Stepper Motors

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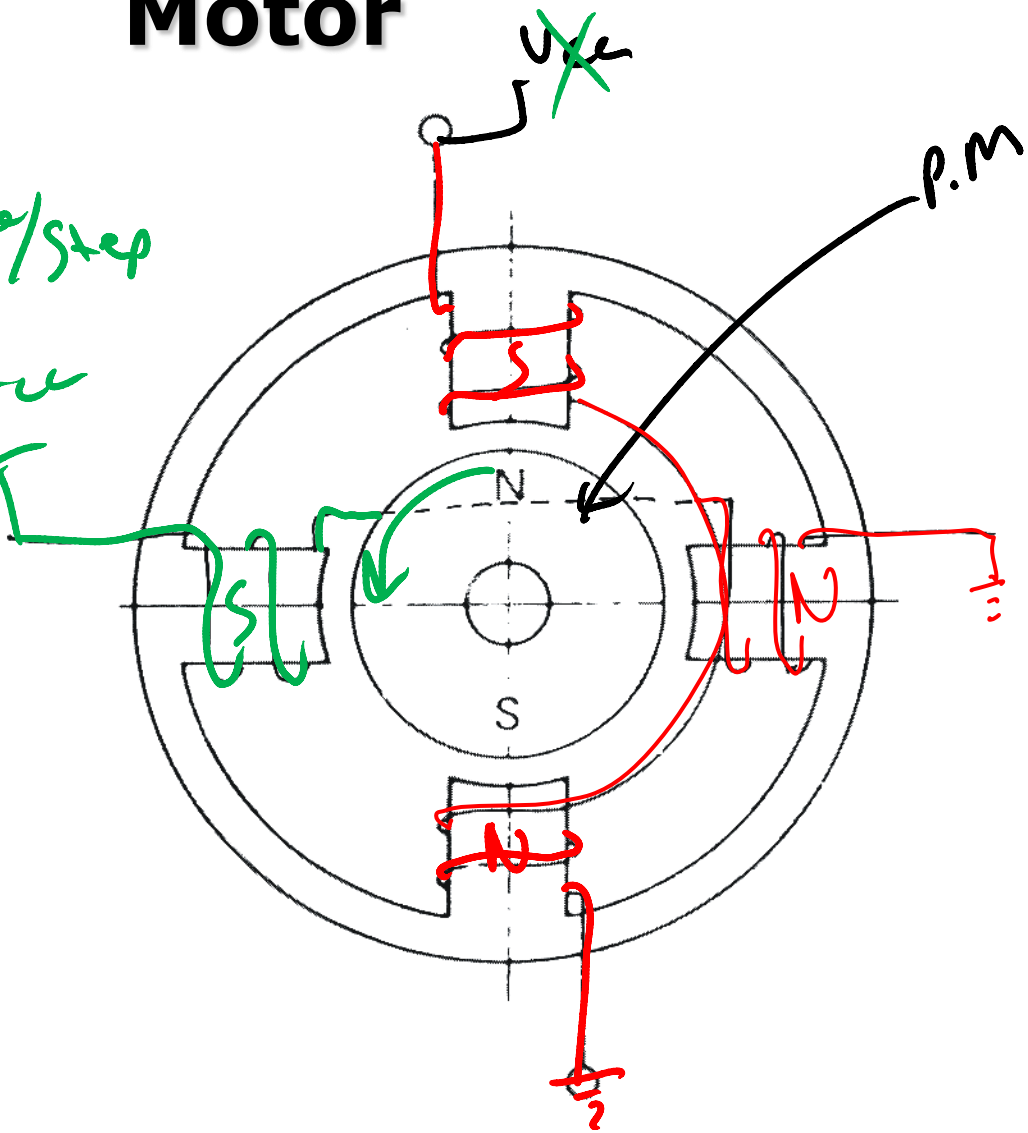
Stepper Motors

- Different types of stepper motors (P.M., V.R., Hybrid)
- Differences in Characteristics
- Stepper Drive Techniques (Lab)
- Stepper Dynamics (Detent Torque)
- Snubbing for Stepper Motors

Permanent Magnet (PM) Stepper Motor

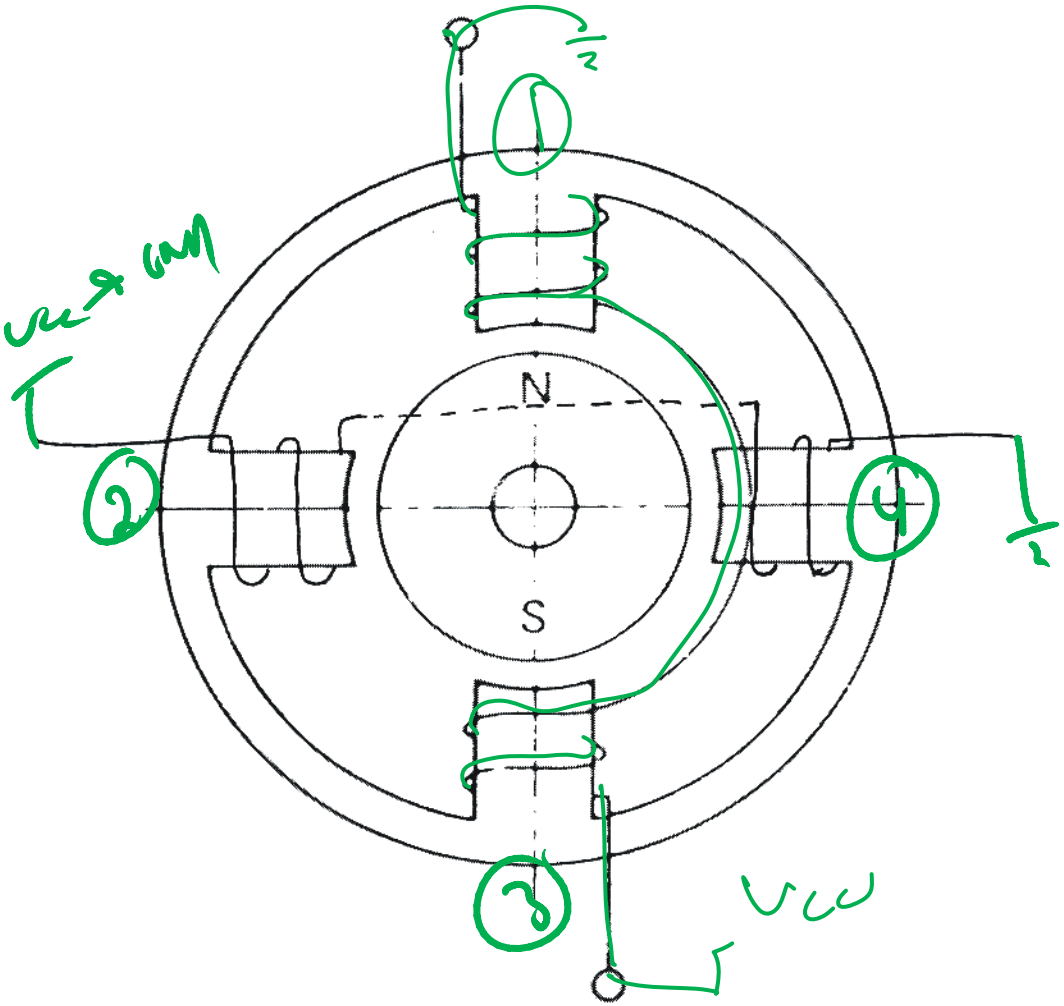
2 windings

- 24 steps 15°/step
- 48 steps 7.5° 1 coil / step

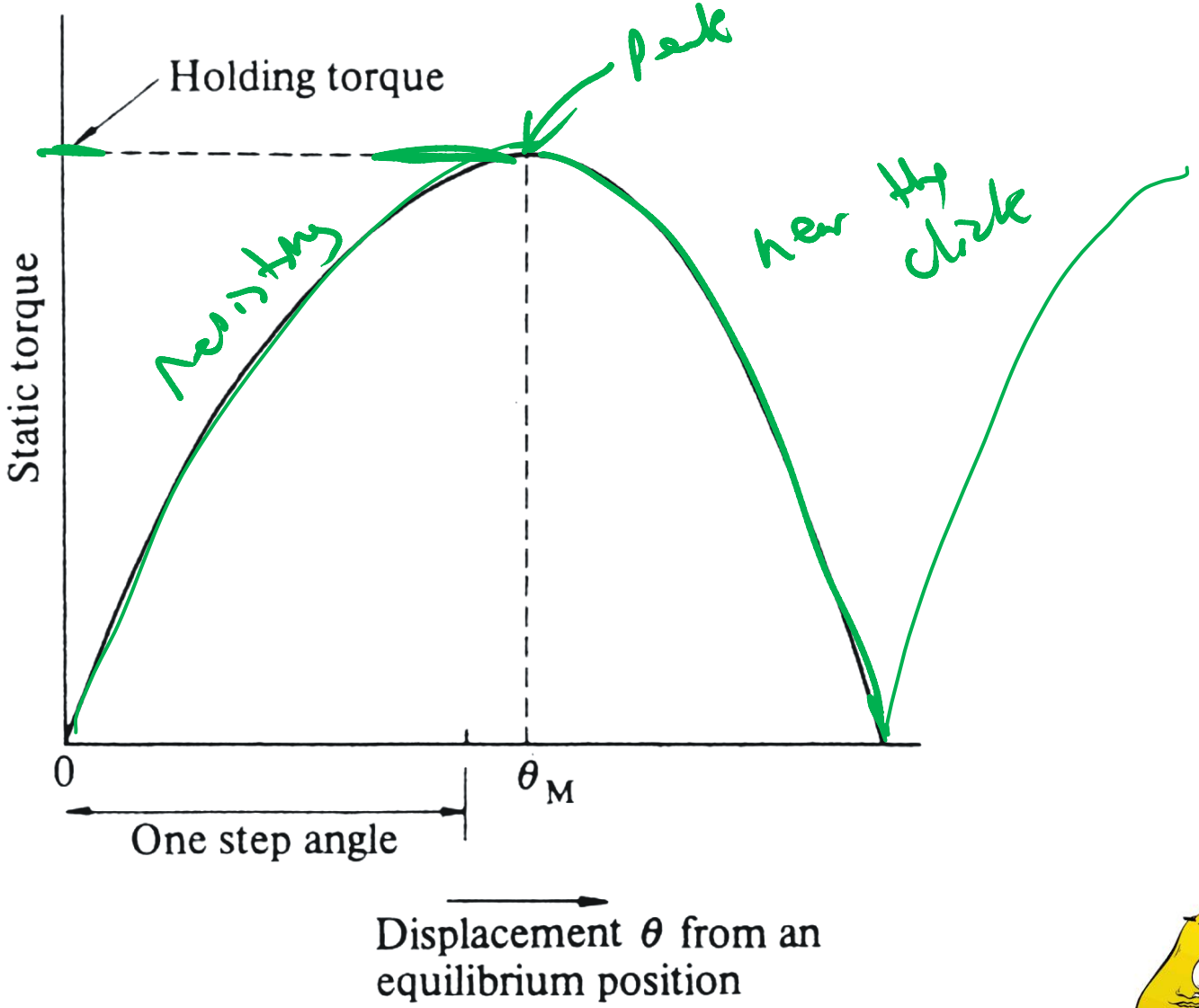


PM Stepper Motor Operation

1 → 3
2 → 4
3 → 1
4 → 2



Torque vs. Angular Displacement



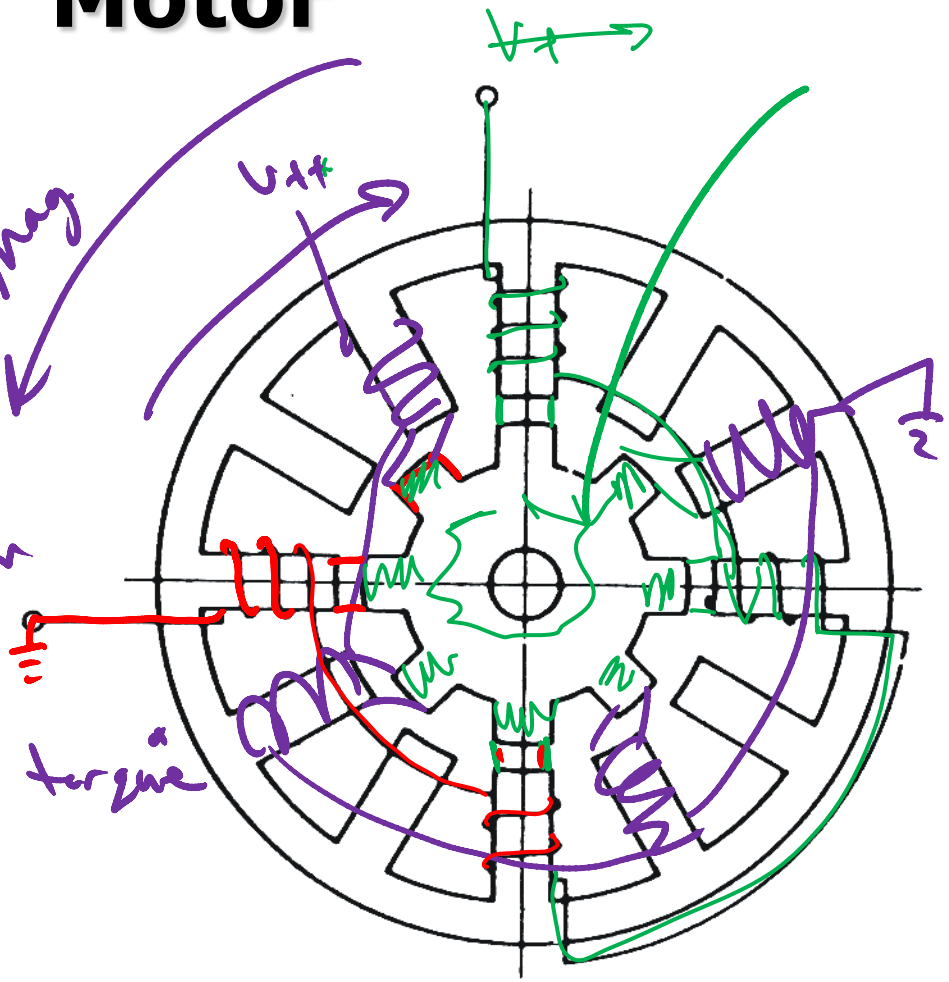
Variable Reluctance (VR) Stepper Motor

PM ADV

- Higher T *
- Detent Torque

VR ADV

- lower inertial motor weight less
- higher top speed
- higher top end torque



Hybrid Stepper Motor

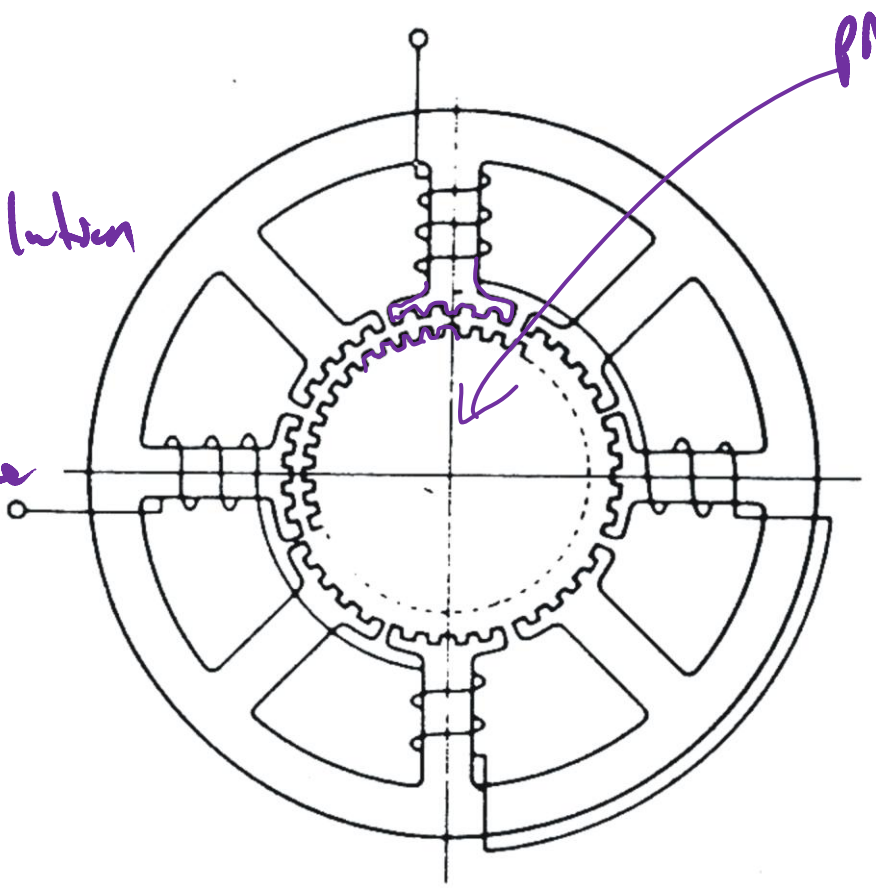
VR

Tooth structure

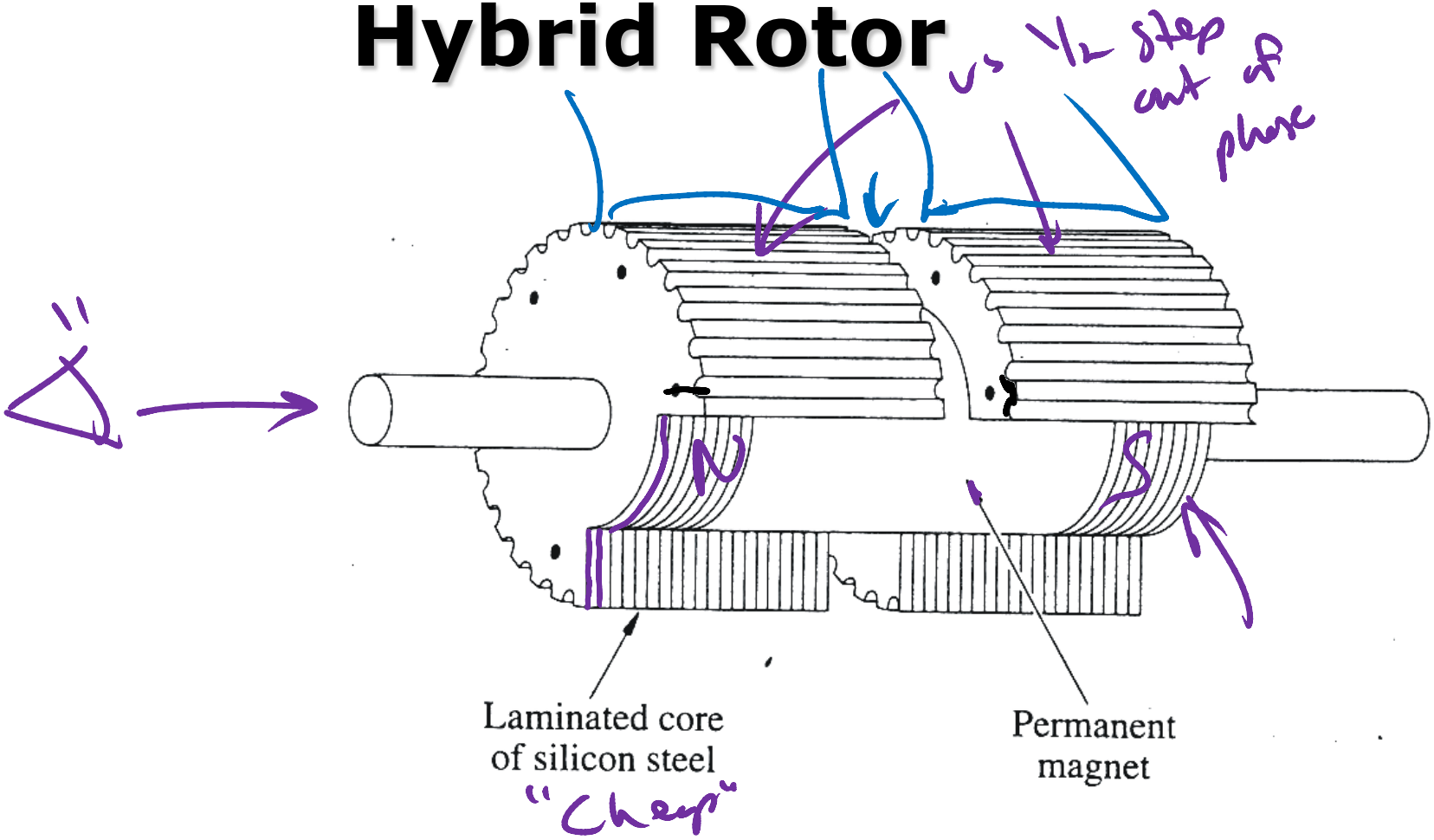
– Fine resolution

PM

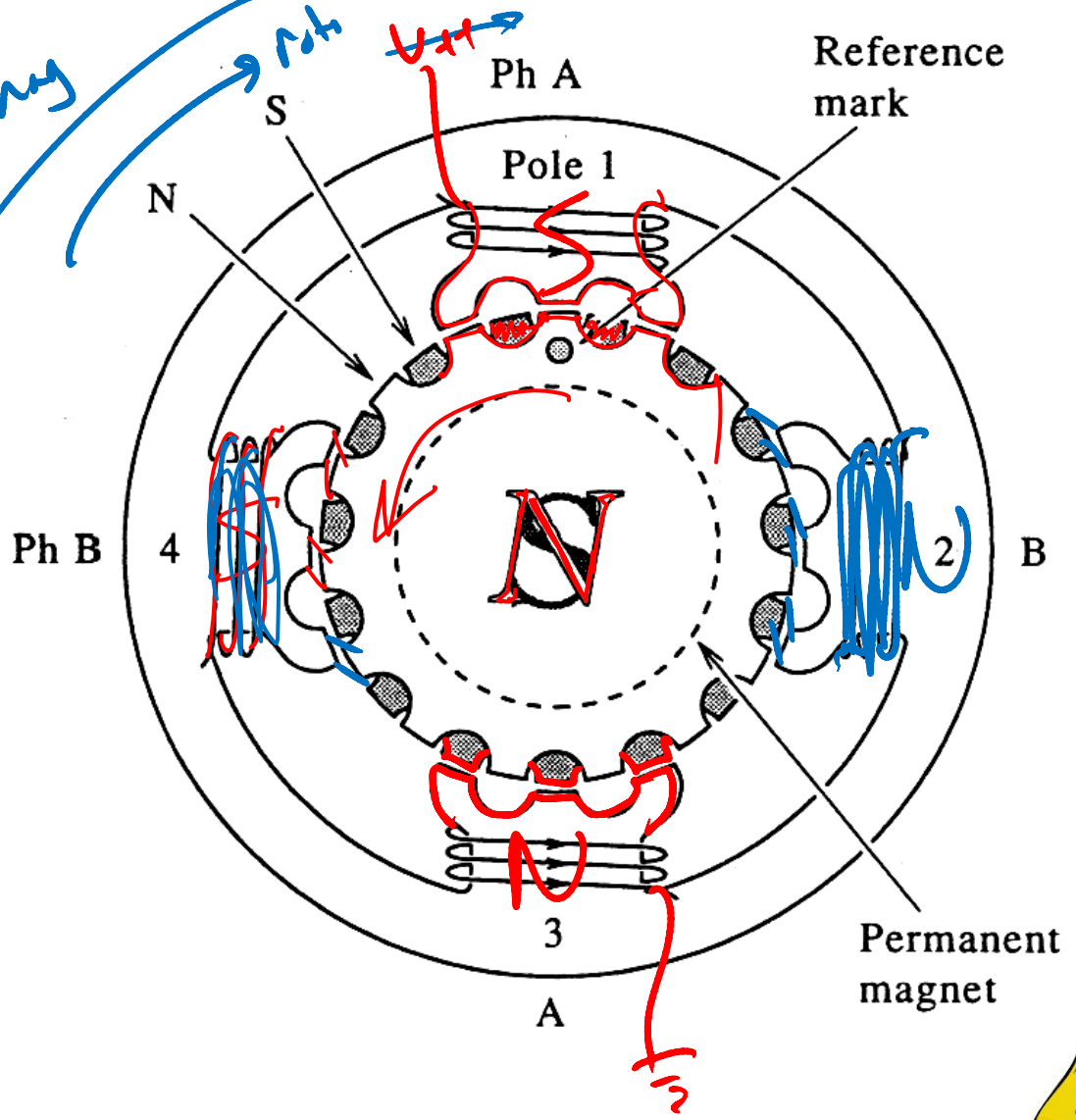
Detent torque



Hybrid Rotor



Hybrid Rotor Offset Teeth



Variations in Output Torque

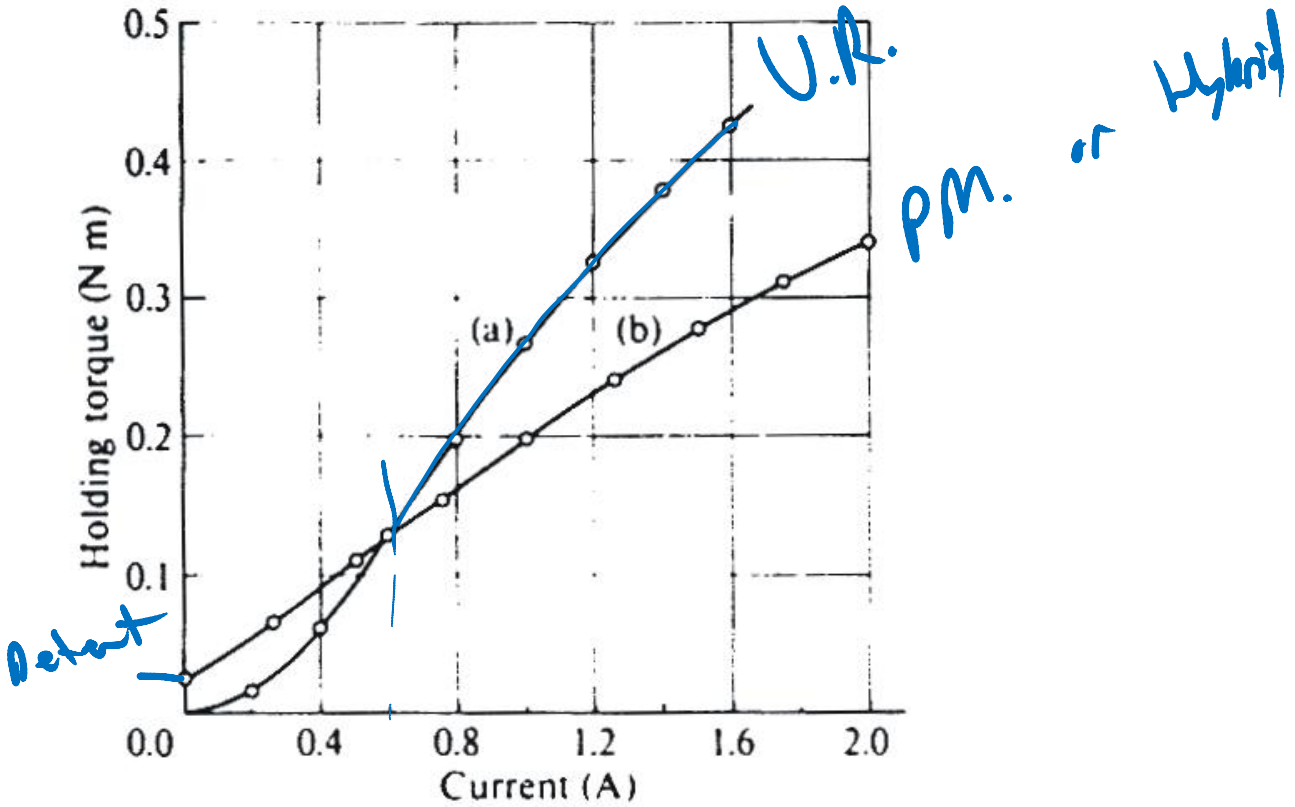
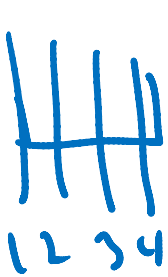
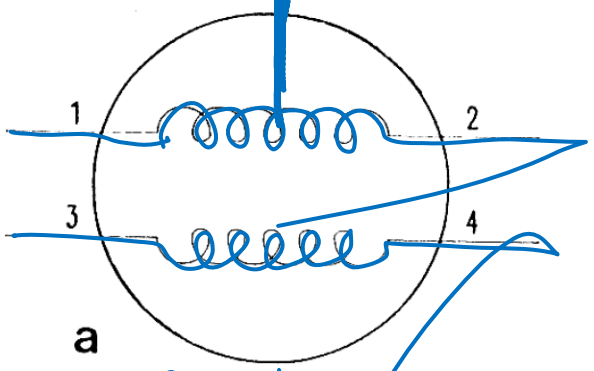


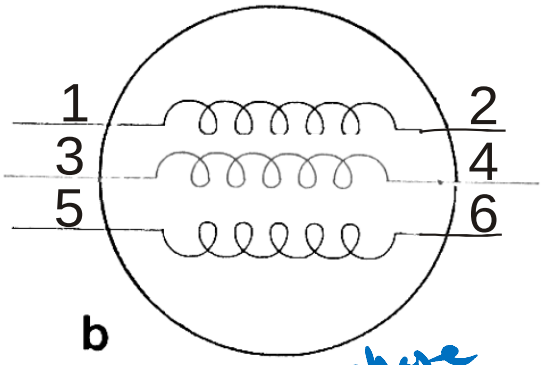
Fig. 2.74. Examples of *T/I* characteristics: (a) a 1.8° four-phase VR motor; and (b) a 1.8° four-phase hybrid motor. (After Ref. [17].)

Stepper Motor Wiring

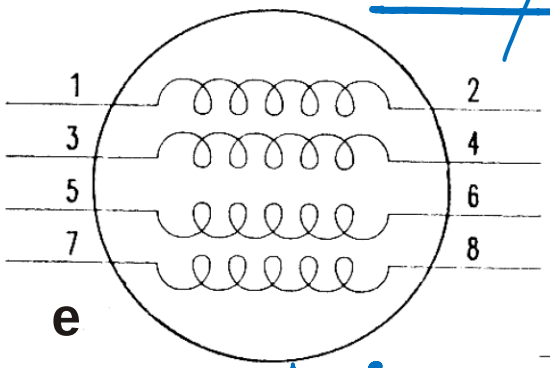




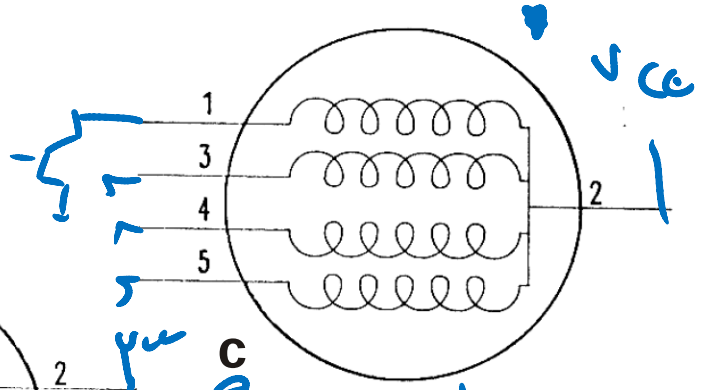
2-phase



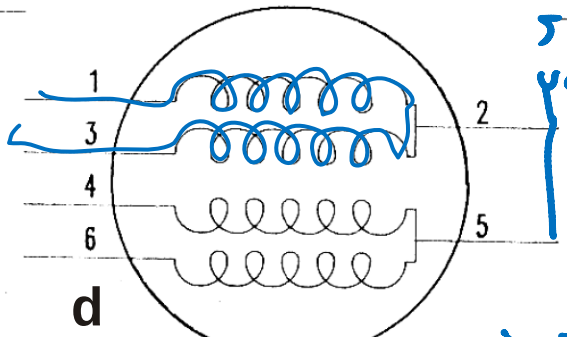
3-phase



4-phase

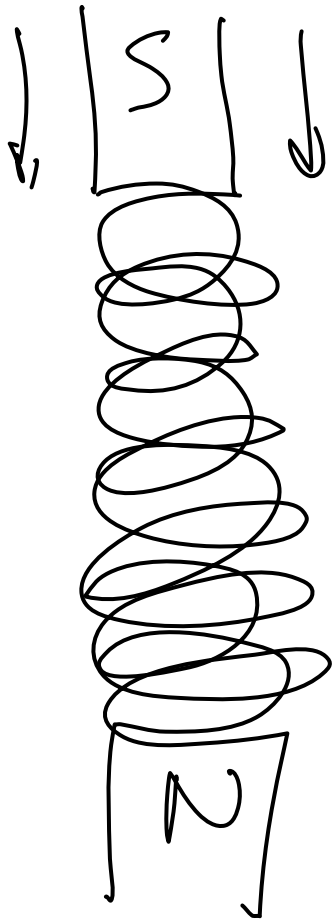


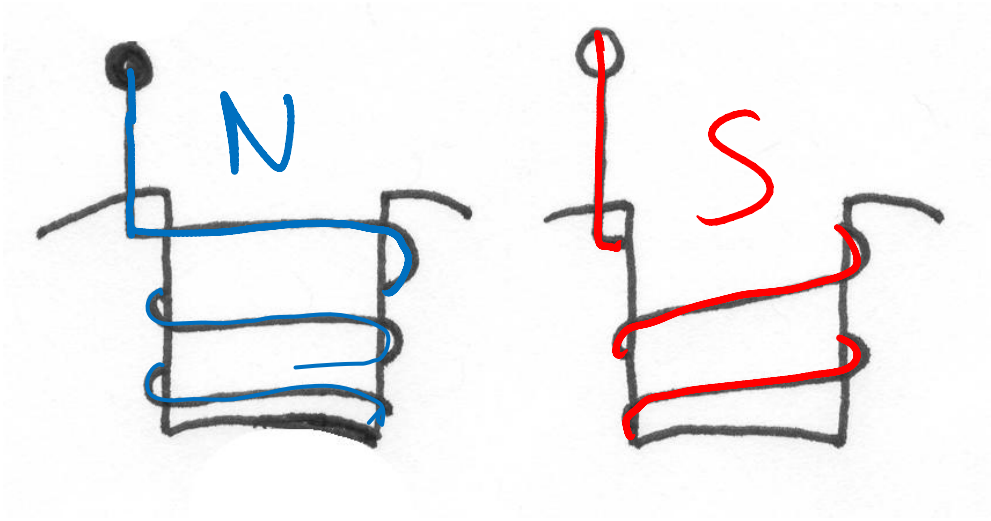
2-phase



2 phase universally used

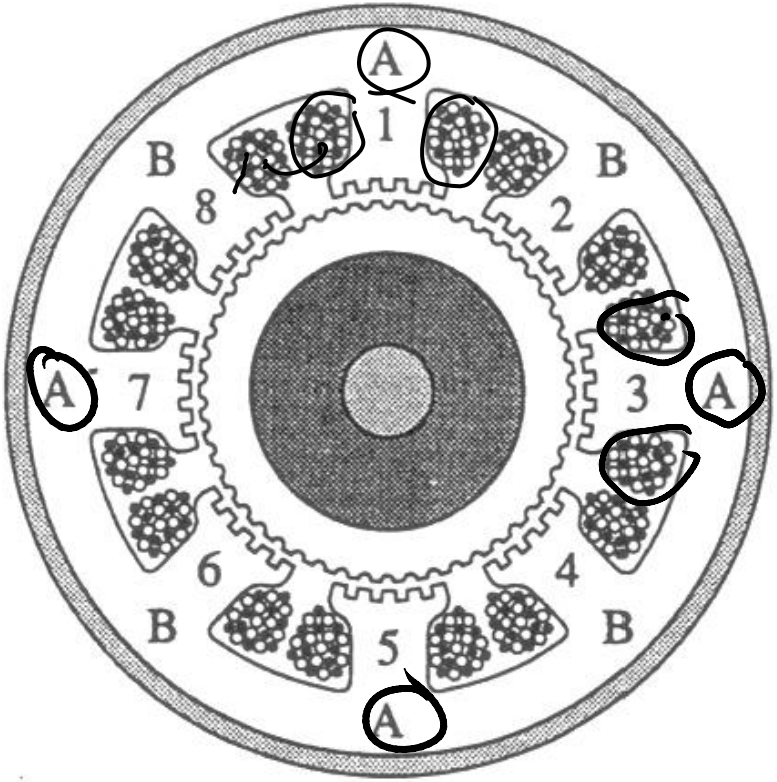
Wiring Direction is Important



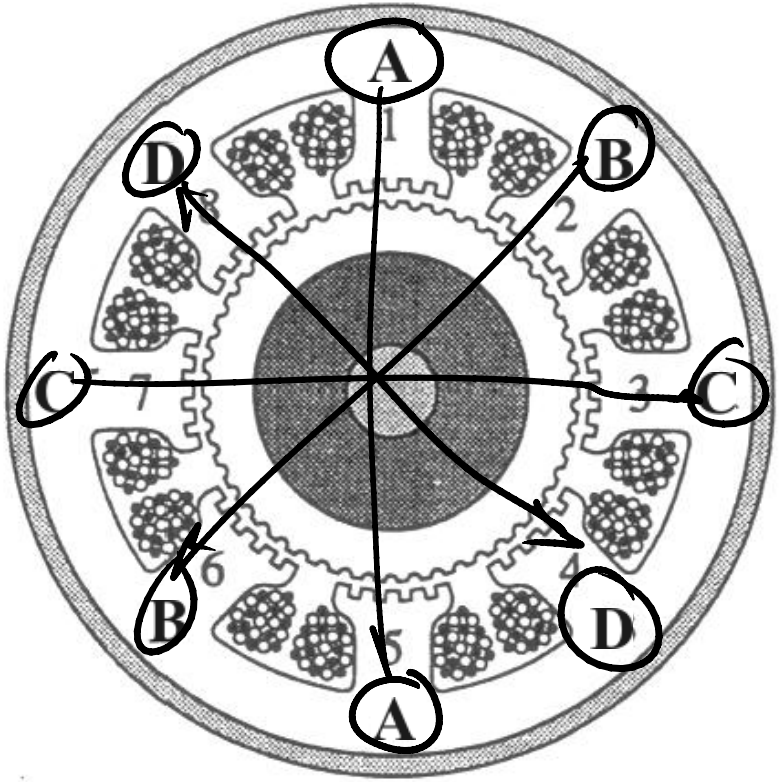


Bifilar Wound

2-Phase Universal Wound vs. 4-Phase

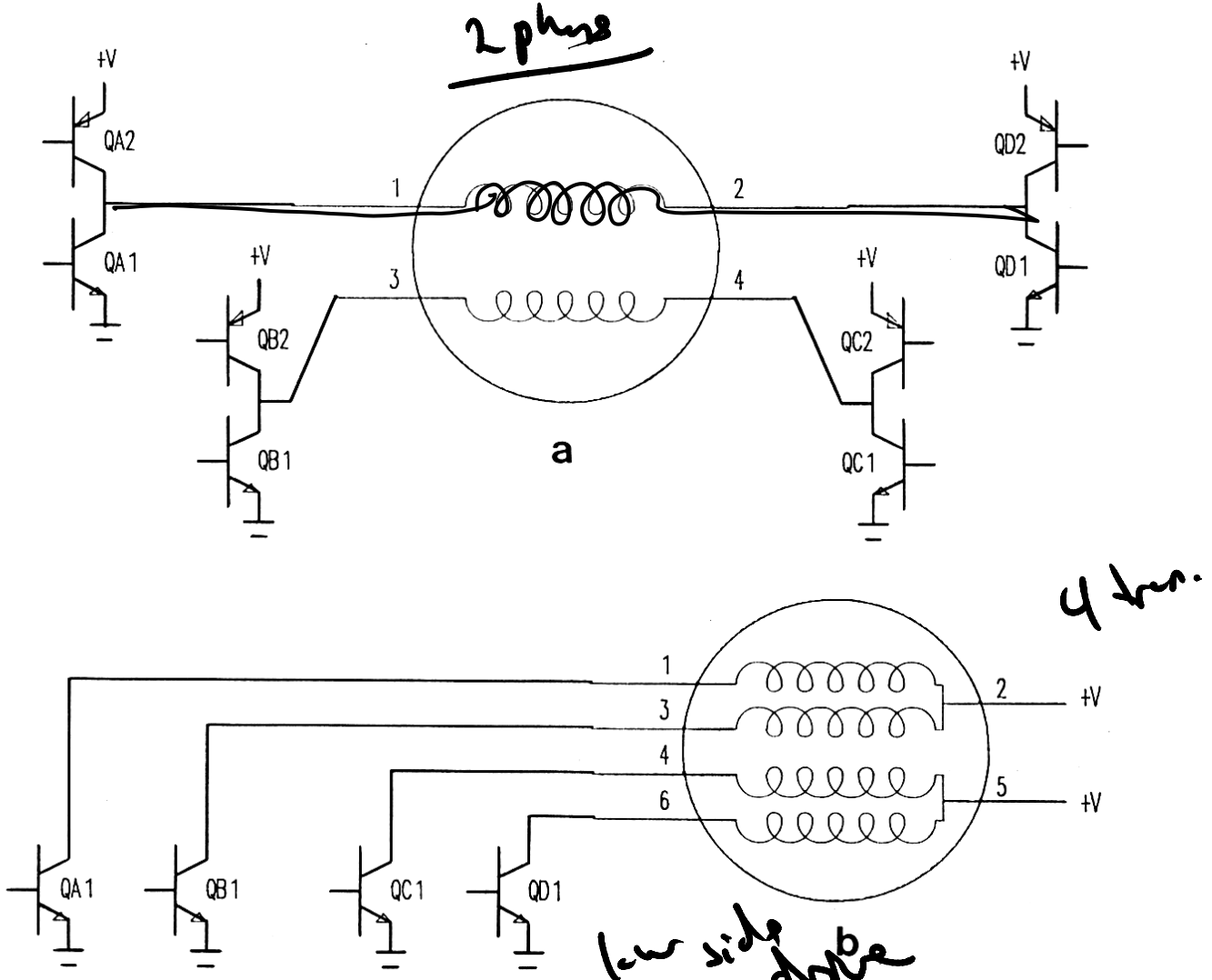


a

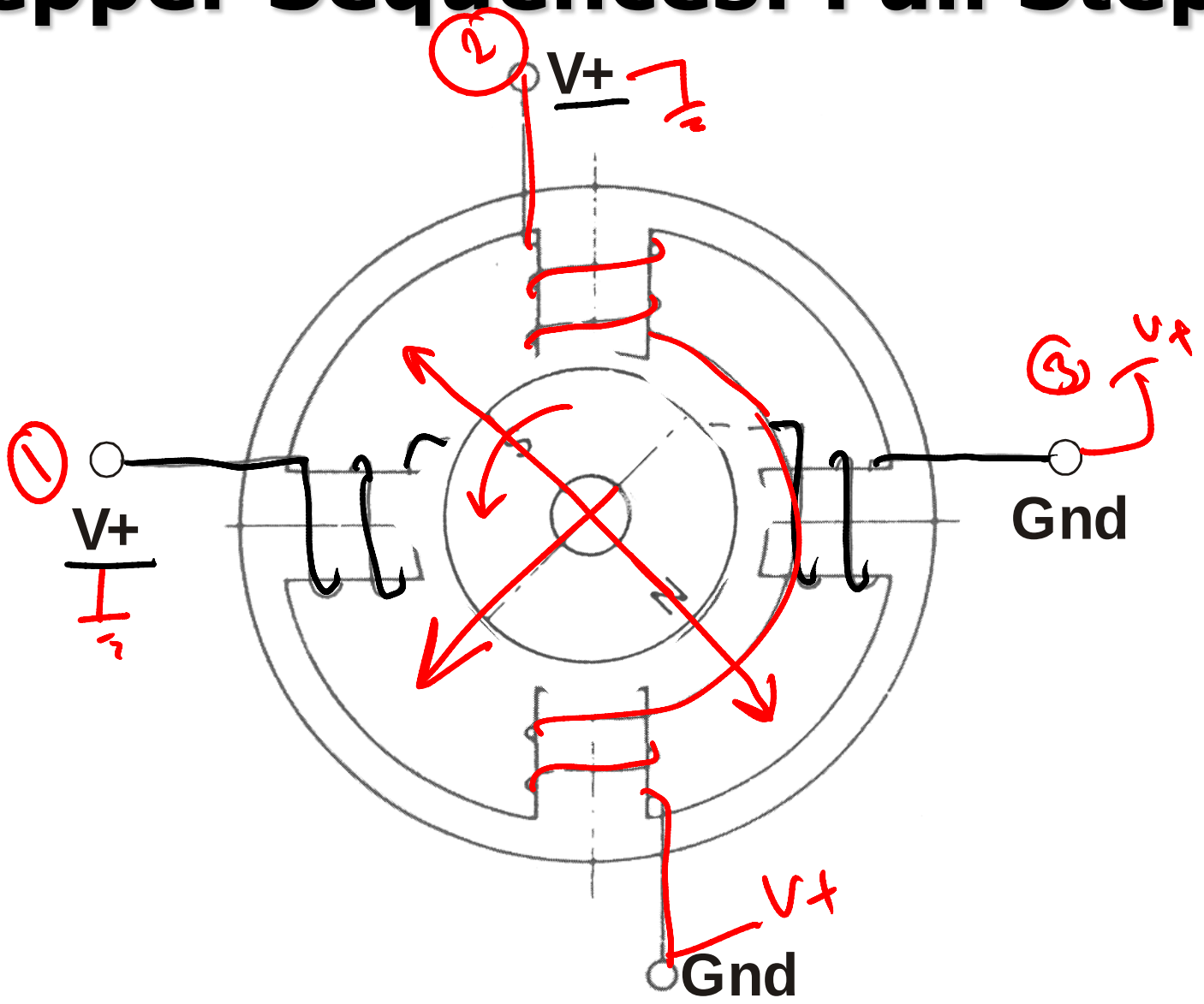


b

Driving Stepper Motors



Stepper Sequences: Full Step



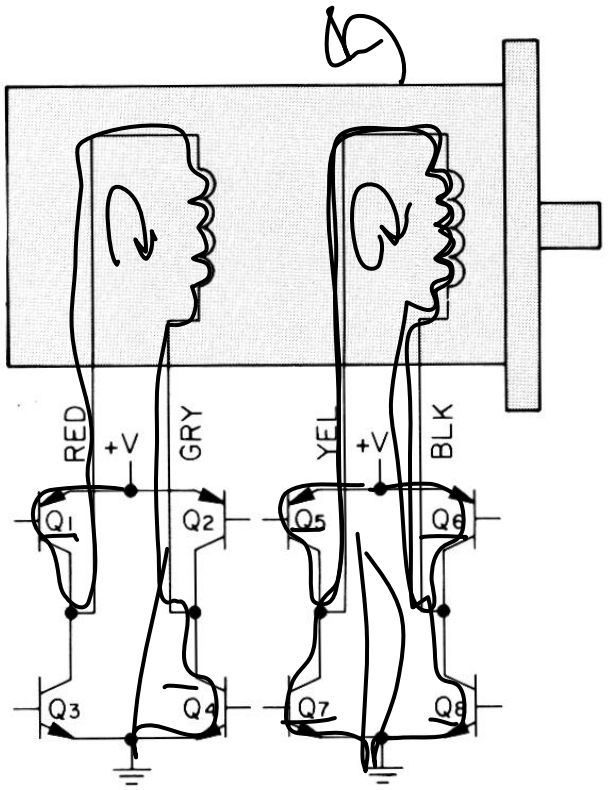
Stepper Sequences: Full Step

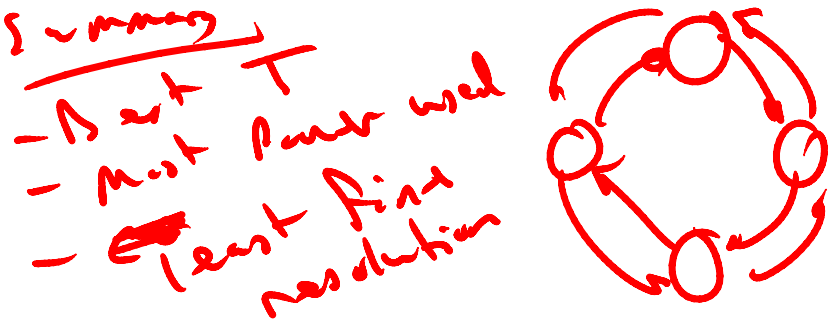
BIPOLAR

CW ROTATION ↓

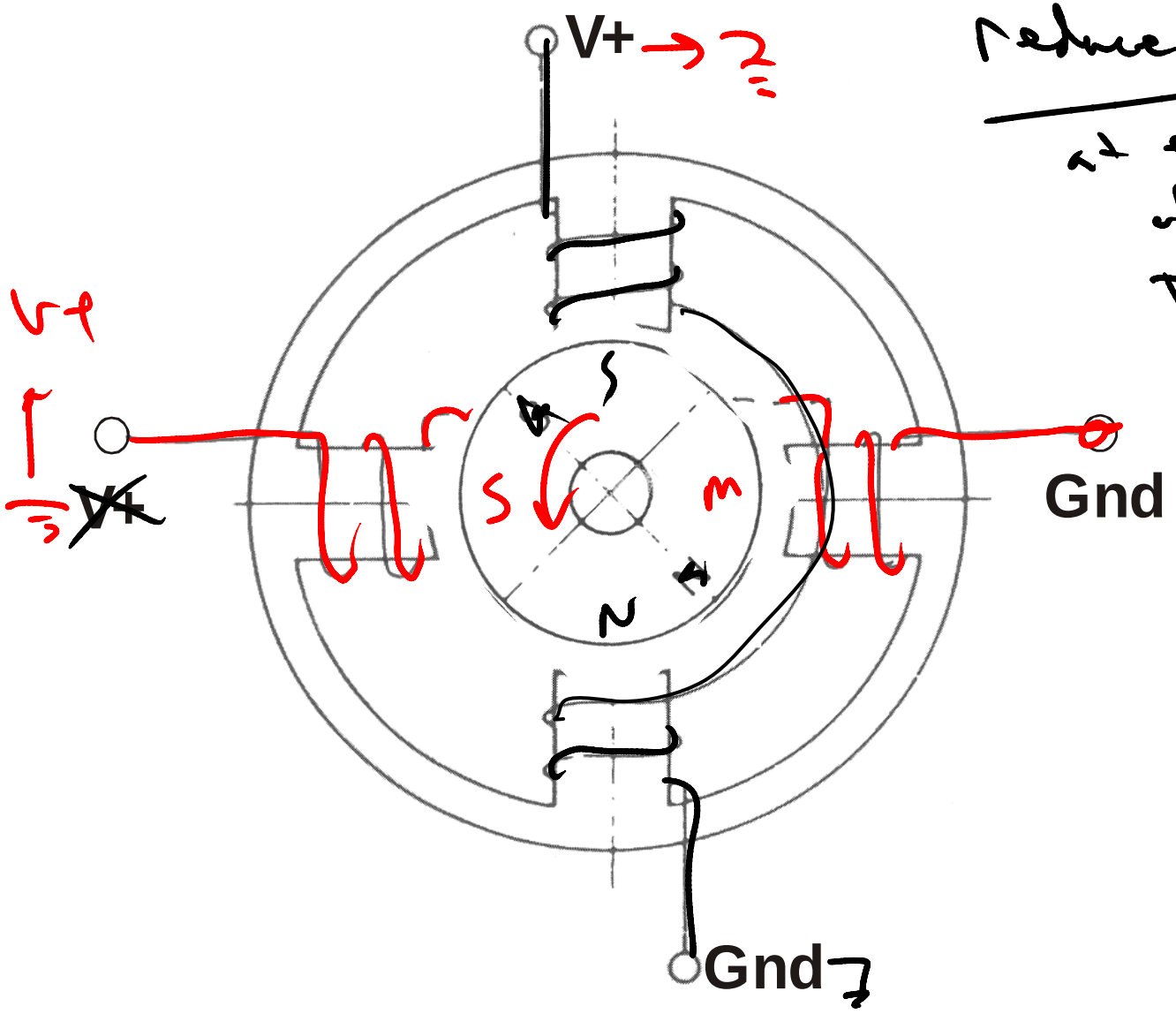
Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

↑ CCW ROTATION





Stepper Sequences: Wave Drive

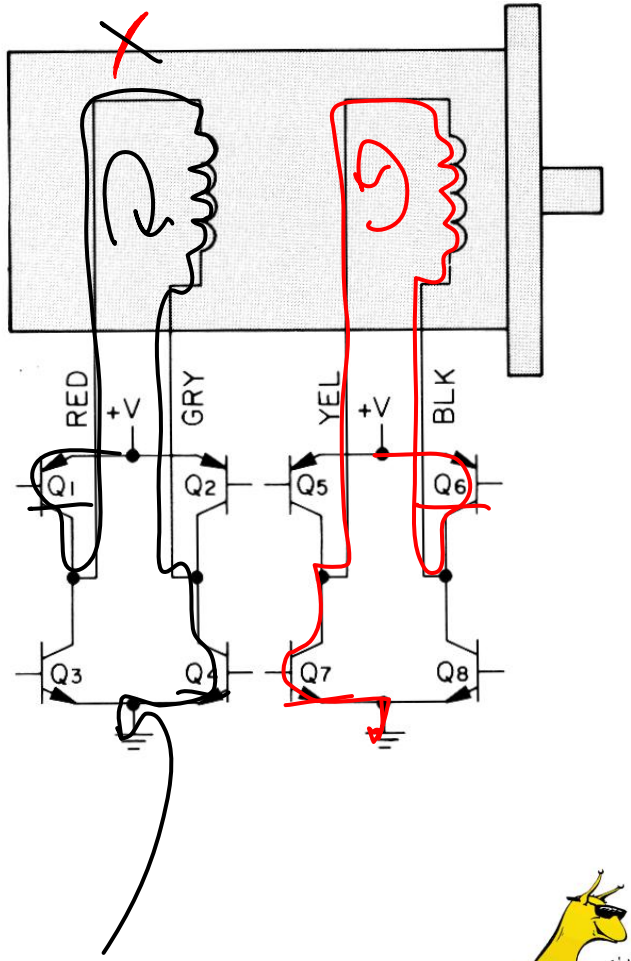


Stepper Sequences: Wave Drive

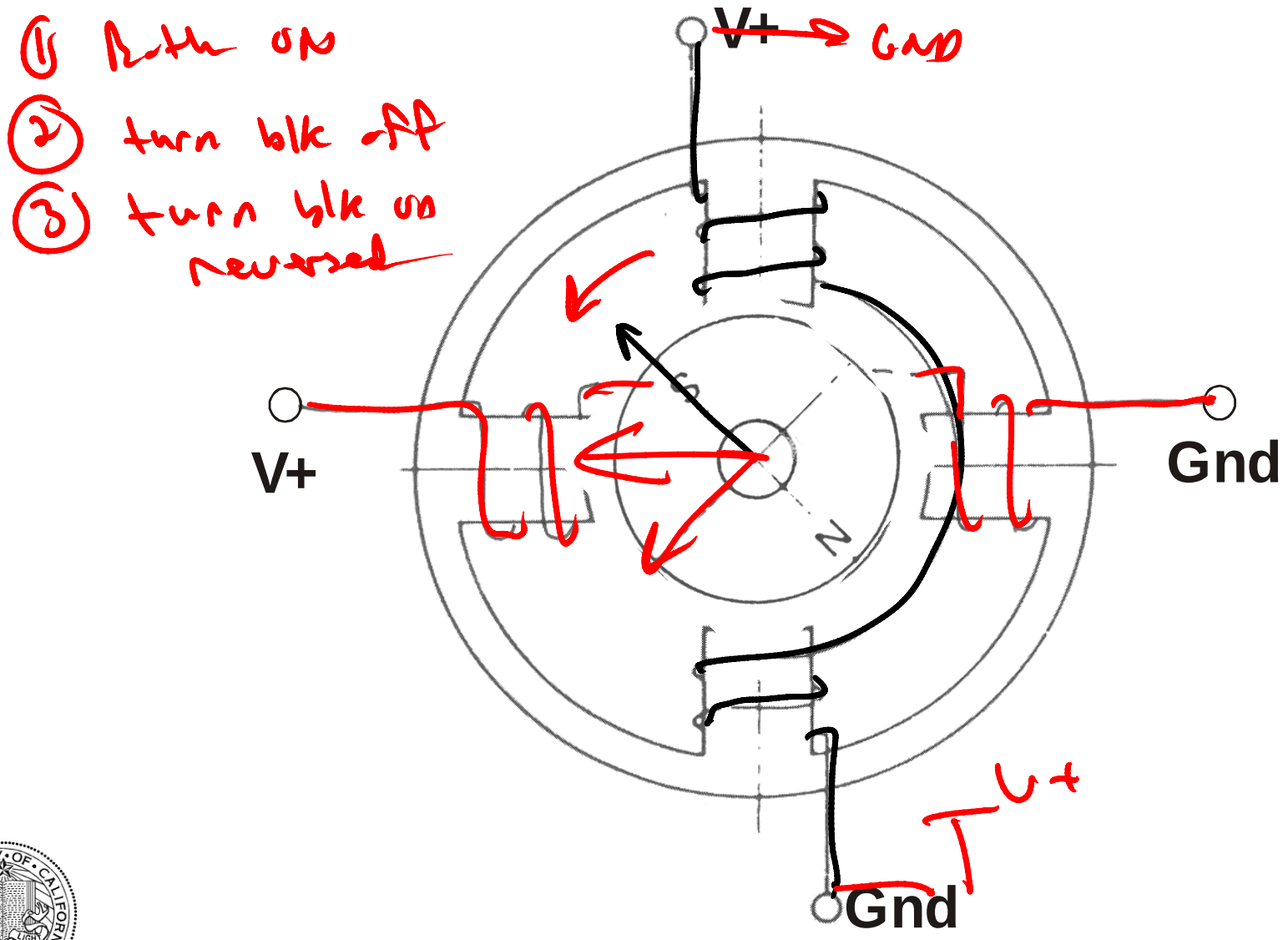
CW ROTATION

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

CCW ROTATION



Stepper Sequences: Half-Step

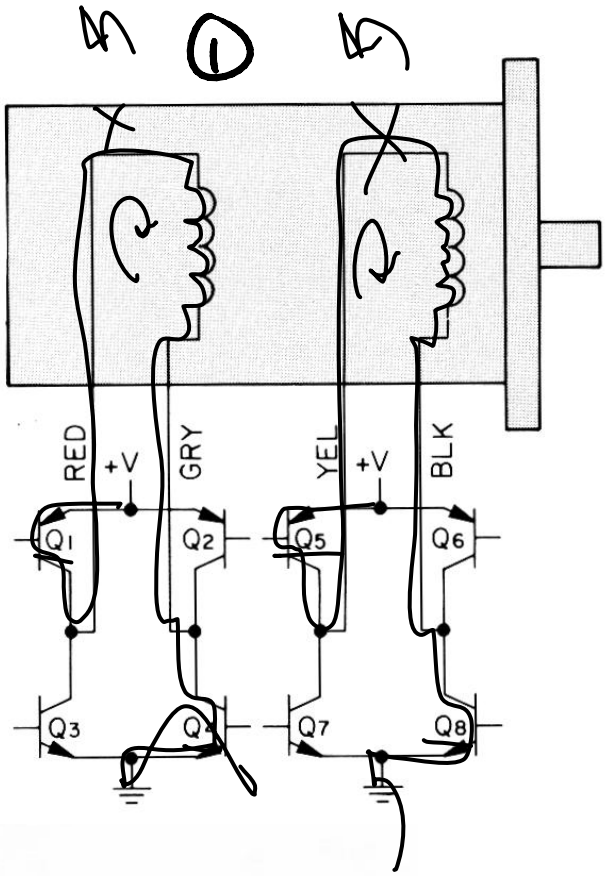


Stepper Sequences: Half-Step Drive

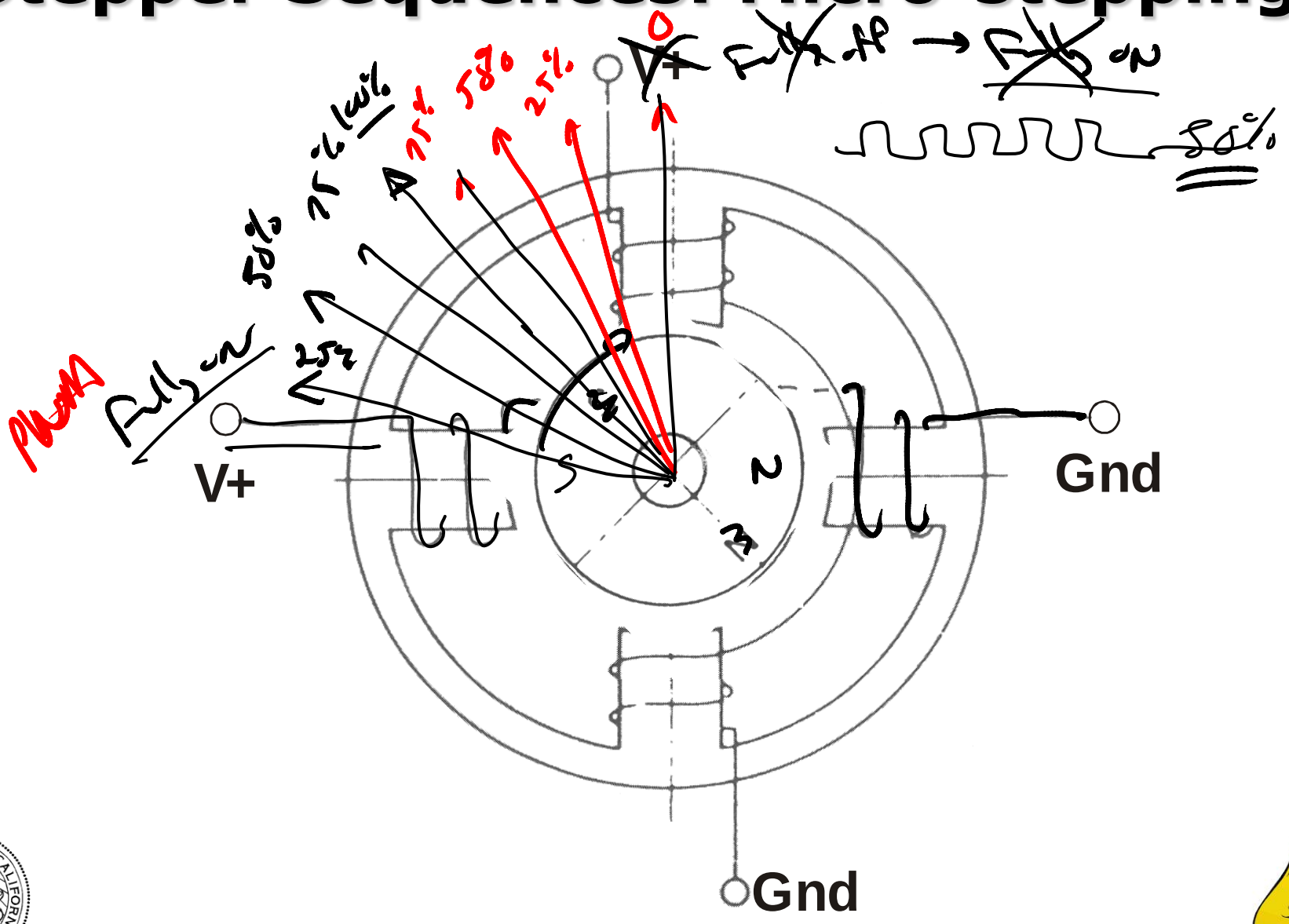
Step	Q_1-Q_4	Q_2-Q_3	Q_5-Q_8	Q_6-Q_7
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	OFF
3	ON	OFF	OFF	ON
4	OFF	OFF	OFF	ON
5	OFF	ON	OFF	ON
6	OFF	ON	OFF	OFF
7	OFF	ON	ON	OFF
8	OFF	OFF	ON	OFF
1	ON	OFF	ON	OFF

CW ROTATION

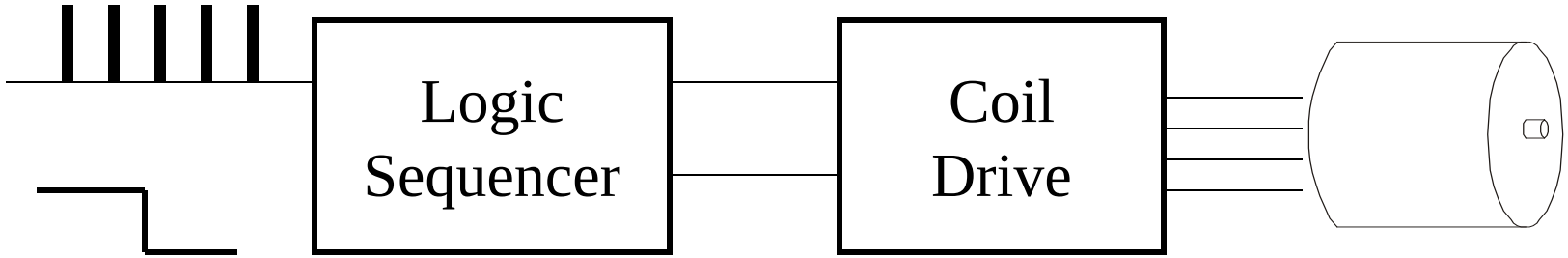
CCW ROTATION



Stepper Sequences: Micro-stepping



Generating the Drive



MC

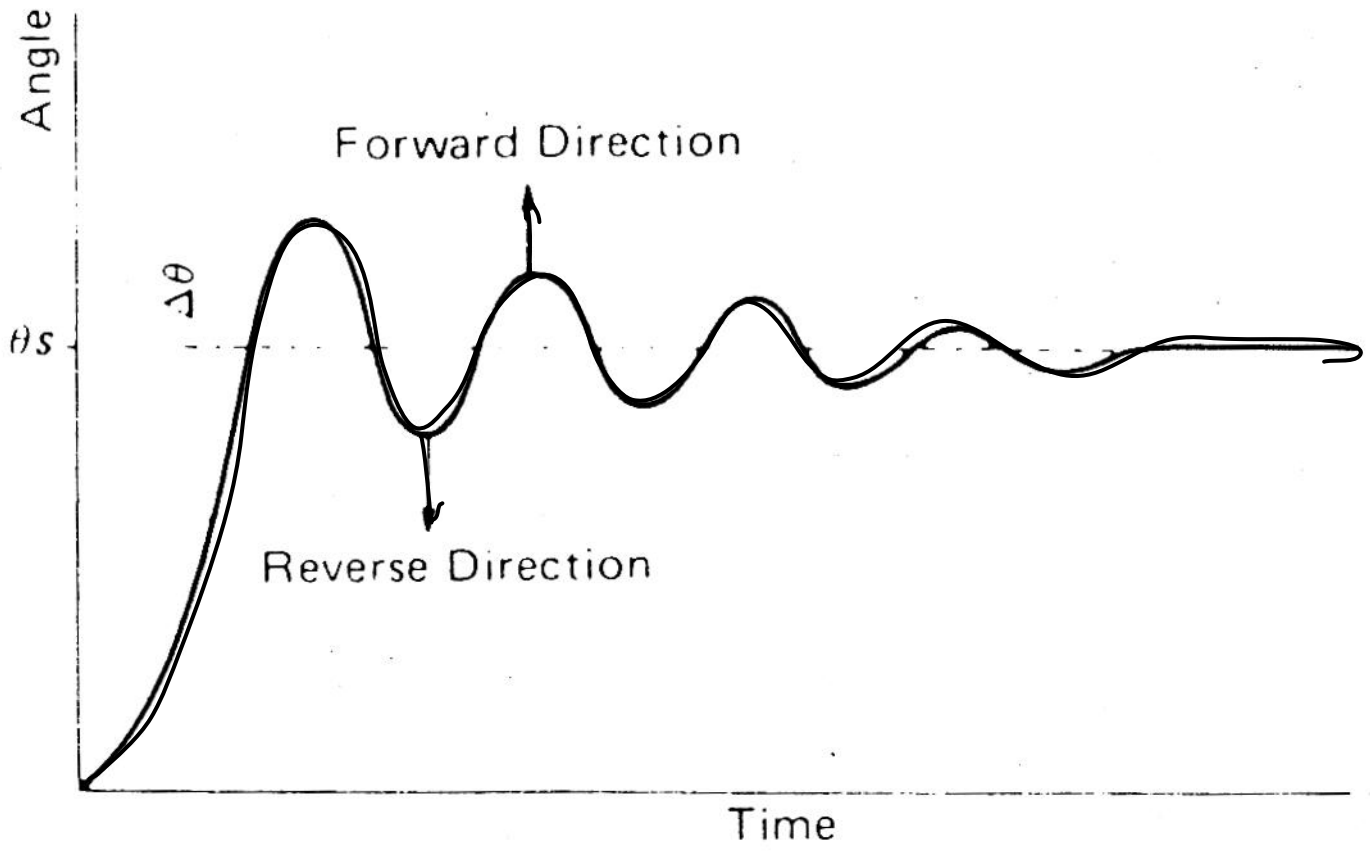
H-Bridge

in lab → HC12 A3949 ①

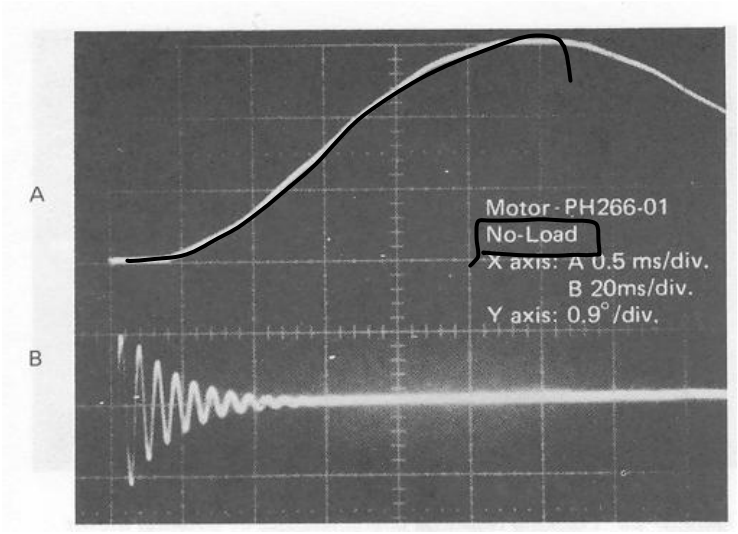
② Combinational control + drive A3982 stepper Driver

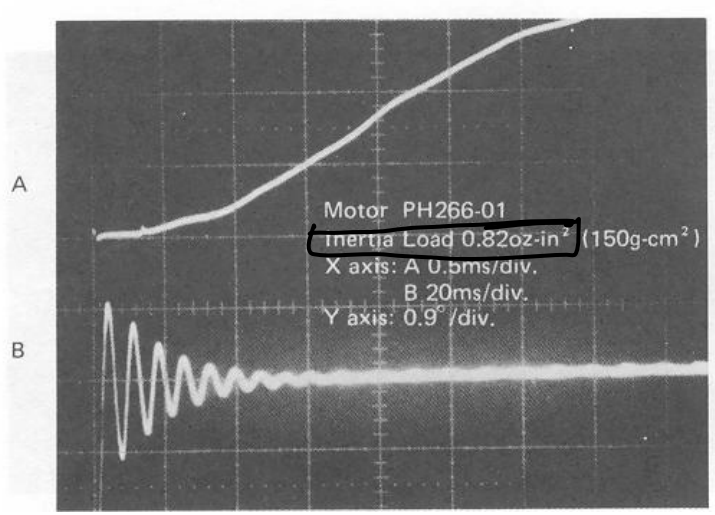
③ L297 stepper motor ctrl. & L298 Dual Full Bridge Driver

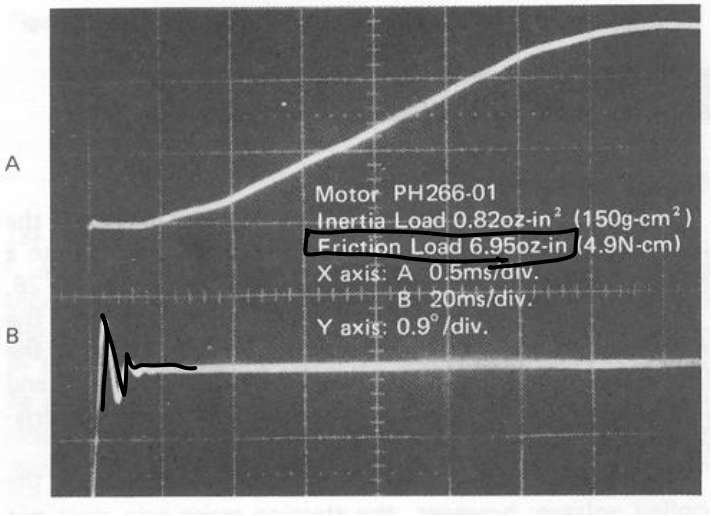
Stepping Dynamics



Load Effects on Step Dynamics







Drive Effects on Step Dynamics

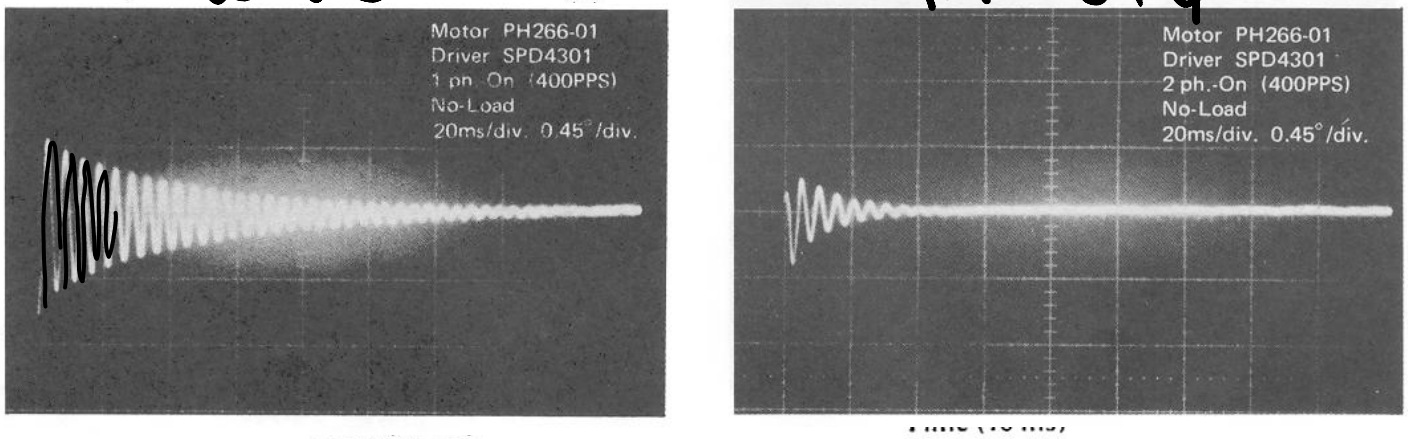
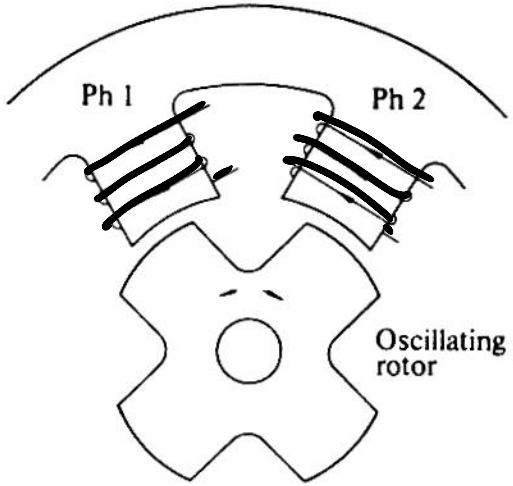
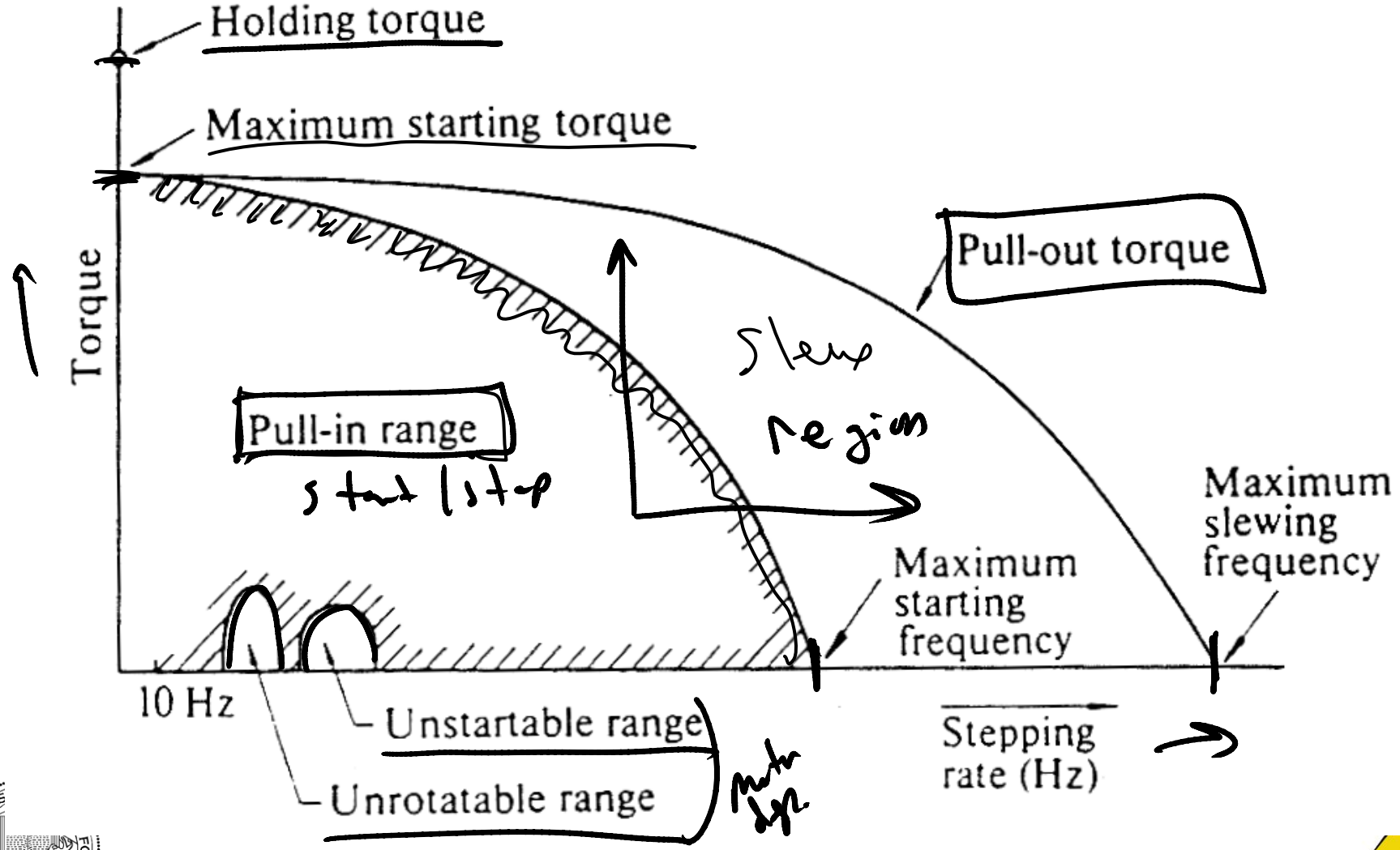


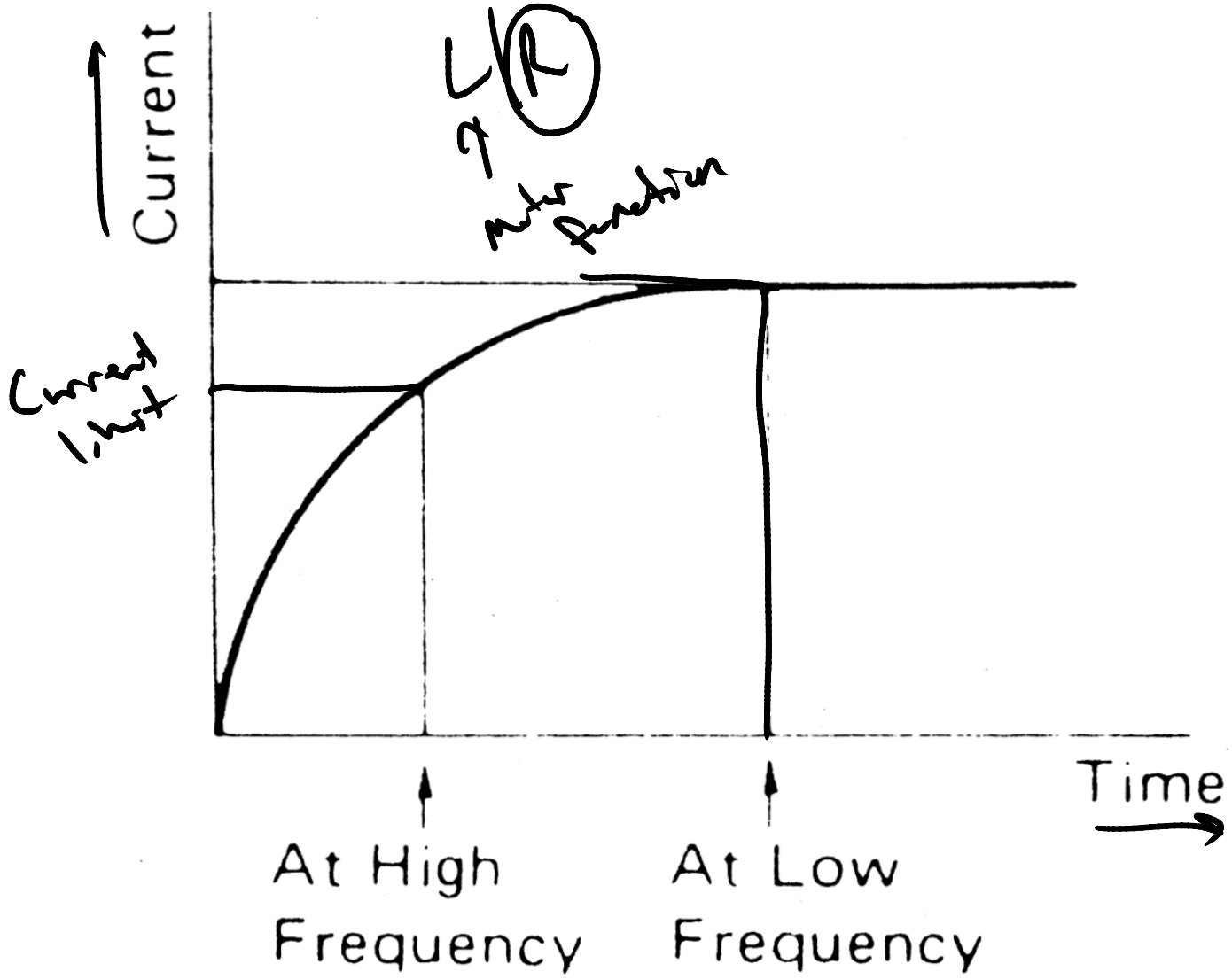
Fig. 2.55. Difference in single-step response between the single-phase (a) and two-phase (b) excitation.



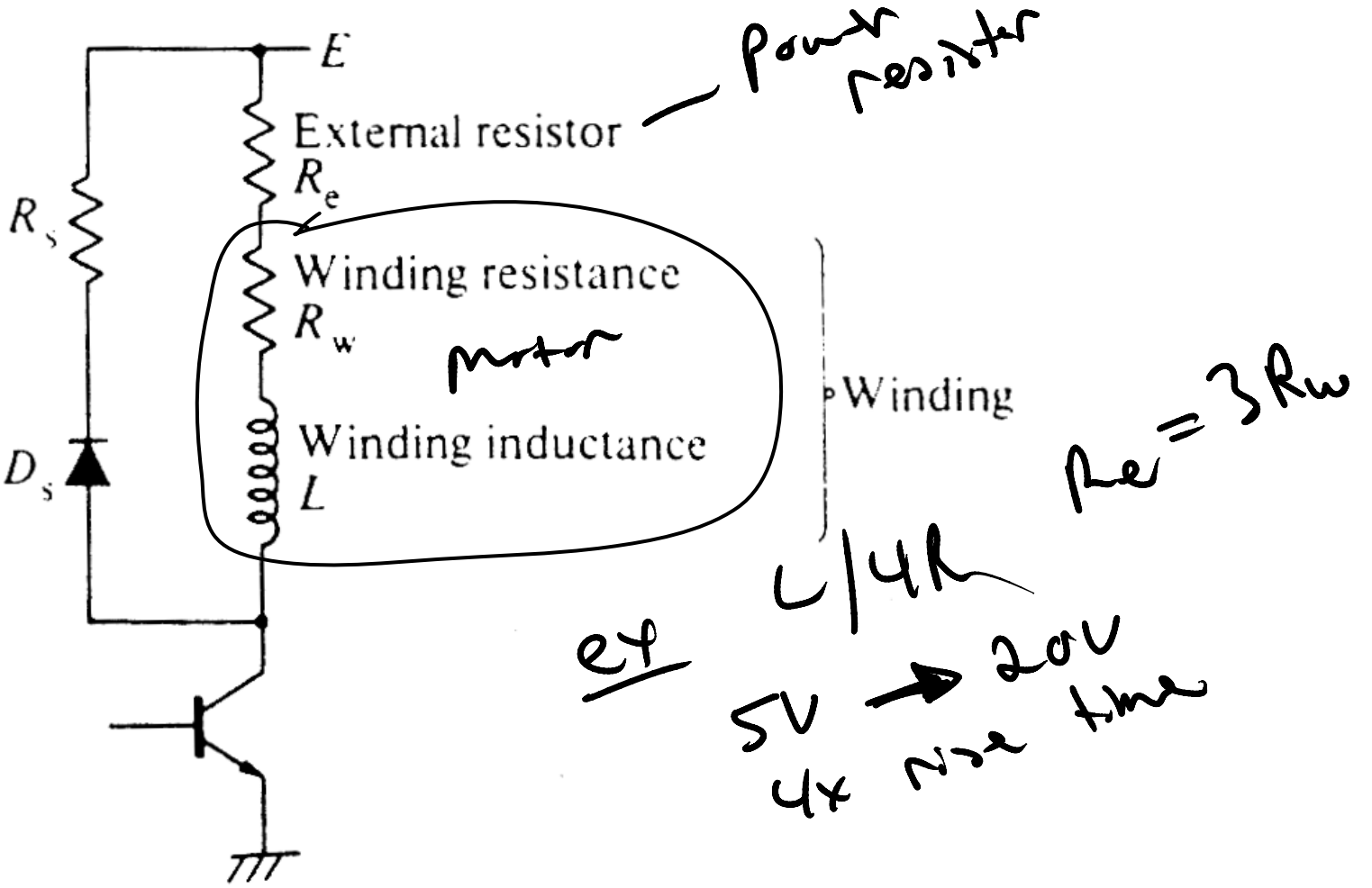
Stepper Motor Performance Curves



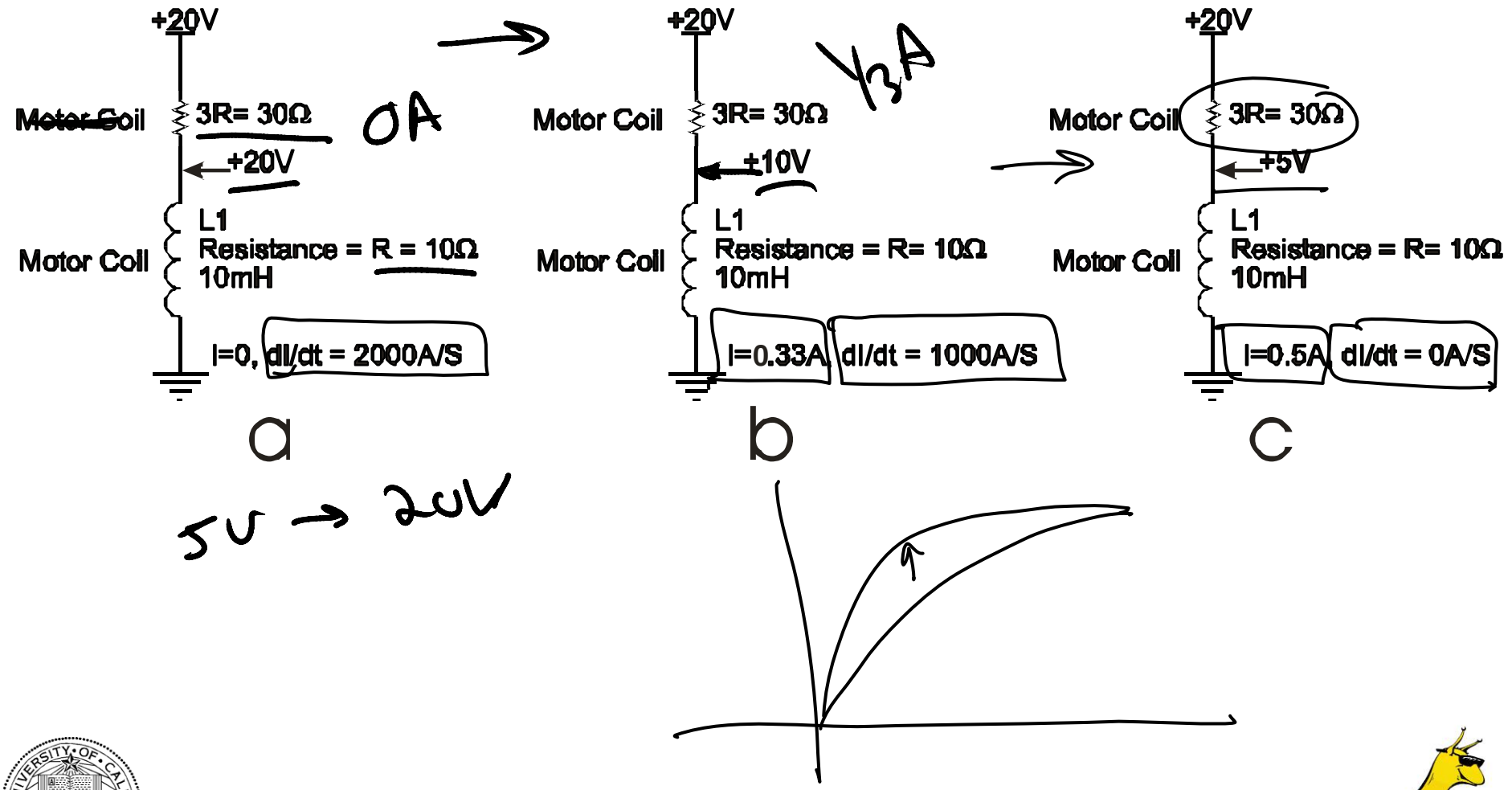
Stepper Motor Current Dynamics



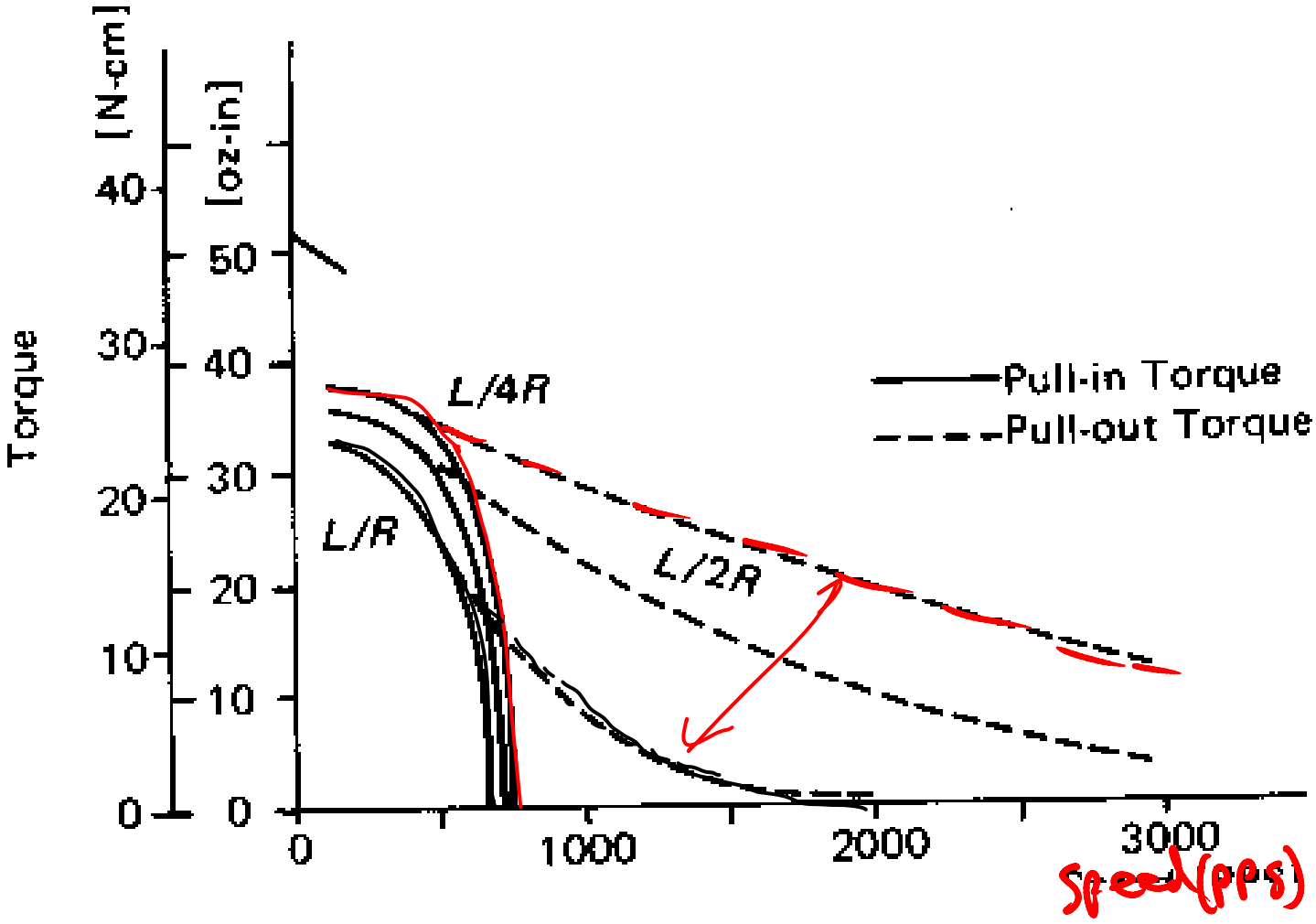
L/nR Drive (1.3)


E
External resistor
R_e
R_s
Winding resistance
R_w
Winding
Winding inductance
L
D_s
power resistor
motor
$R_e = 3R_w$
L/4R
ex
5V → 20V
4x rise time

L/nR Drive (2.3)


V/4R
+20V
Motor Coil
3R= 30Ω
+20V
L1
Resistance = R = 10Ω
10mH
Motor Coil
I=0, dI/dt = 2000A/S
0A
a
5V → 20V
+20V
Motor Coil
3R= 30Ω
±10V
L1
Resistance = R= 10Ω
10mH
Motor Coil
I=0.33A dI/dt = 1000A/S
1/3A
b
+20V
Motor Coil
3R= 30Ω
+5V
L1
Resistance = R= 10Ω
10mH
Motor Coil
I=0.5A dI/dt = 0A/S
c

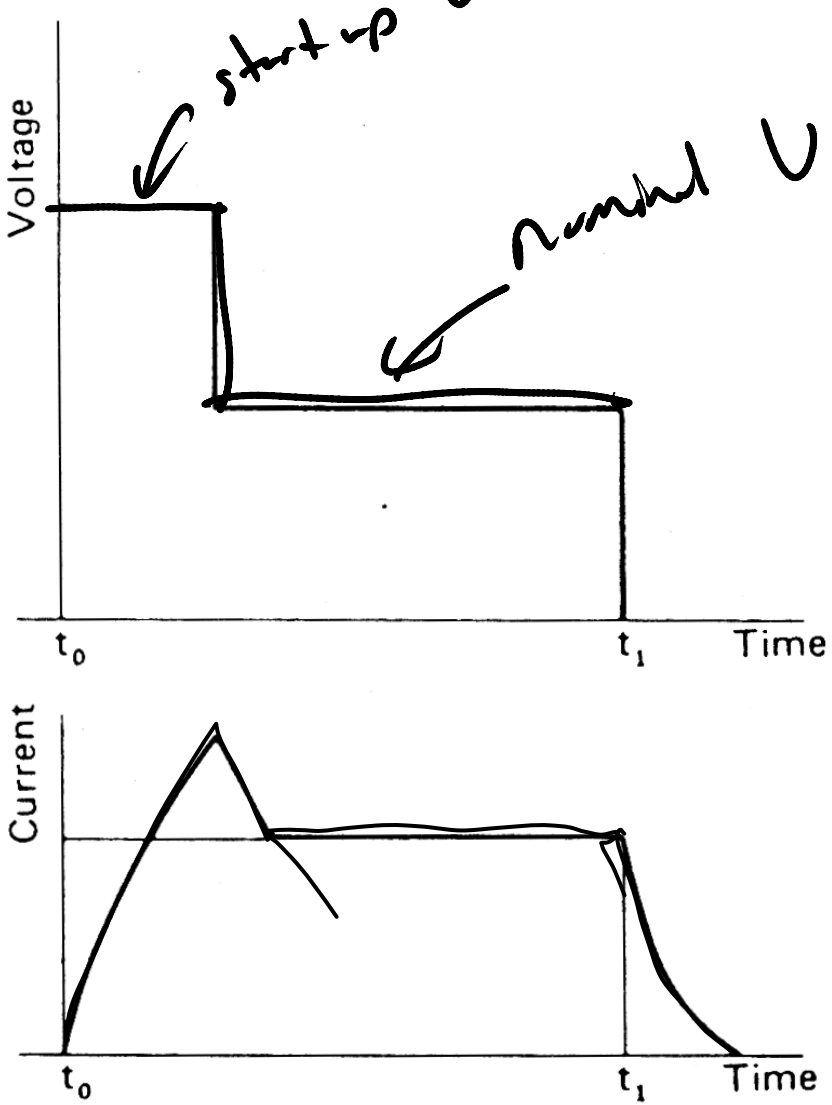
L/nR Drive (3.3)


Torque
[N-cm]
[oz-in]
40
30
20
10
0
50
40
30
20
10
0
L/4R
L/R
L/2R
Pull-in Torque
Pull-out Torque
0
1000
2000
3000
Speed(pps)

2-Level Drive

Pros
works well

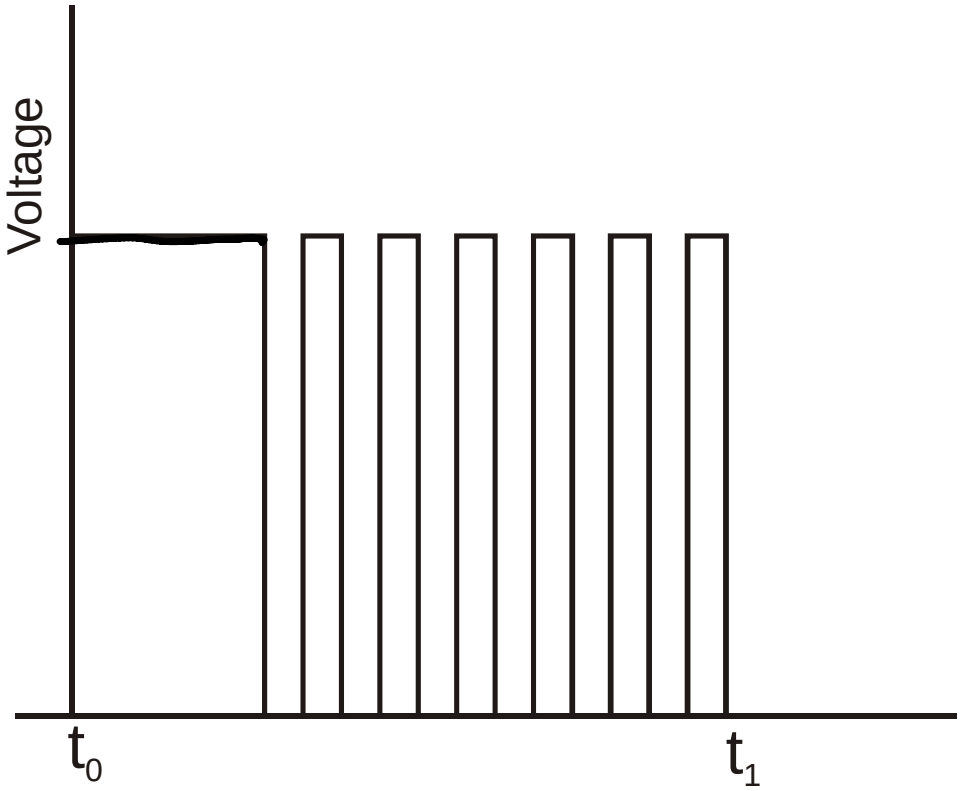
Cons
2 voltages

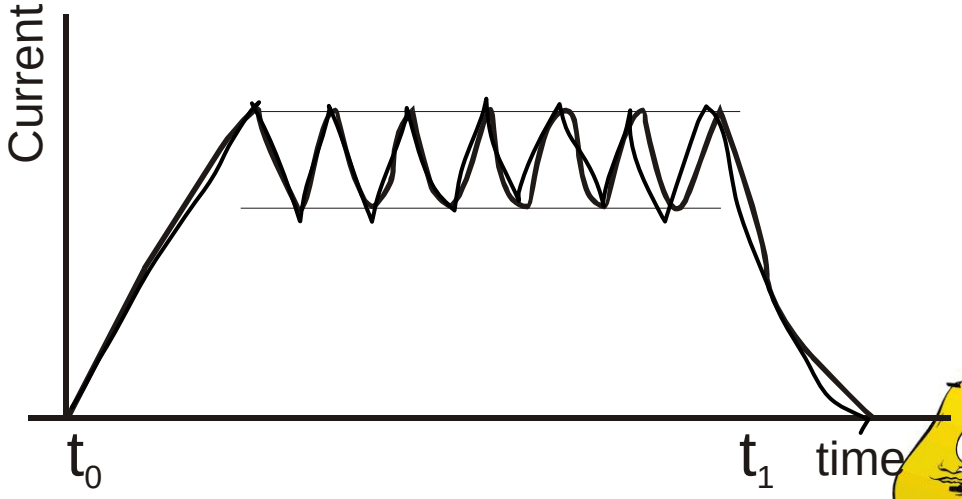


Chopper Drive

Peak & Hold

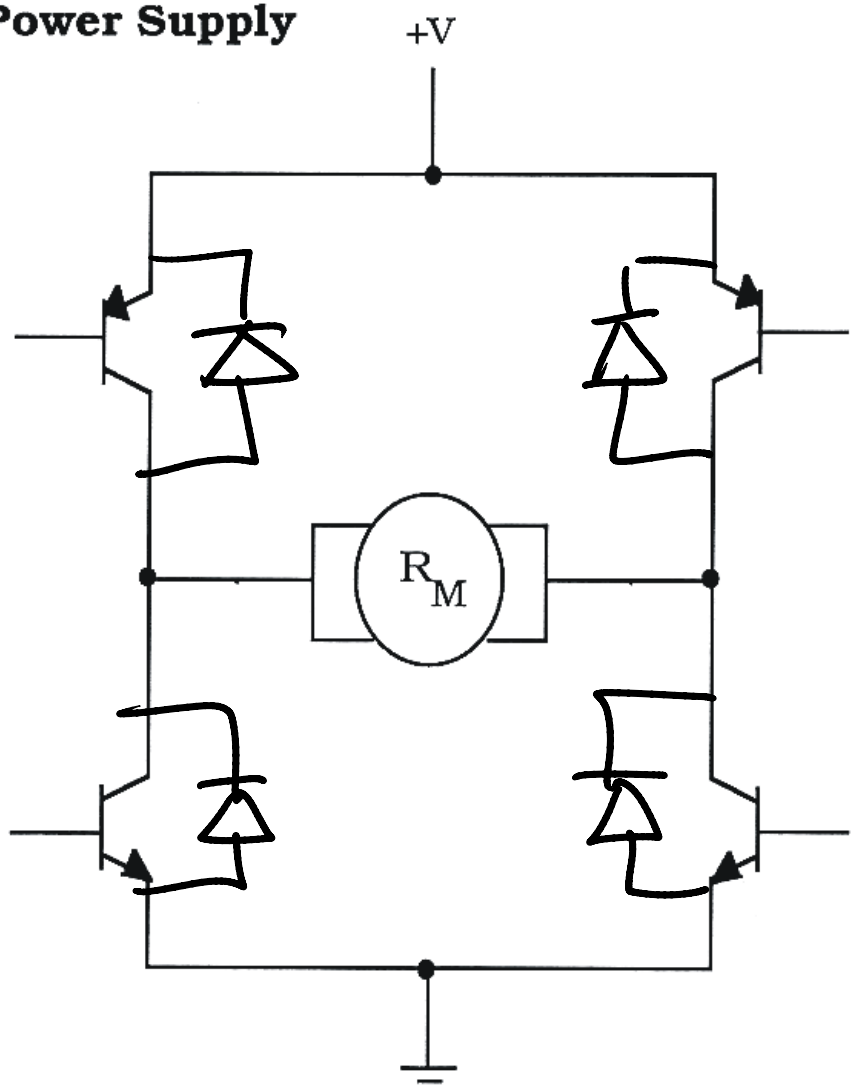
Con / Notoriously high EMI





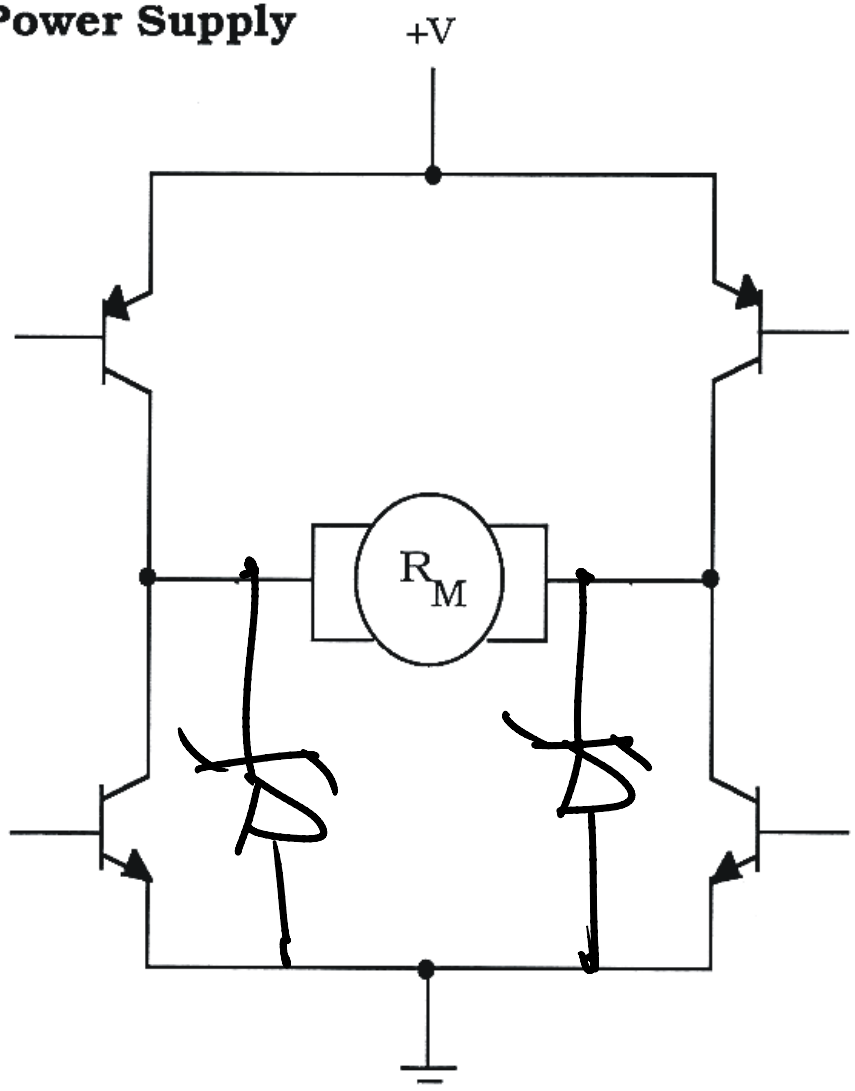
Diode Snubber for H-bridge

Single Power Supply

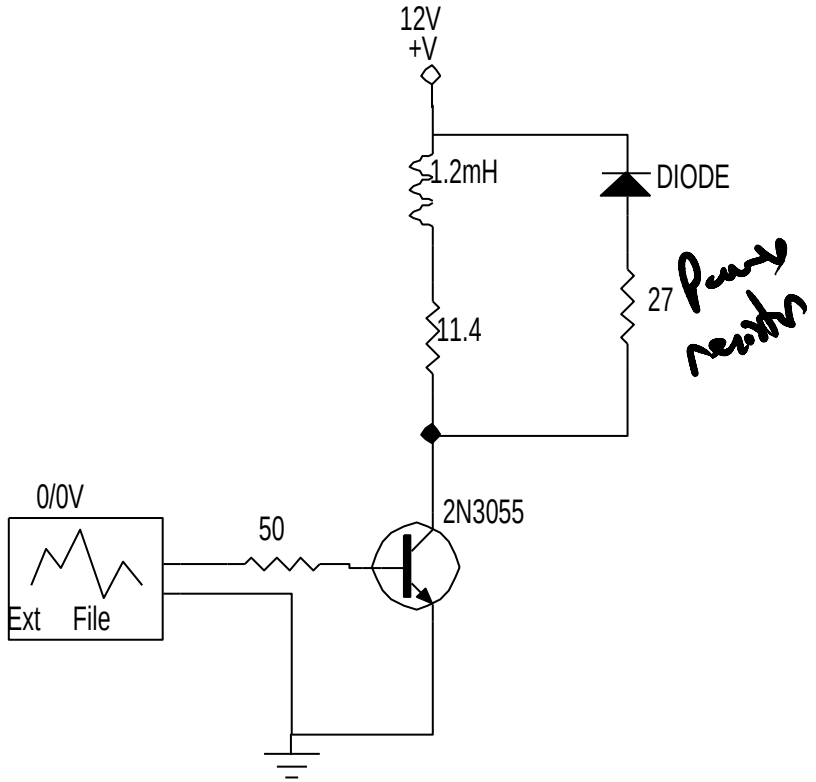


Zener Snubber for H-bridge

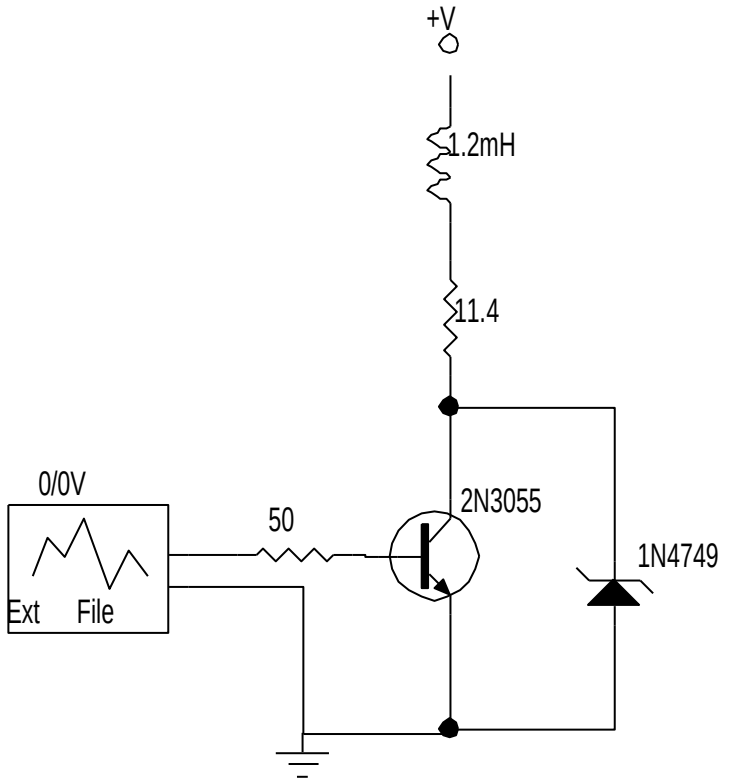
Single Power Supply



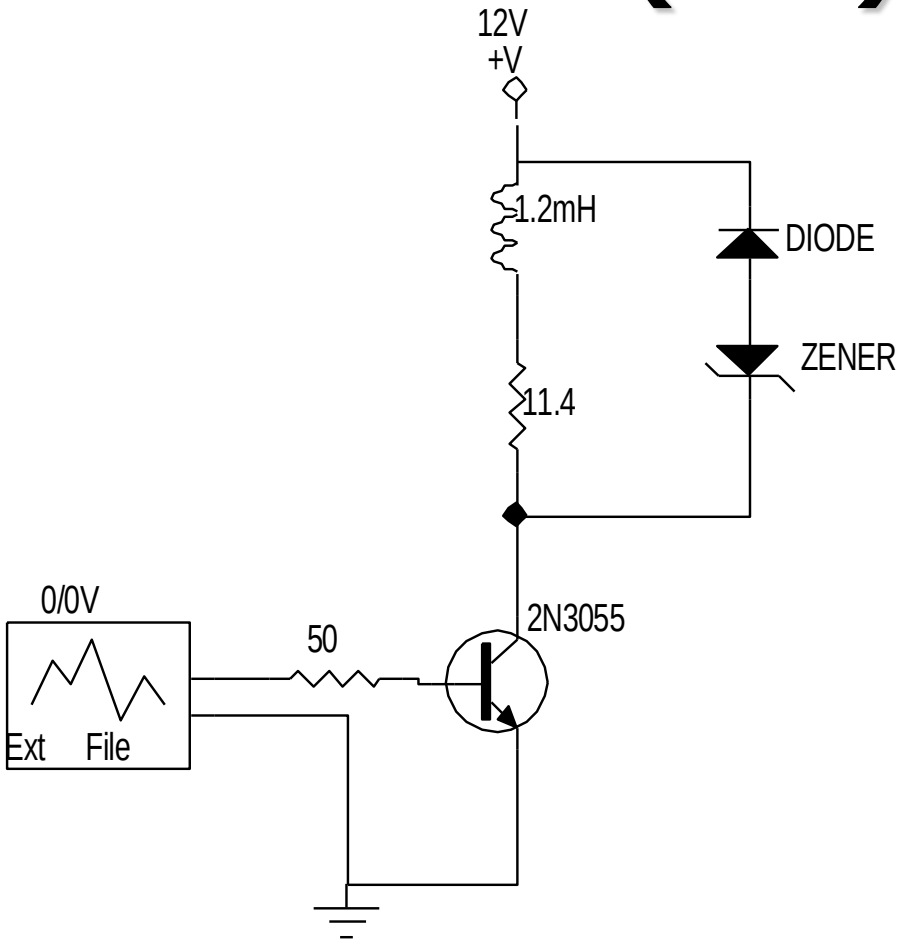
Other Snubbing Alternatives (1.3)



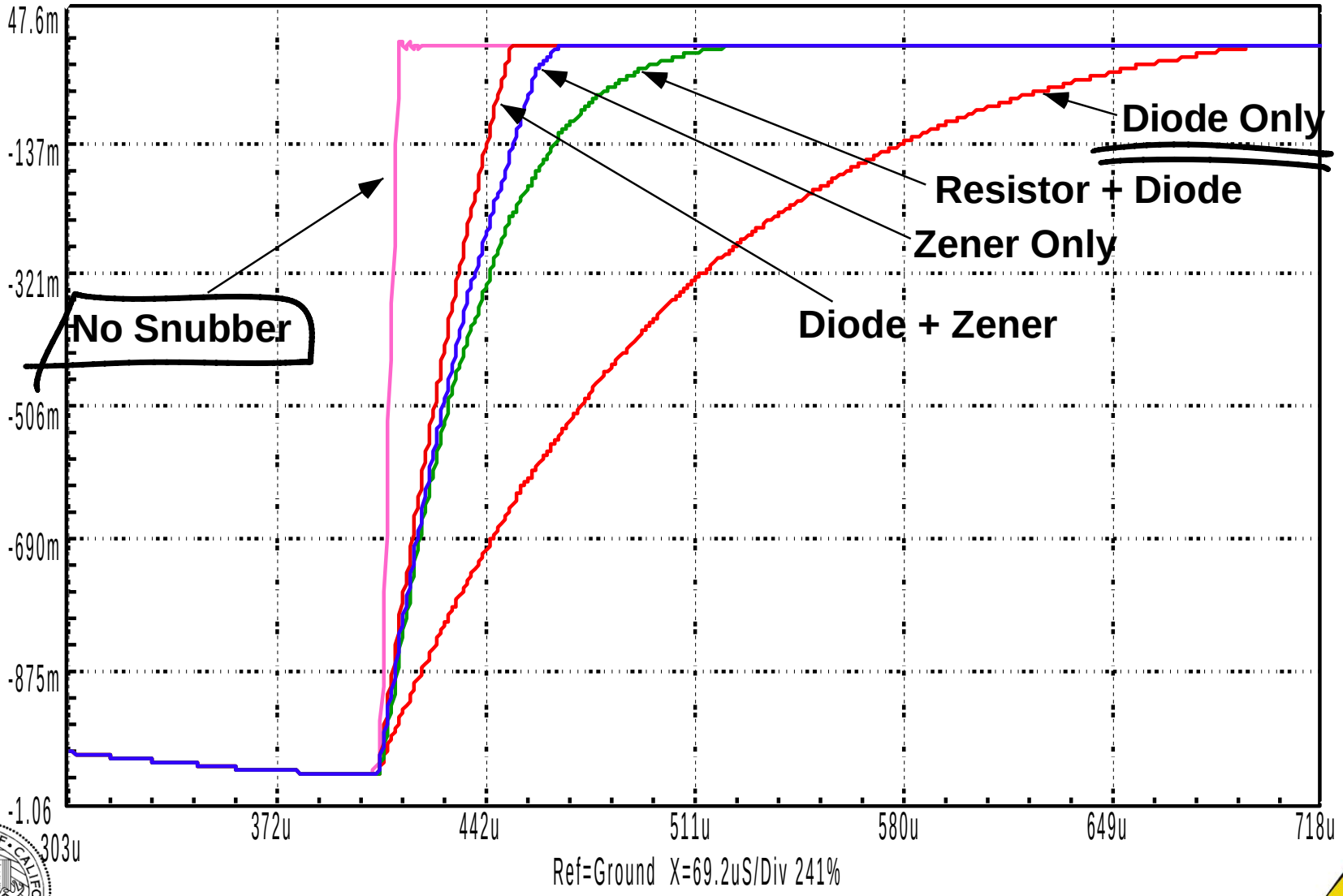
Other Snubbing Alternatives (2.3)



Other Snubbing Alternatives (3.3)



Snubbing Techniques Compared (1.2)



Snubbing Techniques Compared (2.2)

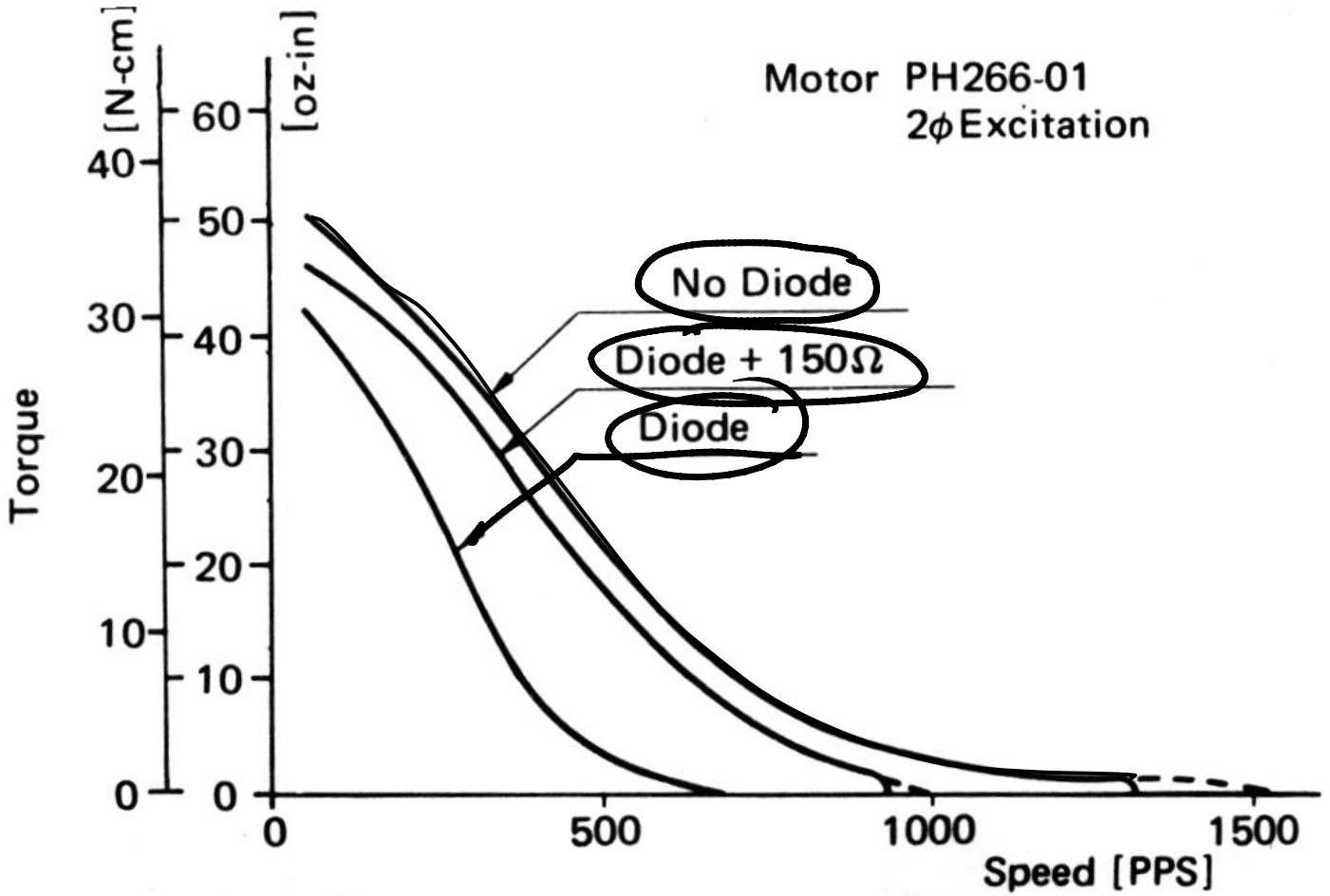
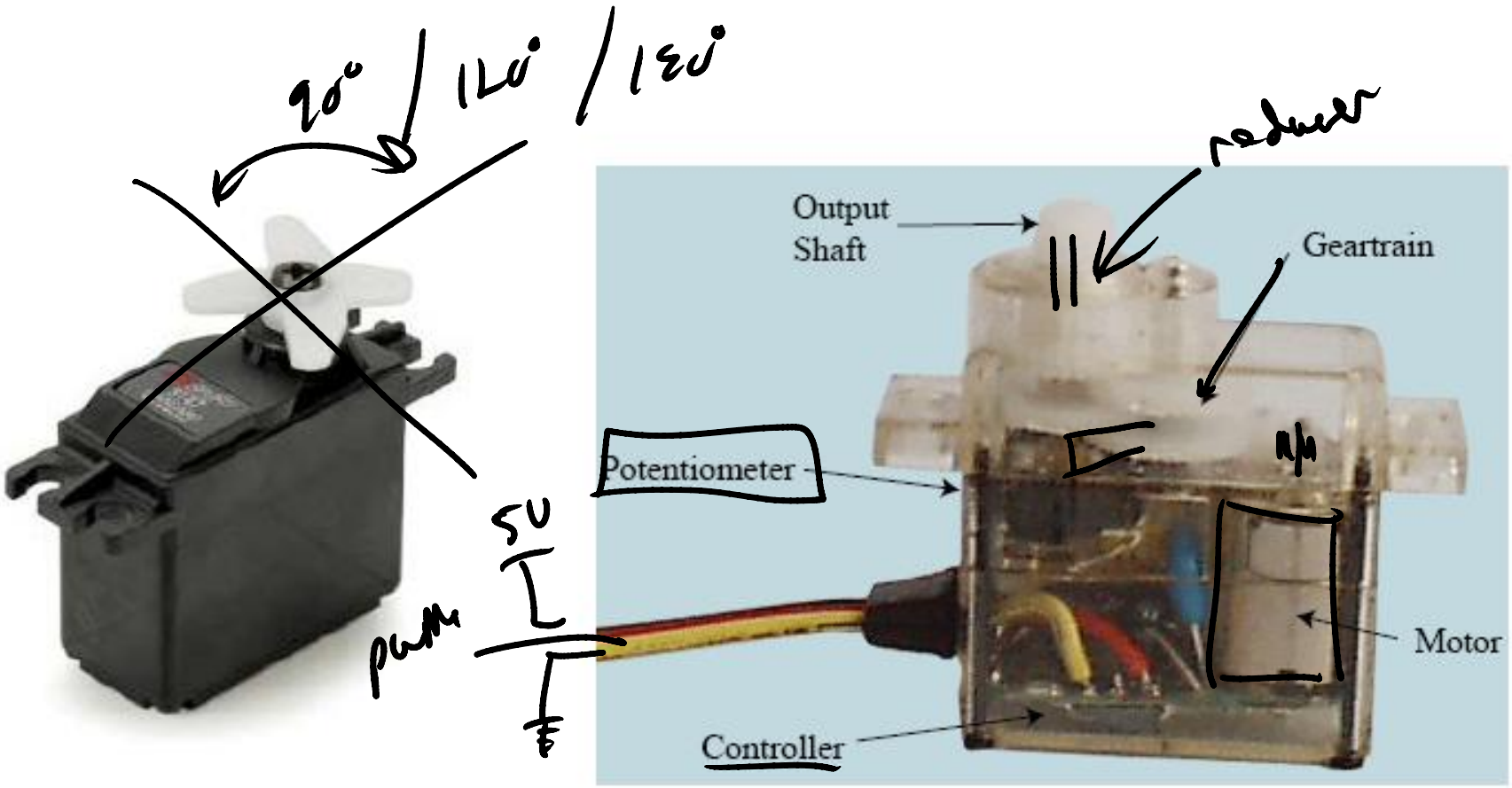


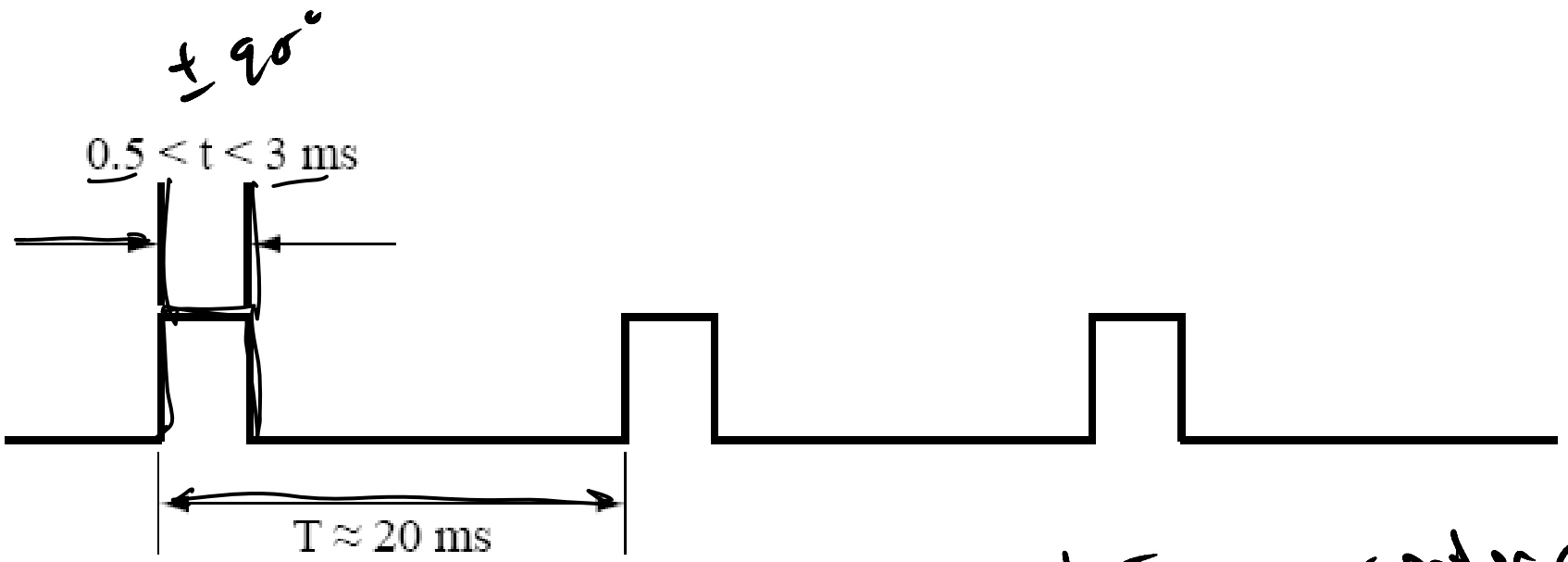
Figure 6–5 Torque-speed curves of Oriental Motor PH266-01 stepping motor with no diode, diode +150 ohm resistor and diode suppression circuits

R/C Servos



www.parallax.com #13

R/C Servos



Questions?