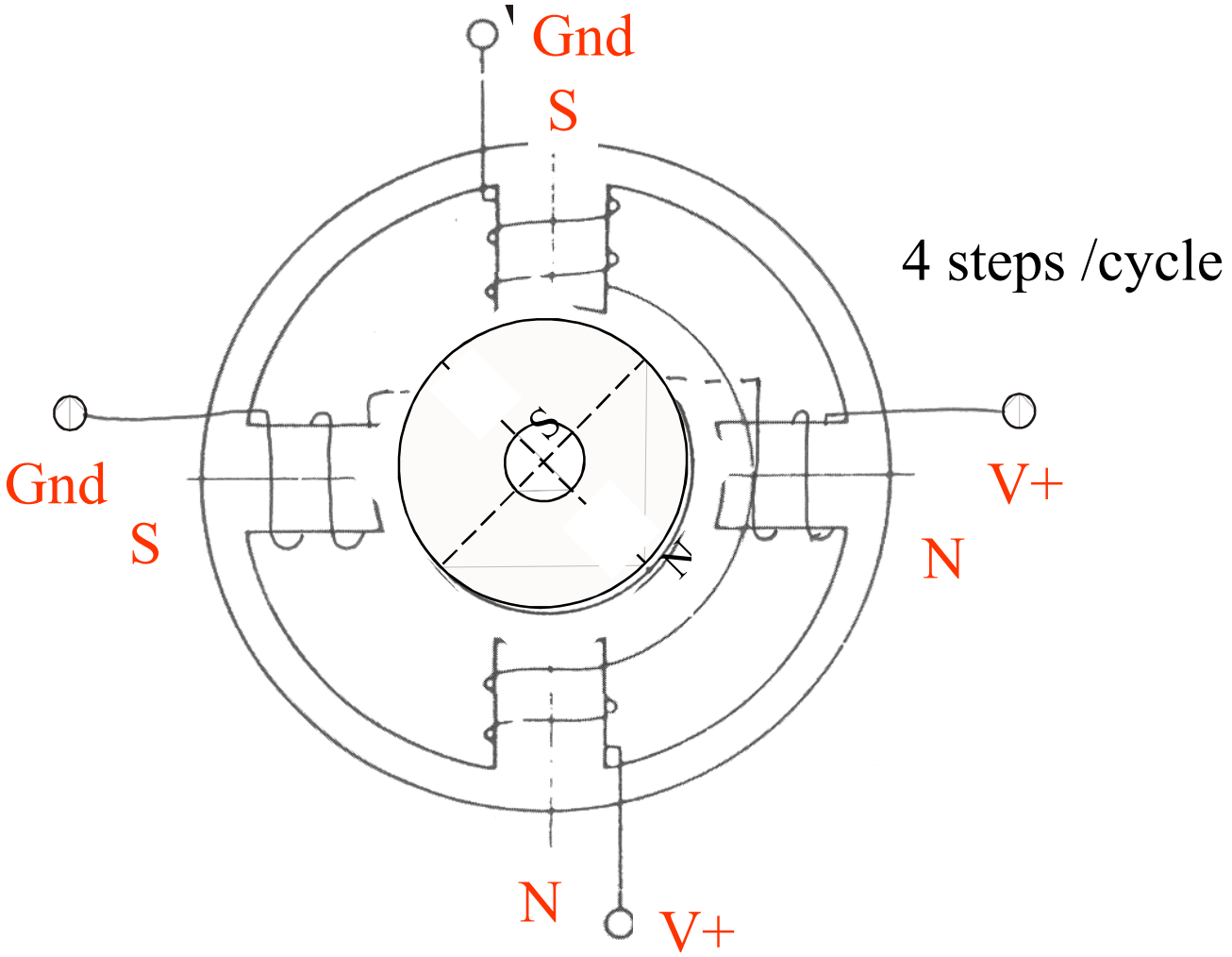
Torque Spec for Vexta PK266-02A



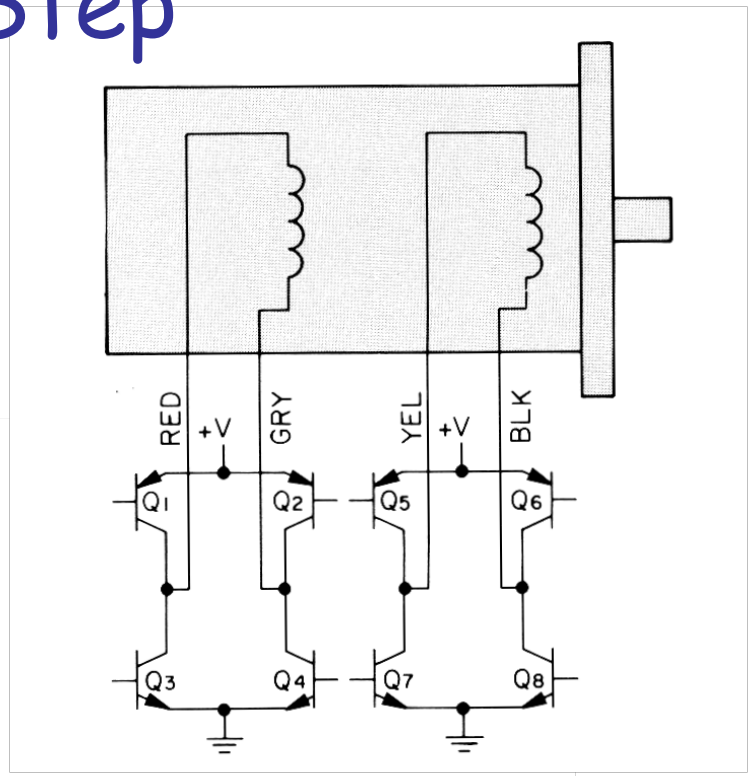
- 1.17Nm Holding T.
- 1.4A/phase
- 3.6 ohm/phase
- 5V nominal

Stepper Sequences: Full Step

(two phases on)



Driving Full Step



BIPOLAR

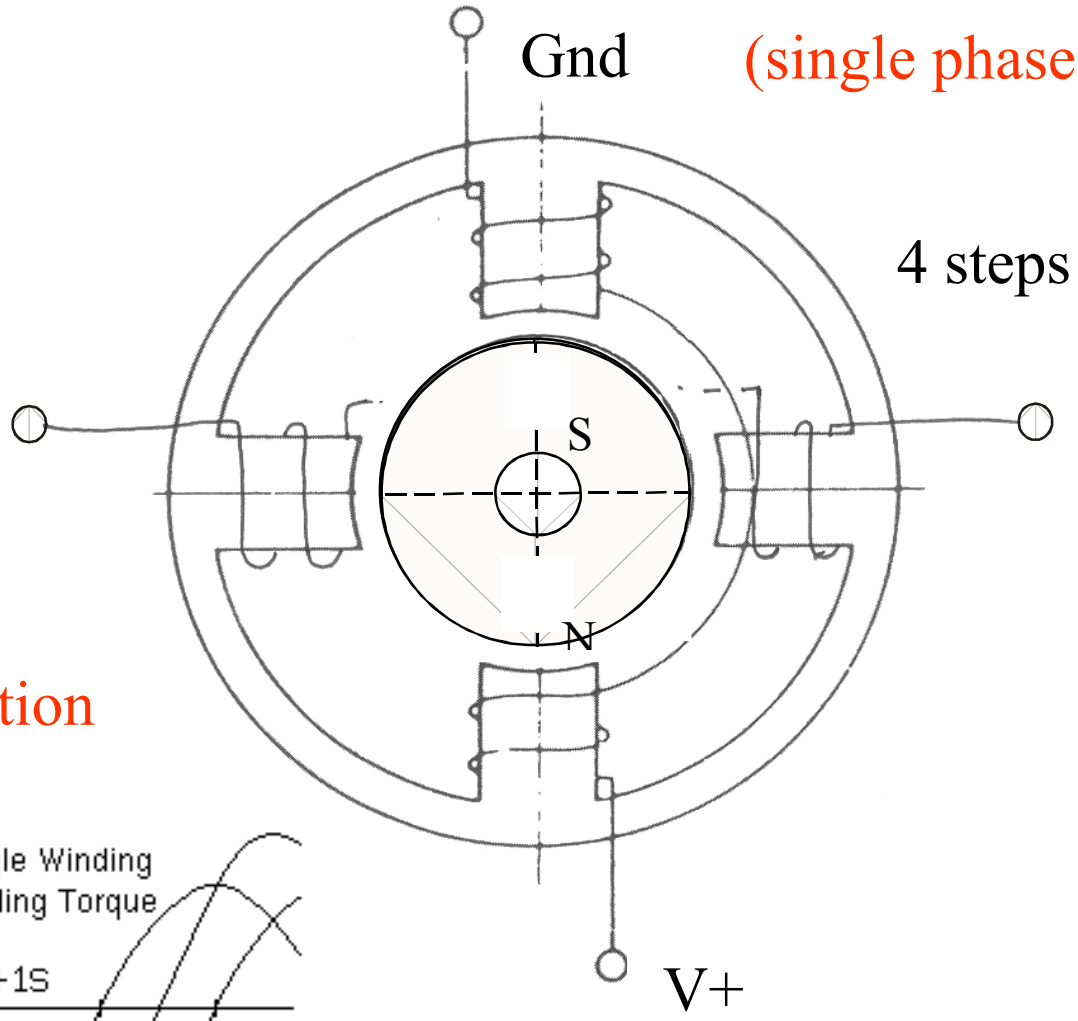
CW ROTATION

Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

CCW ROTATION

Normal
4 Step Sequence

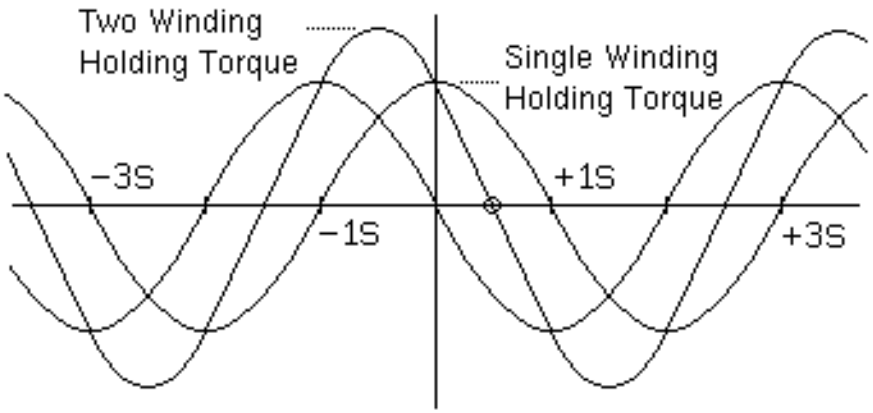
Stepper Sequences: Wave Drive



(single phase on)

4 steps /cycle

Less holding torque
Less power consumption



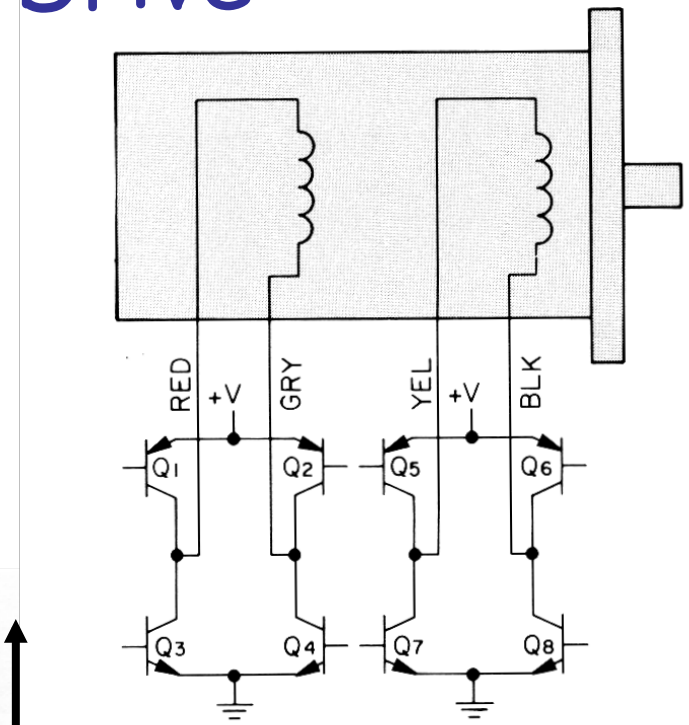
Driving: Wave Drive

Bipolar

Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	OFF	OFF
2	OFF	OFF	OFF	ON
3	OFF	ON	OFF	OFF
4	OFF	OFF	ON	OFF
1	ON	OFF	OFF	OFF

CW ROTATION ↓

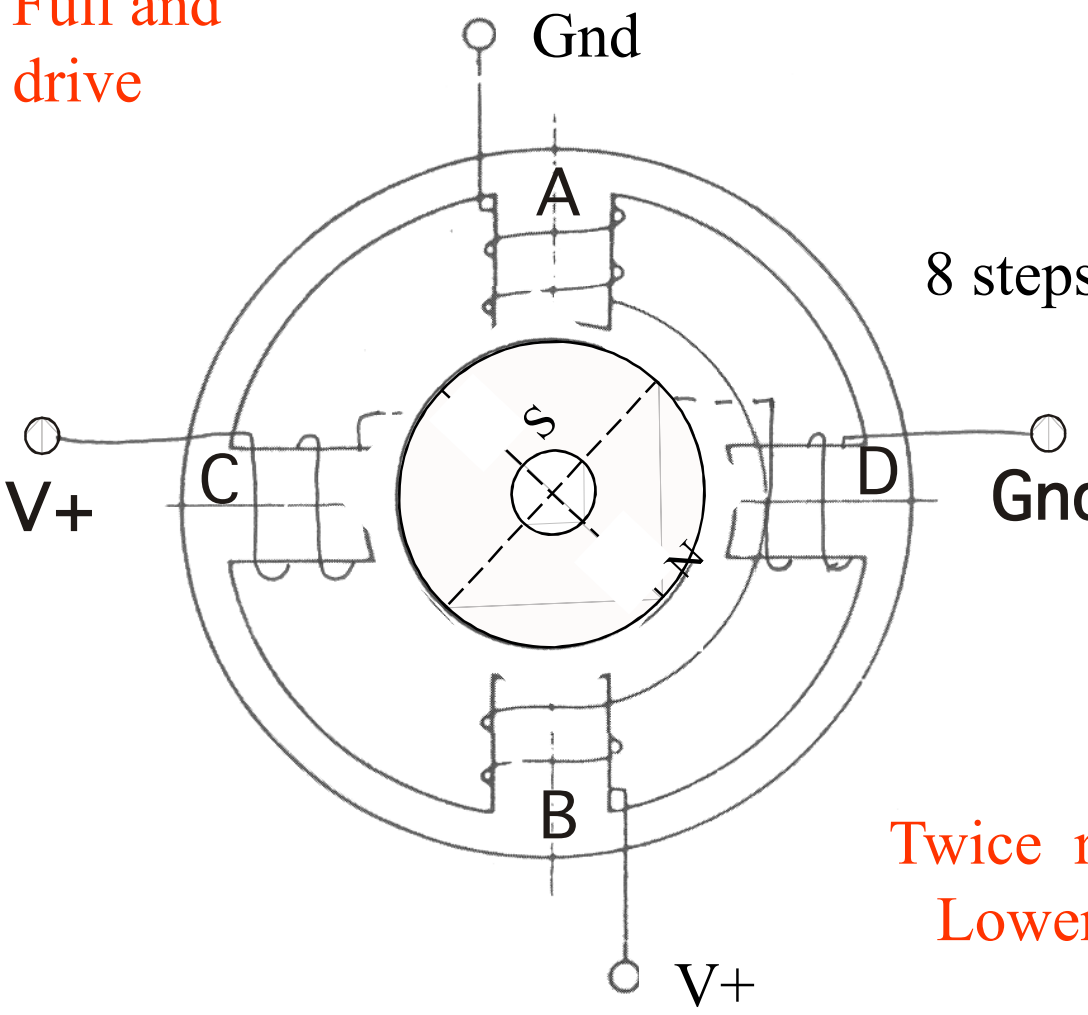
↑ CCW ROTATION



Wave Drive
4 Step Sequence

Stepper Sequences: Half-Step

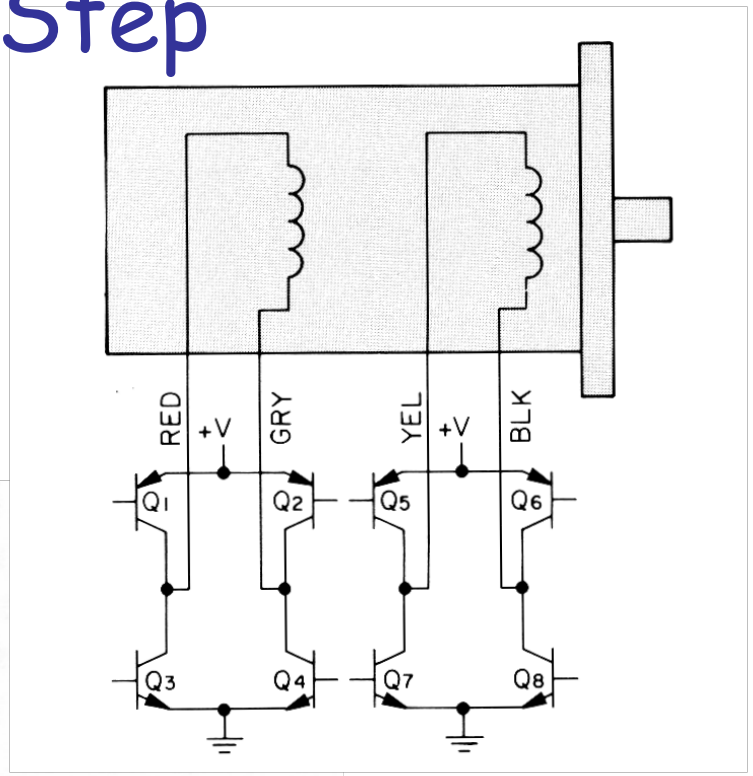
Alternate Full and
Wave drive



Twice resolution
Lower torque

Driving: Half-Step

1-2 phase on



Bipolar

Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

CW ROTATION

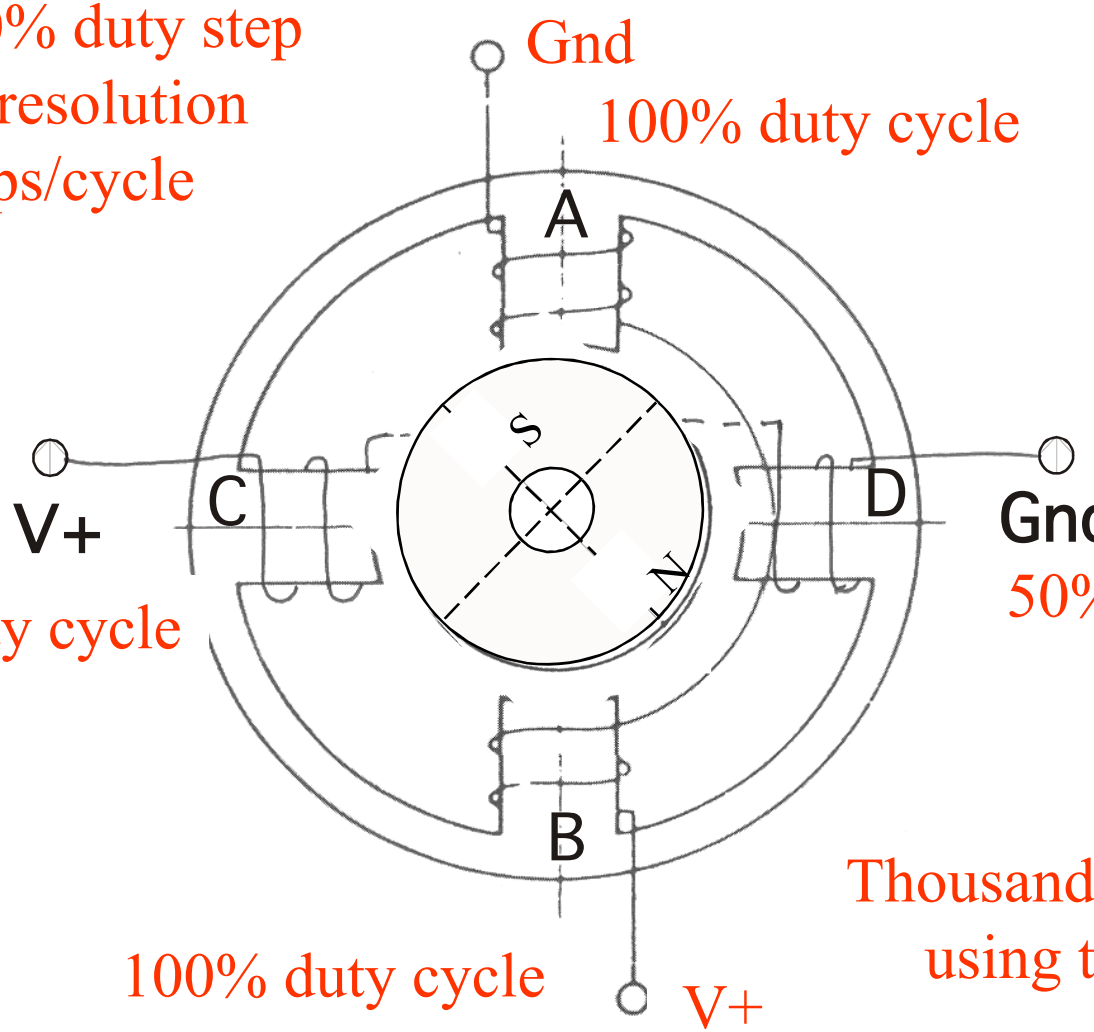
CCW ROTATION

½ Step

8 Step Sequence

Stepper Sequences: Micro-Stepping

Adding 50% duty step
doubles resolution
16 steps/cycle



Thousands of micro steps
using this technique

Stepper Code Sample (two phase-on)

```
void fullstep(                    char direction) {
  static char currentstep;
  currentstep += direction; // 1 = forward, -1 = backwards
  if (currentstep > 3) currentstep = 0; // check for wrap
  if (currentstep < 0) currentstep = 3;


  switch (currentstep) {
    case 0:  PTT = TWOPHASEON1;  break; // 0x0A
    case 1:  PTT = TWOPHASEON2;  break; // 0x09
    case 2:  PTT = TWOPHASEON3;  break; // 0x05
    case 3:  PTT = TWOPHASEON4;  break; // 0x06
  }
}
```

Stepper Code Sample (two phase-on)

```
static char currentstep;
void setdirection(char direction) {

  currentstep += direction; // 1 = forward, -1 = backwards
  if (currentstep > 3) currentstep = 0; // check for wrap
  if (currentstep < 0) currentstep = 3;
}
void fullstep() {
  switch (currentstep) {
    case 0:  PTT = TWOPHASEON1;  break; // 0x0A
    case 1:  PTT = TWOPHASEON2;  break; // 0x09
    case 2:  PTT = TWOPHASEON3;  break; // 0x05
    case 3:  PTT = TWOPHASEON4;  break; // 0x06
  }
}
```