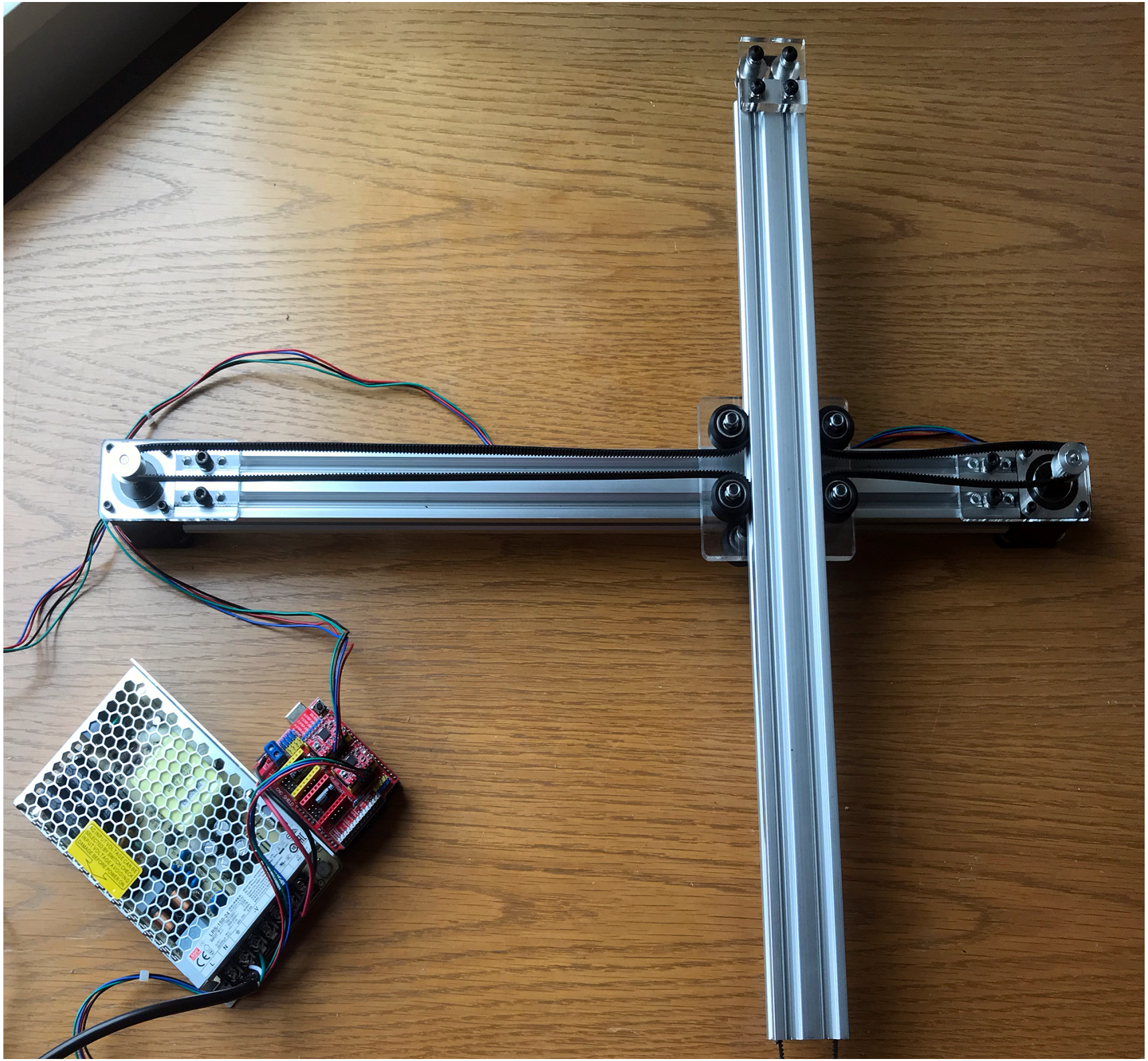
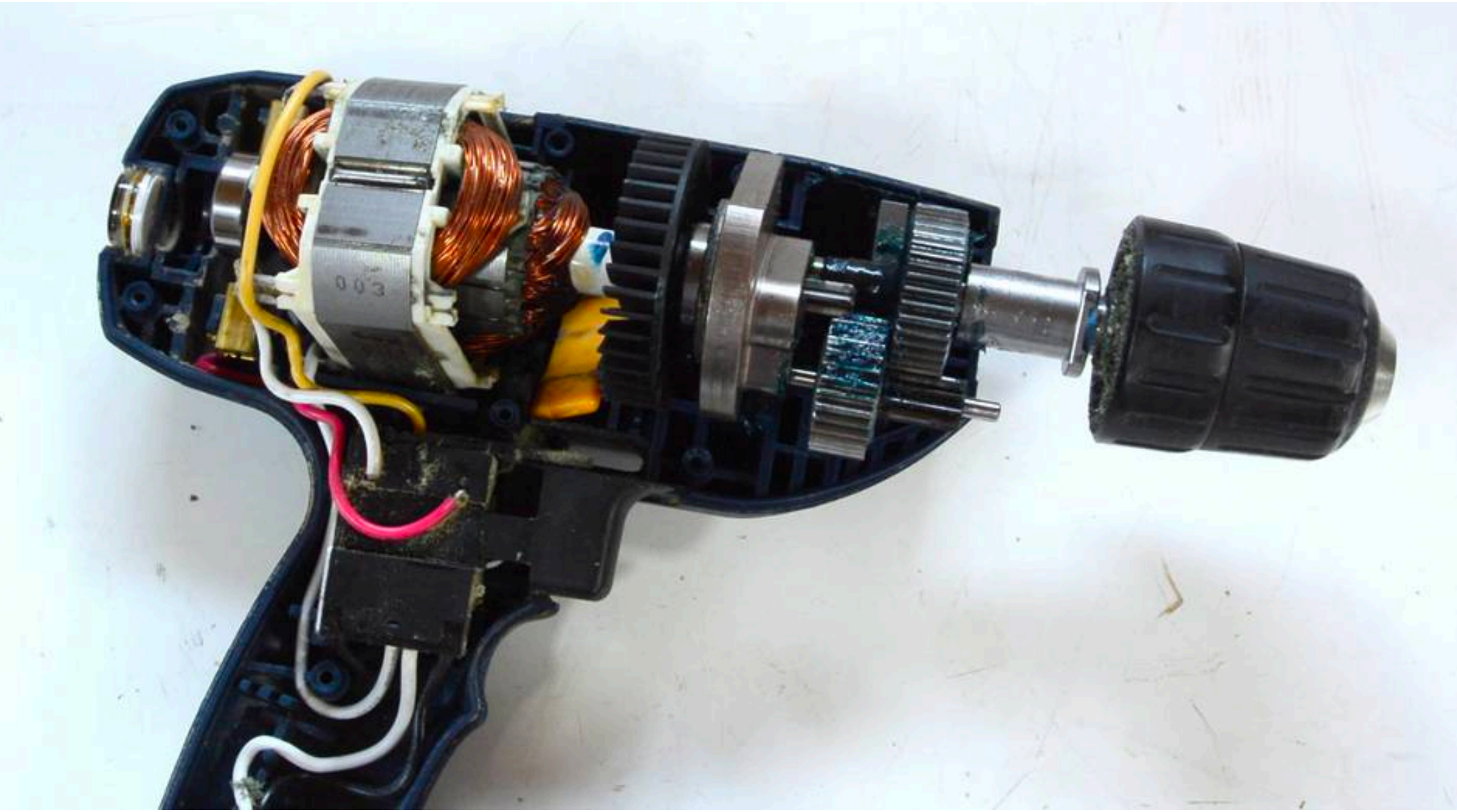
T-Bot Plotter

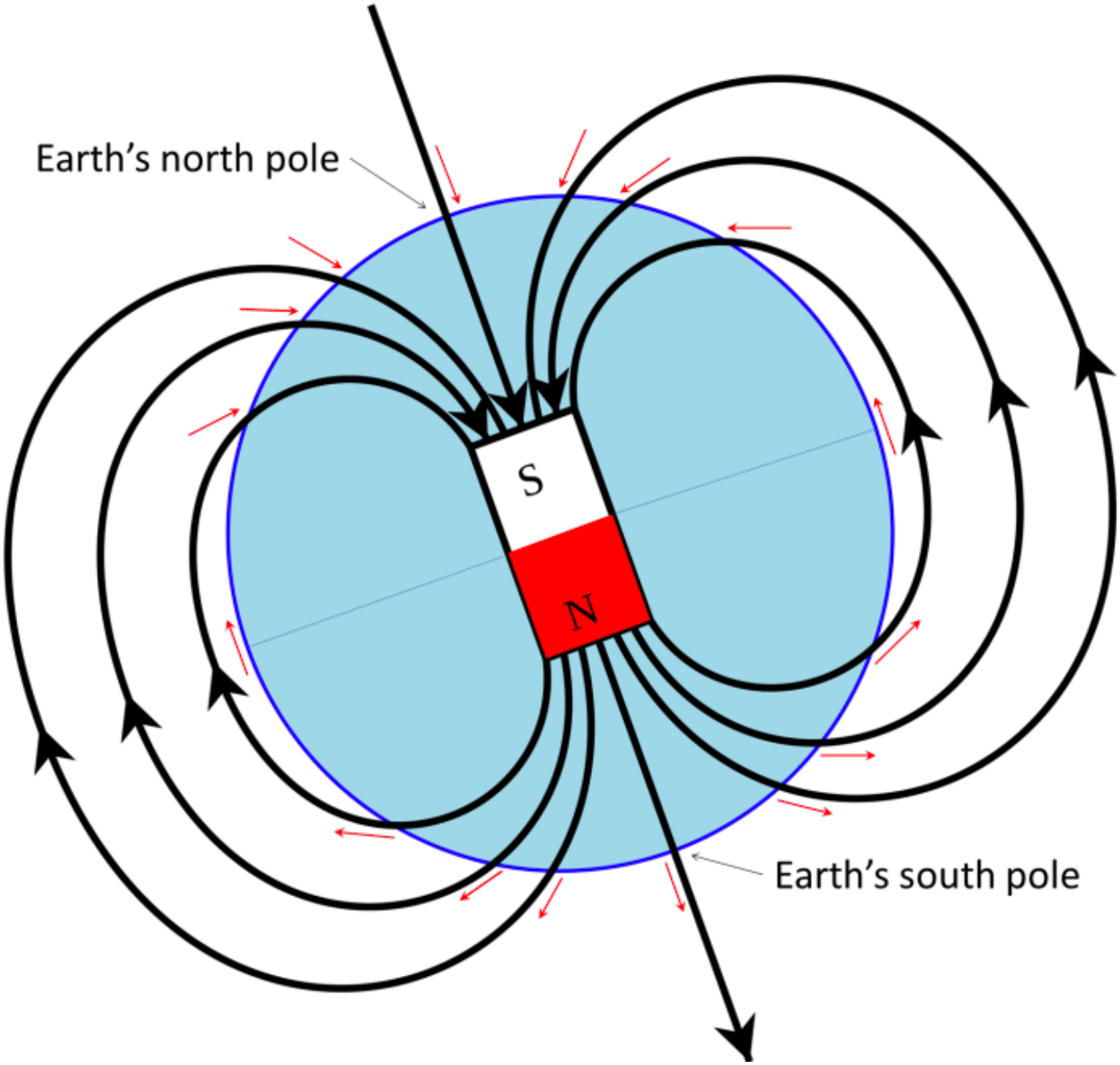
Principles of Operation

Motors, Electronics, Software

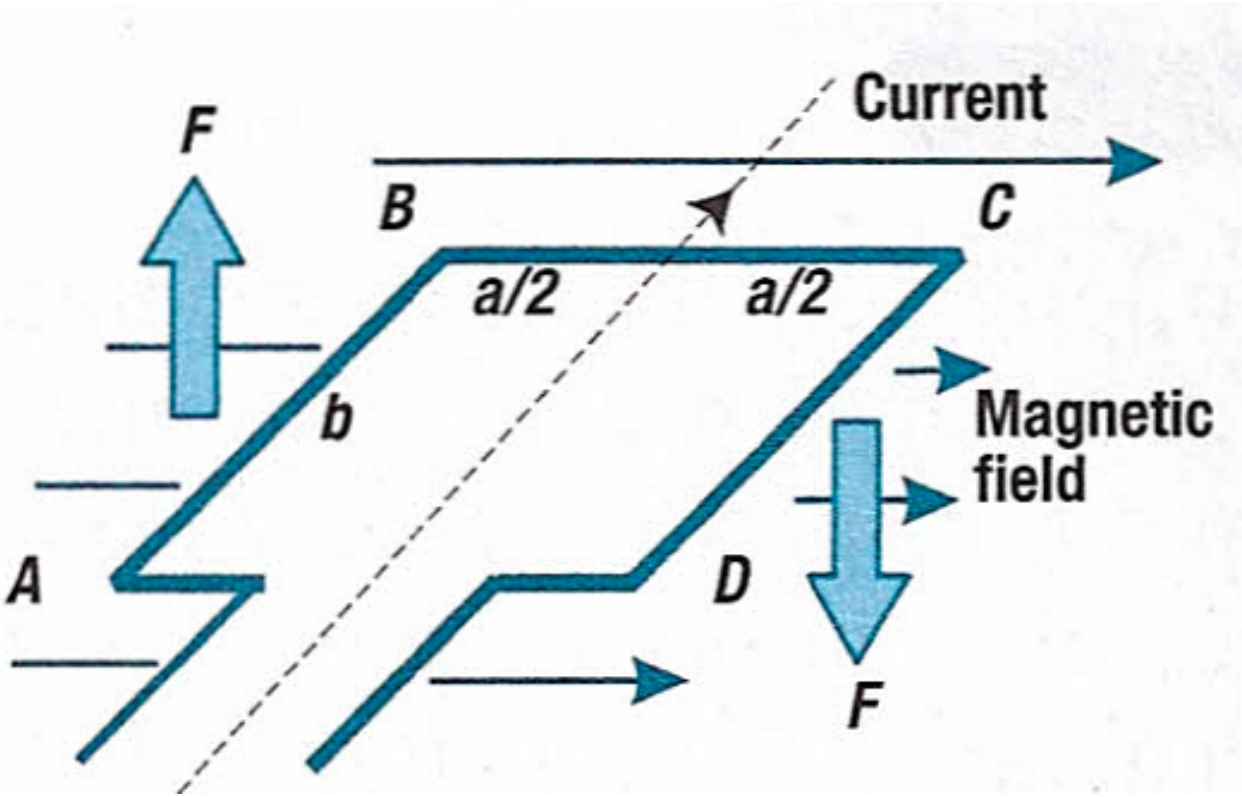




Motors



https://courses.lumenlearning.com/physicalgeology/chapter/9-3-earths-magnetic-field/



$$\vec{\mathbf{F}} = q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$$

$$\vec{\mathbf{F}} = -\vec{\mathbf{I}} \times \vec{\mathbf{B}}$$

$$\vec{\mathbf{T}} = \vec{\mathbf{r}} \times \vec{\mathbf{F}} \qquad T = K_T I$$

https://dc.edu.au/dot-point-summary-motors-and-generators/

Types of Motors

DC motors

AC motors, induction motors

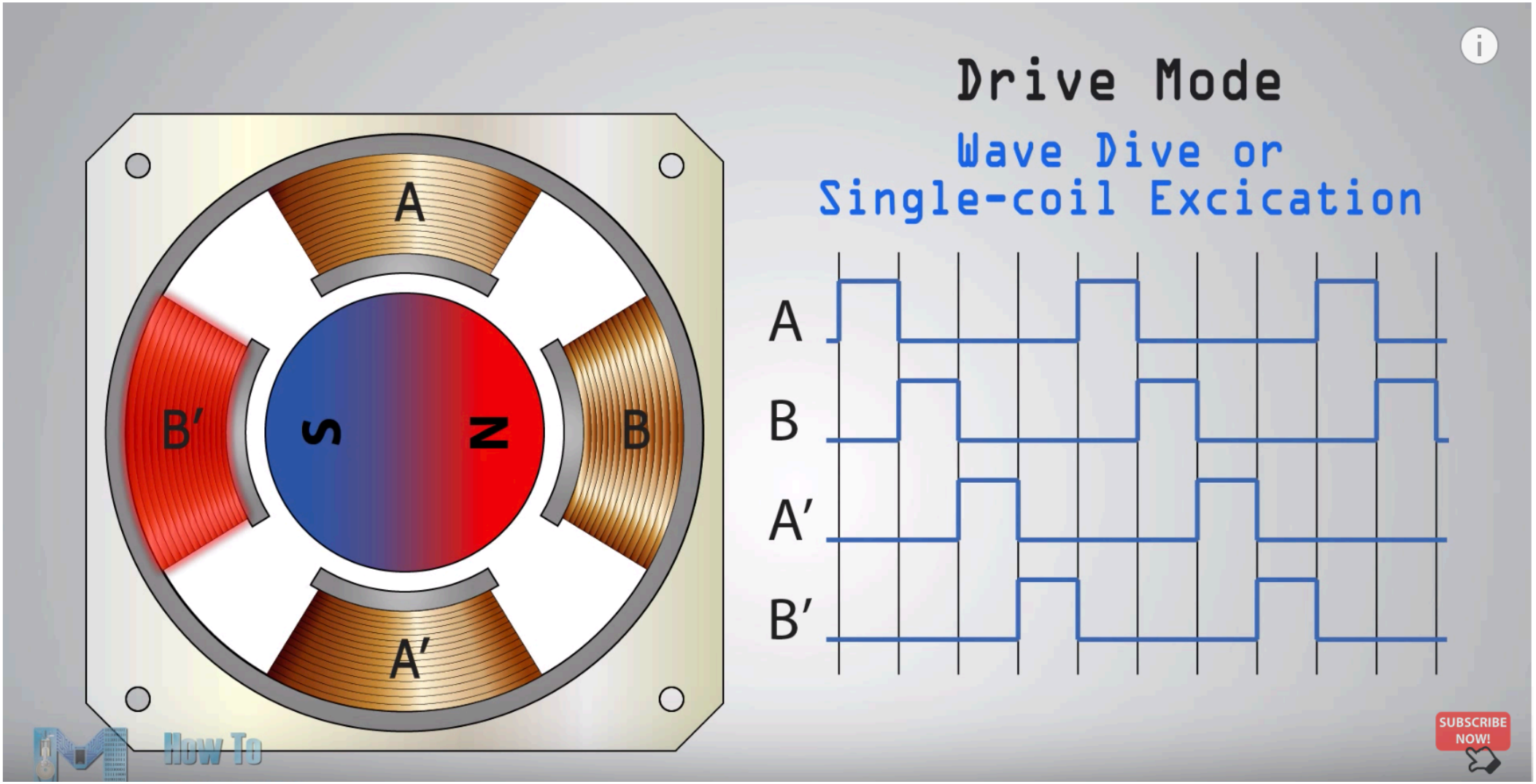
Stepper motors

Servos

Brushless DC motors

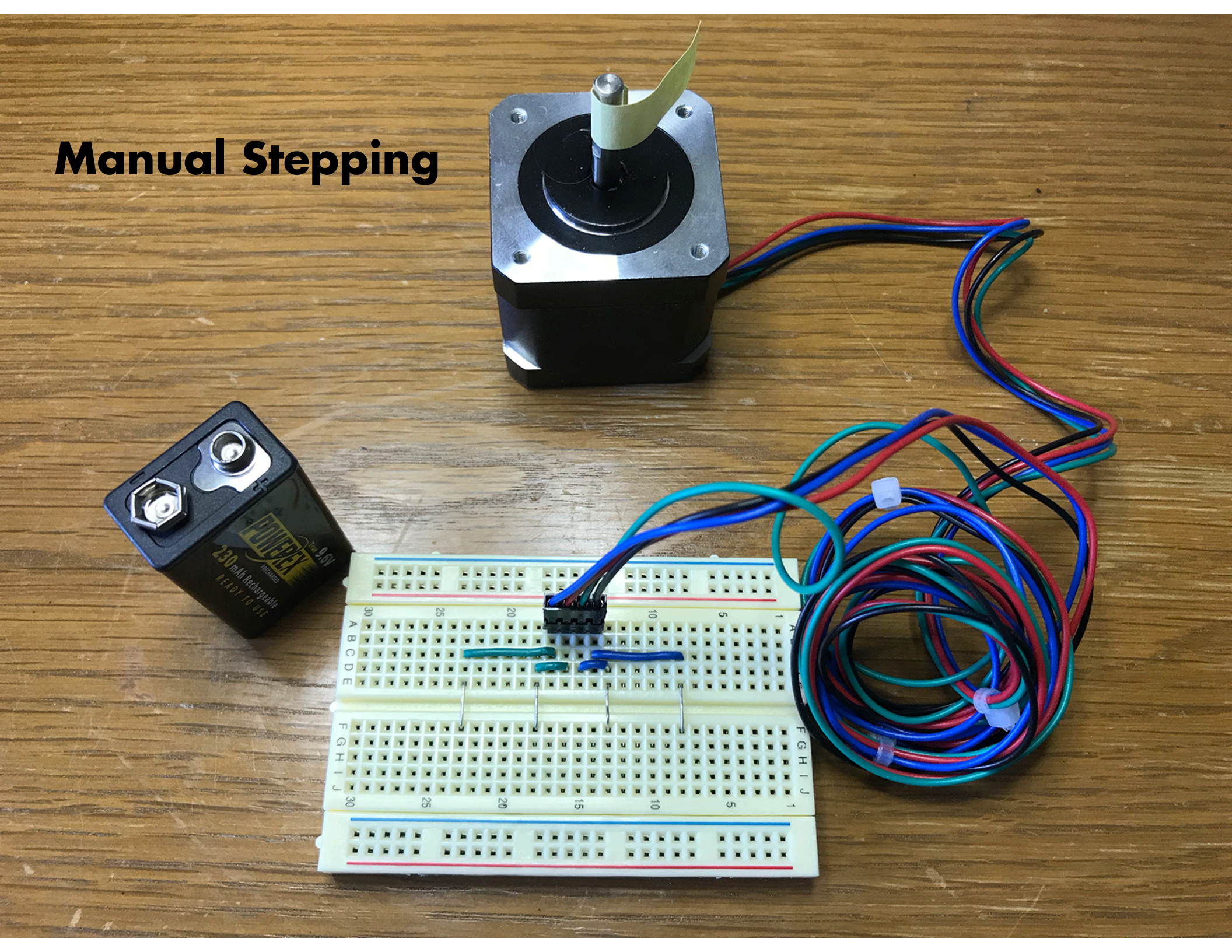
...

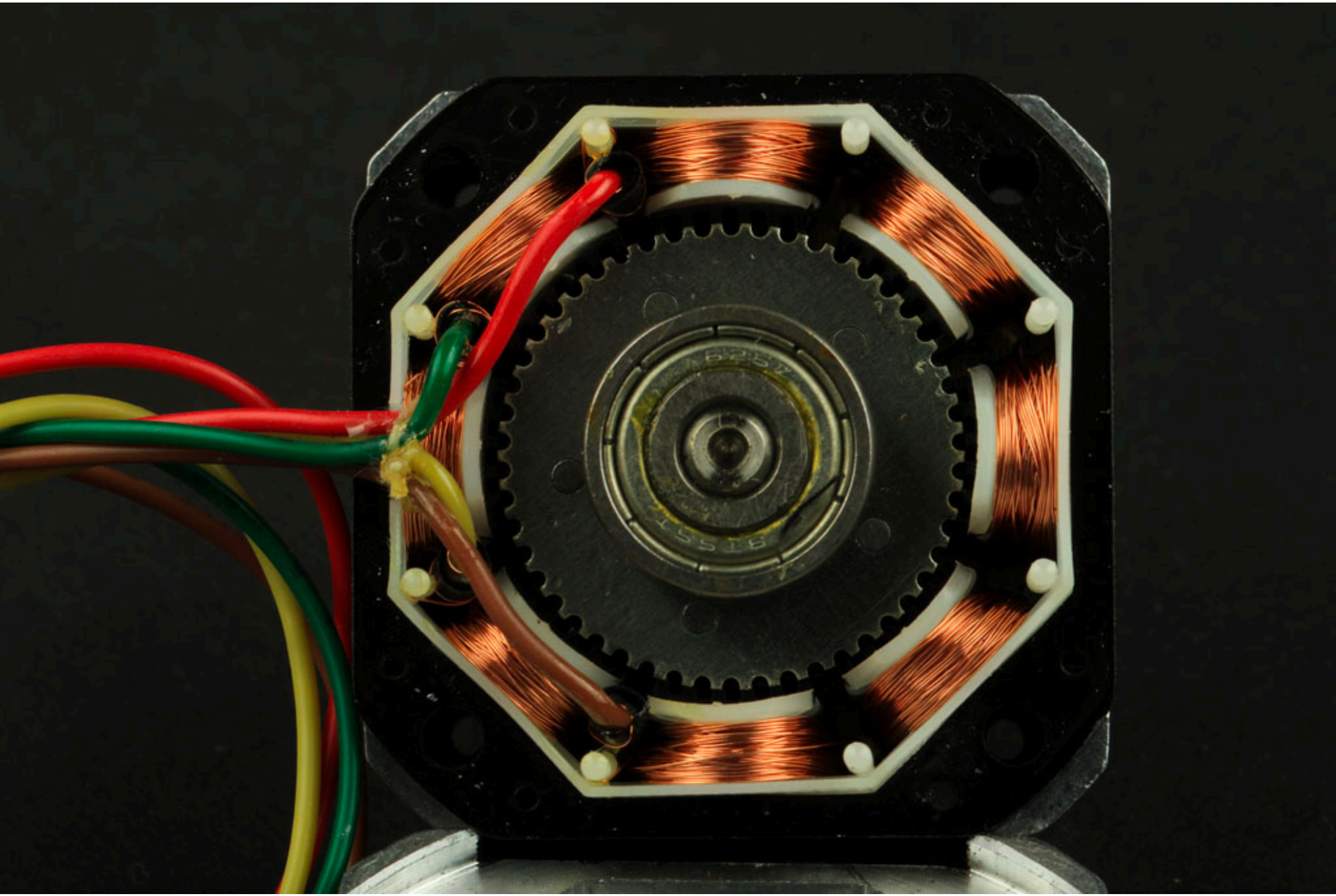
Stepper Motors

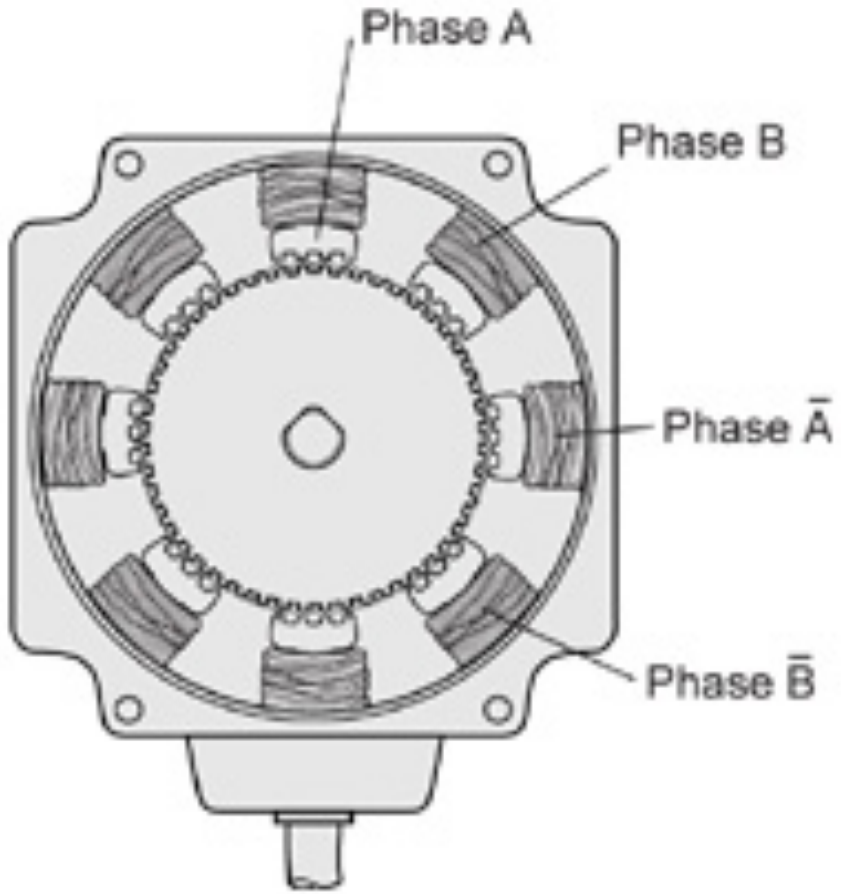


https://www.youtube.com/watch?v=TWMai3oirnM&t=64s

Manual Stepping





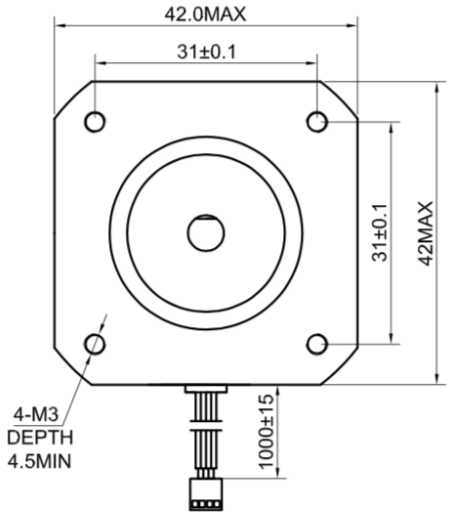


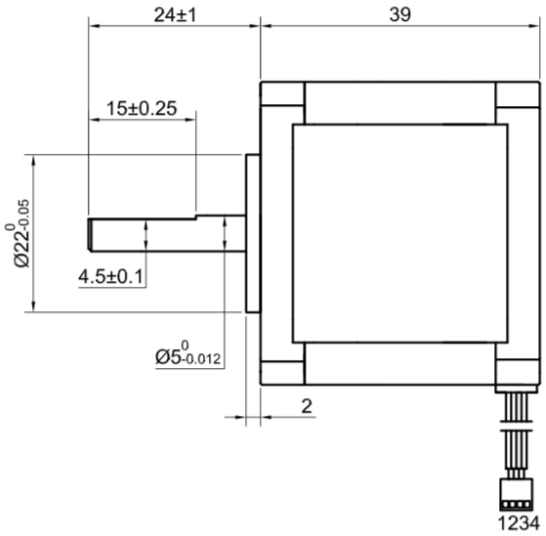
2-Phase

2 phases
8 poles
50 teeth

4 steps moves rotor by 1 tooth position
200 steps per revolution

https://www.orientalmotor.com/stepper-motors/technology/2-phase-vs-5-phase-stepper-motors.html



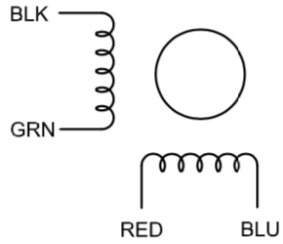


SPECIFICATION / CONNECTION	UNIPOLAR
AMPS/PHASE	1.50
RESISTANCE/PHASE(Ohms)@25°C	2.30±10%
INDUCTANCE/PHASE(mH)@1KHz	4.40±20%
HOLDING TORQUE(Nm)[lb-in]	0.45[3.98]
STEP ANGLE(°)	1.80
STEP ACCURACY(NON-ACCUM)	±5.00%
ROTOR INERTIA(g-cm²)	54.00
WEIGHT(Kg)[lb]	0.28[0.62]
TEMPERATURE RISE:MAX.80°C（MOTOR STANDSTILL;FOR 2PHASE ENERGIZED）	
AMBIENT TEMPERATURE -10°C~50°C[14°F~122°F]	
INSULATION RESISTANCE 100 Mohm（UNDER NORMAL TEMPERATURE AND HUMIDITY）	
INSULATION CLASS B 130°C[266°F]	
DIELECTRIC STRENGTH 500VAC FOR 1MIN.(BETWEEN THE MOTOR COILS AND THE MOTOR CASE)	
AMBIENT HUMIDITY MAX.85%(NO CONDENSATION)	

TYPE OF CONNECTION (EXTERN)		MOTOR	
PIN NO	BIPOLAR	LEADS	WINDING
1	A —	BLK	A
2	A\ —	GRN	A\
3	B —	RED	B
4	B\ —	BLU	B\

FULL STEP 2 PHASE-Ex. ,
WHEN FACING MOUNTING END (X)

STEP	A	B	A\	B\		CCW
1	+	+	-	-	↓	↑
2	-	+	+	-		
3	-	-	+	+		
4	+	-	-	+	CW	



STEPPERONLINE®

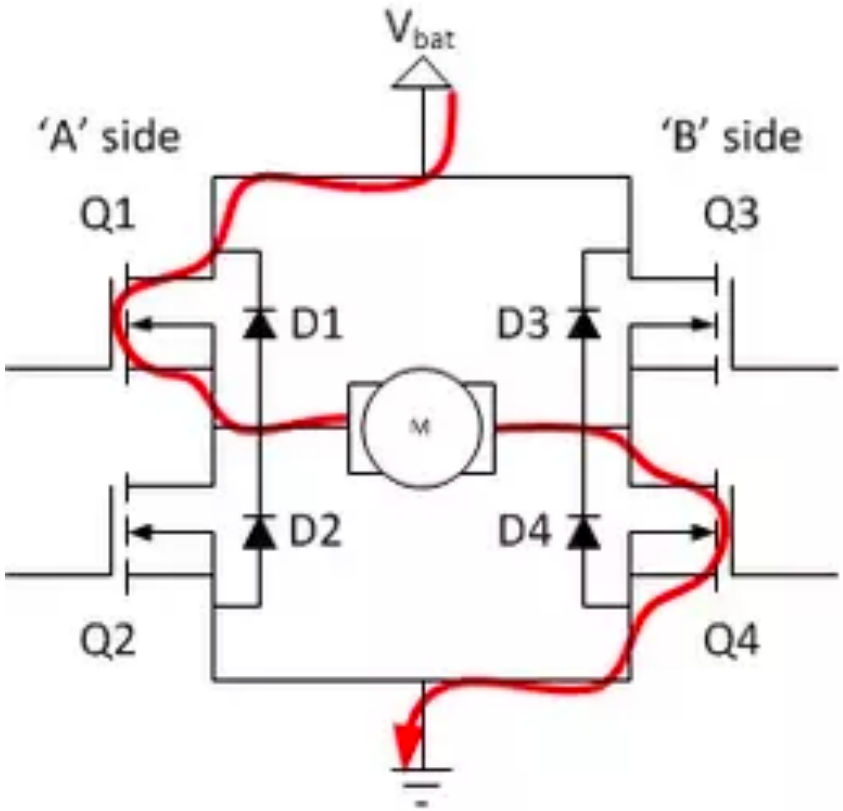
		APVD		
		CHKD		
1:1		DRN		
SCALE		SIGNATURE		DATE

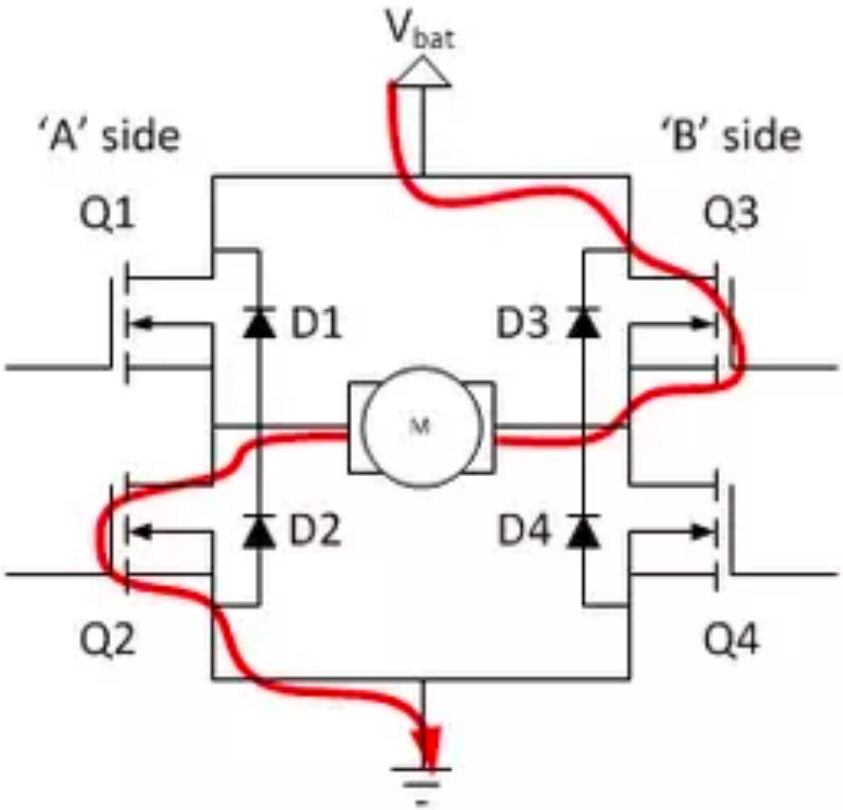
STEPPER MOTOR

17HS15-1504S1

Screenshot

H-Bridge


V_{bat}
'A' side
'B' side
Q1
Q3
D1
D3
M
D2
D4
Q2
Q4


V_{bat}
'A' side
'B' side
Q1
Q3
D1
D3
M
D2
D4
Q2
Q4

Functions

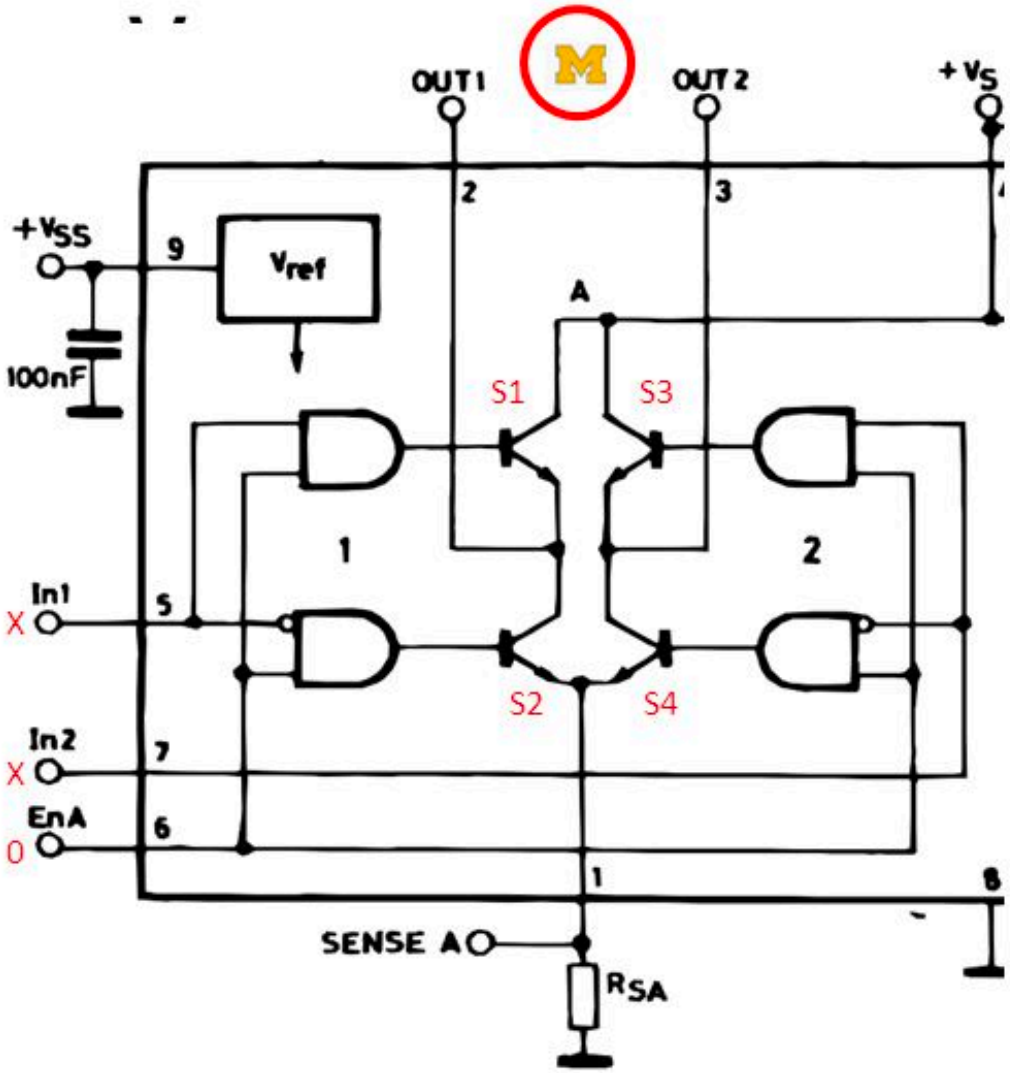
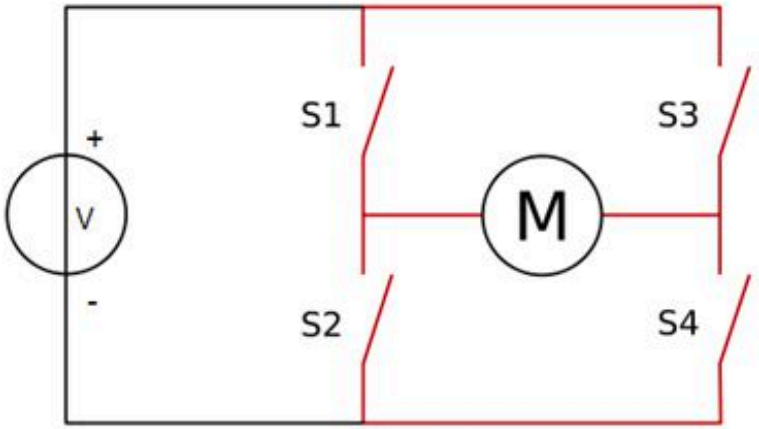


Figure 9. L298N Block Diagram (Left Half) (L298N Datasheet)

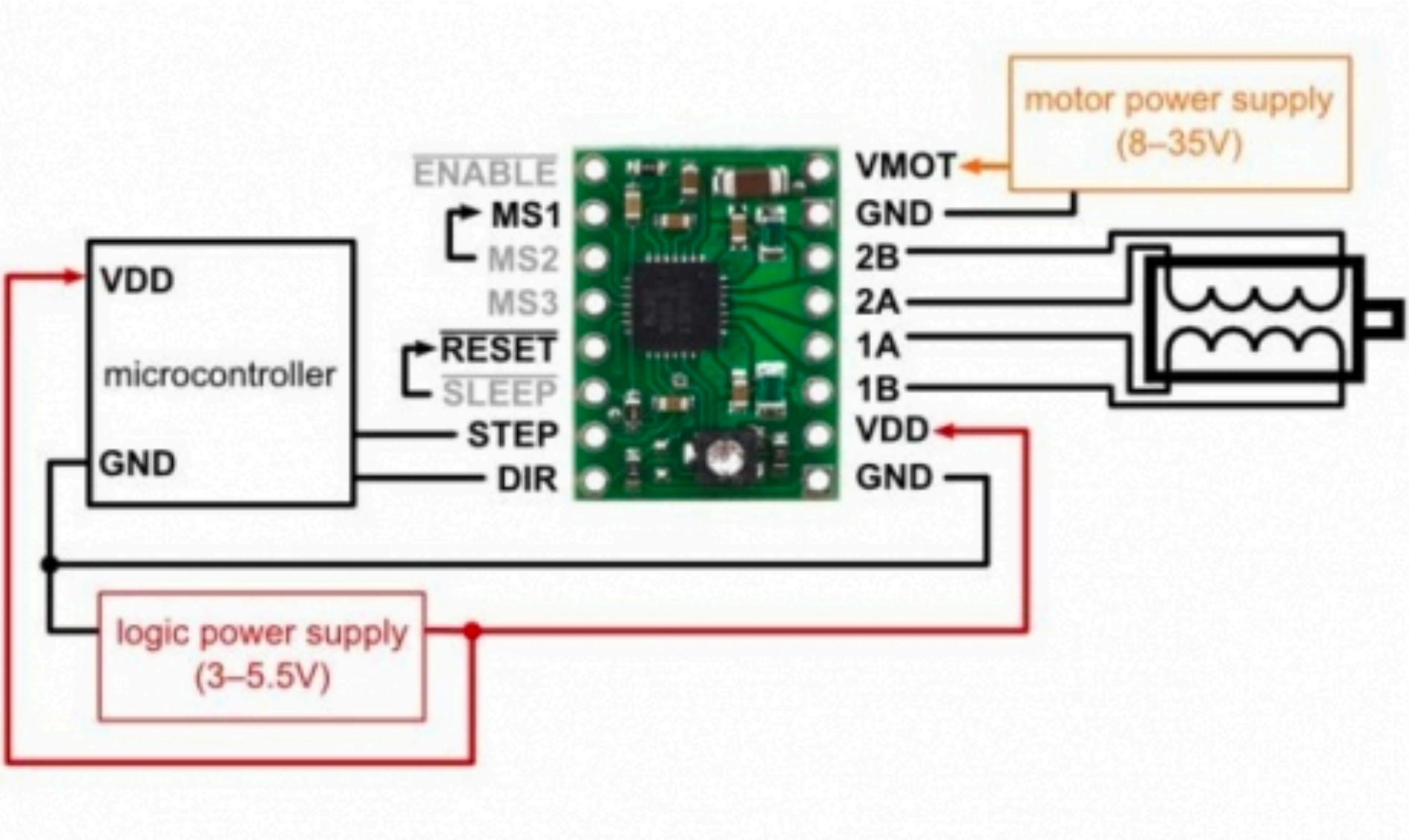


S1	S2	S3	S4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor free runs
0	1	0	1	Motor brakes
1	0	1	0	Motor brakes
1	1	0	0	Shoot-through
0	0	1	1	Shoot-through
1	1	1	1	Shoot-through

Table 2. H Bridge Functions (http://en.wikipedia.org/wiki/H_bridge)

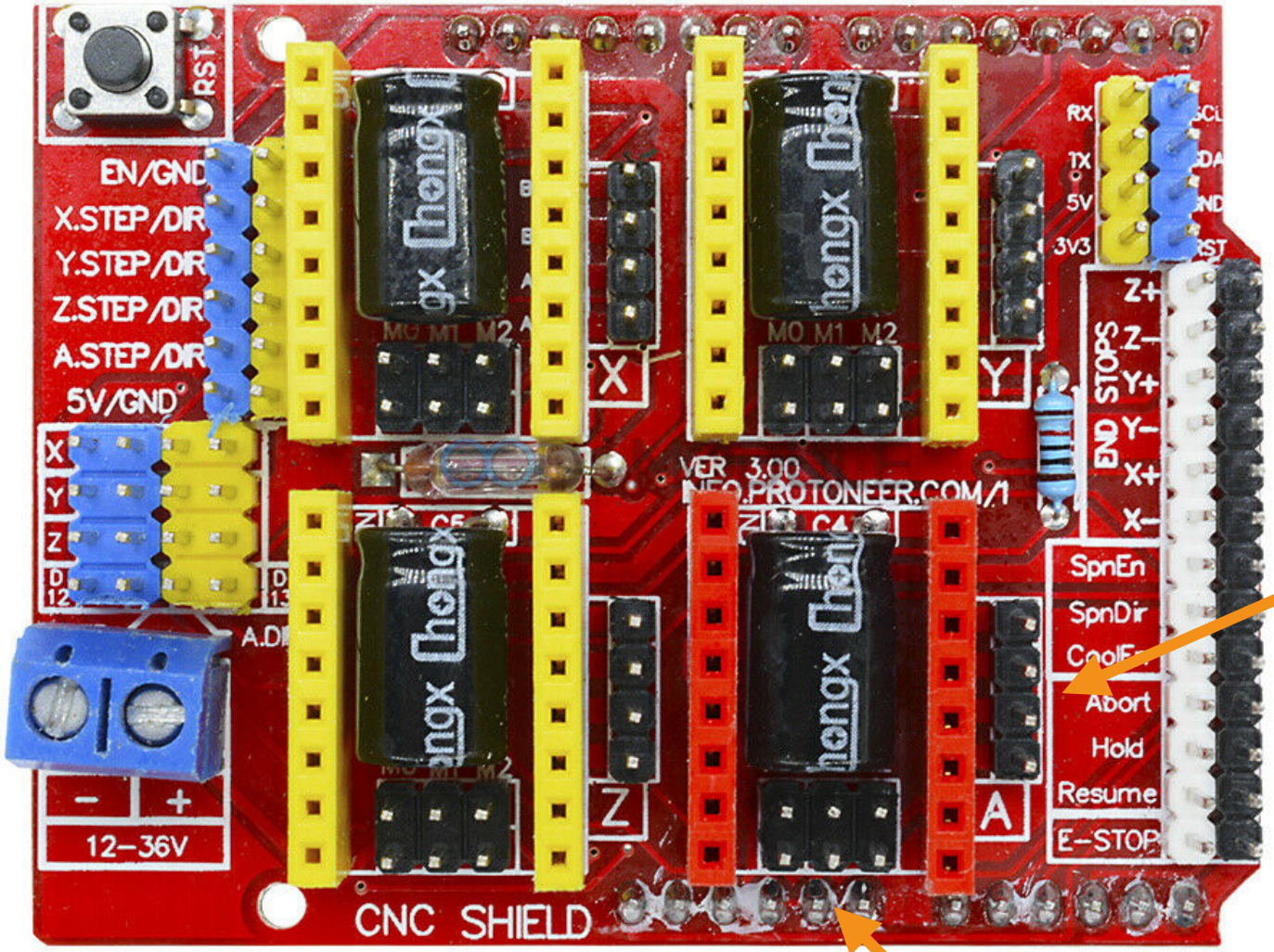
A4988

Stepper Motor Driver Chip



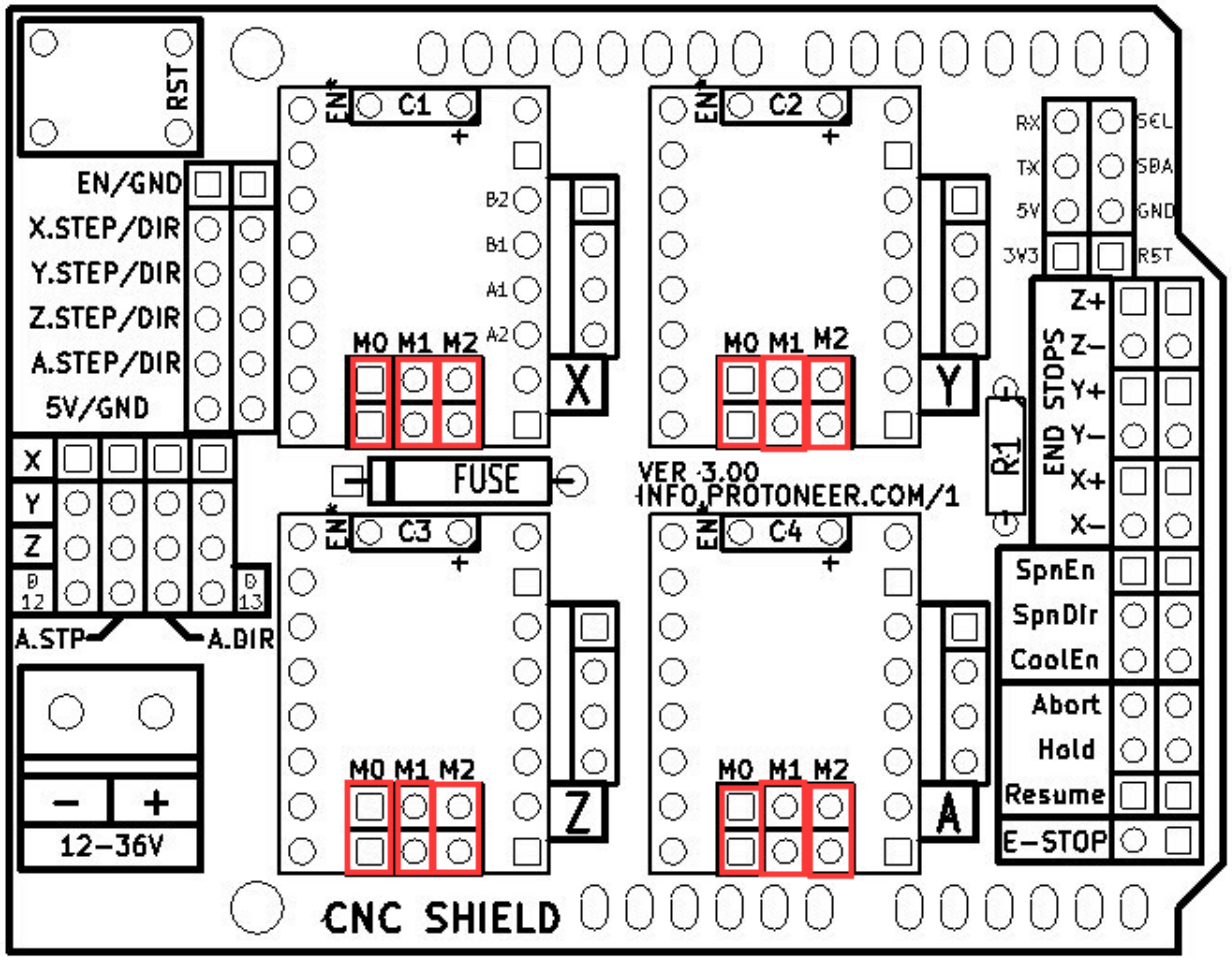
Pololu Stepper Motor Driver Board

Protoneer CNC Shield

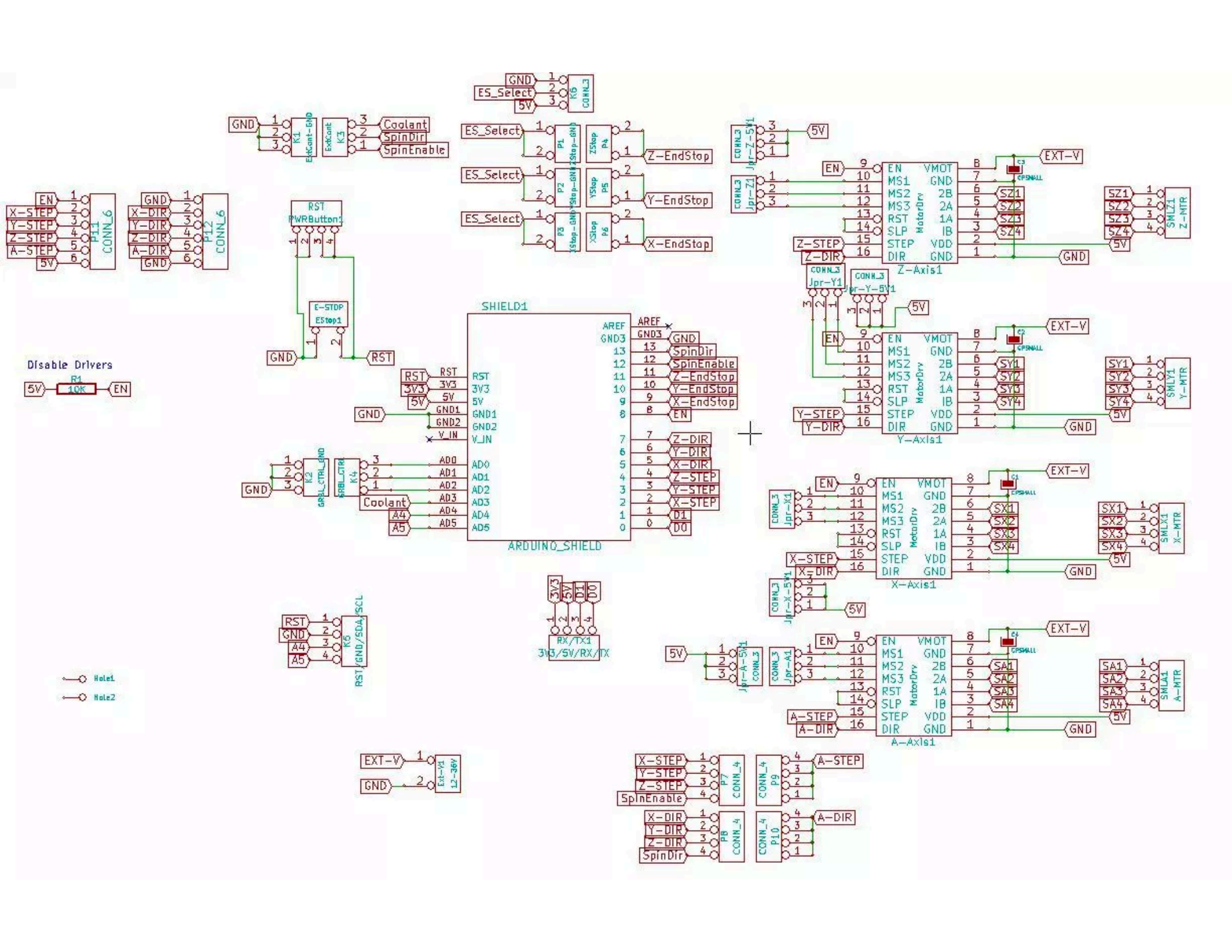


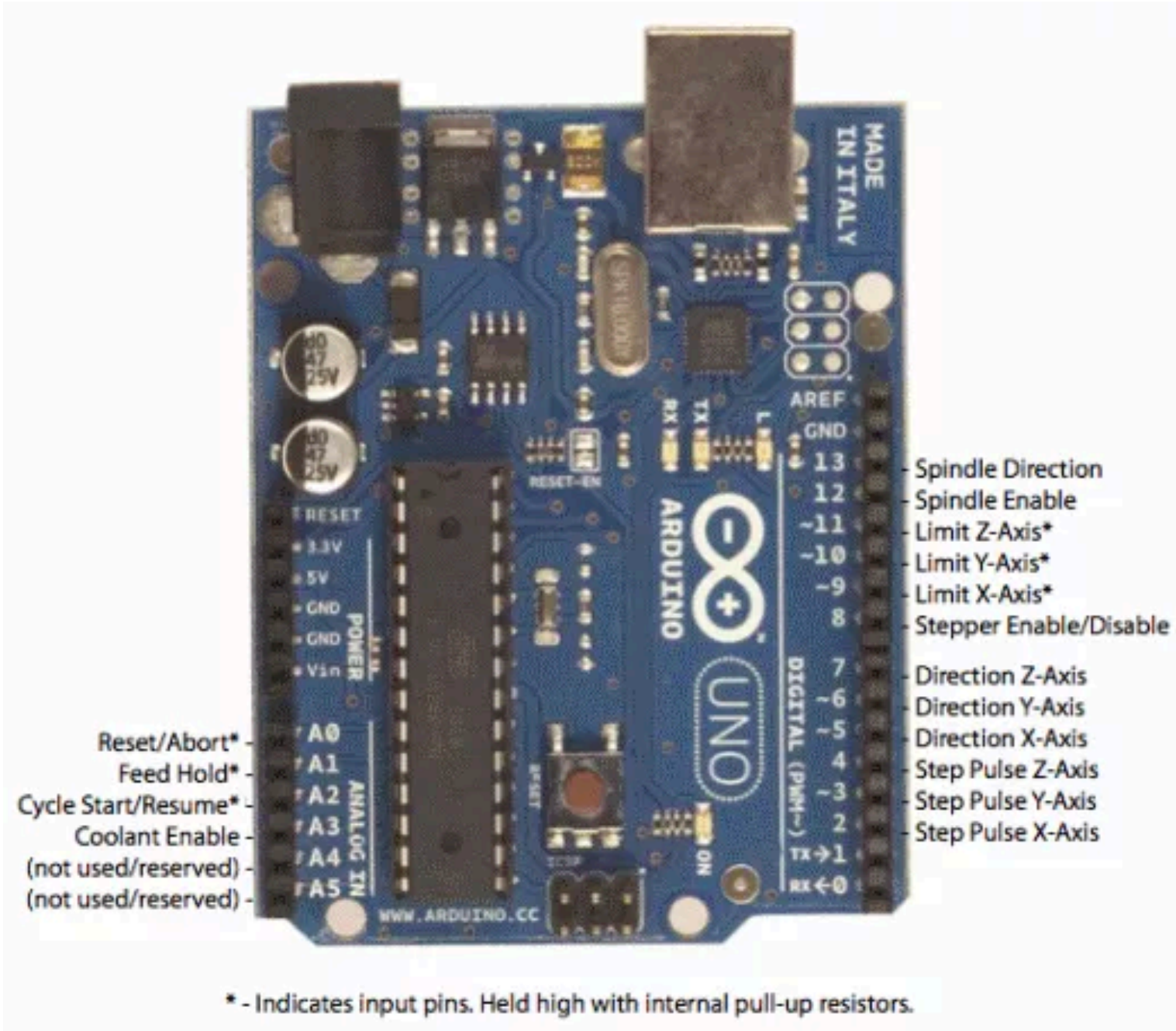
Motor Cable

Jumpers set micro stepping

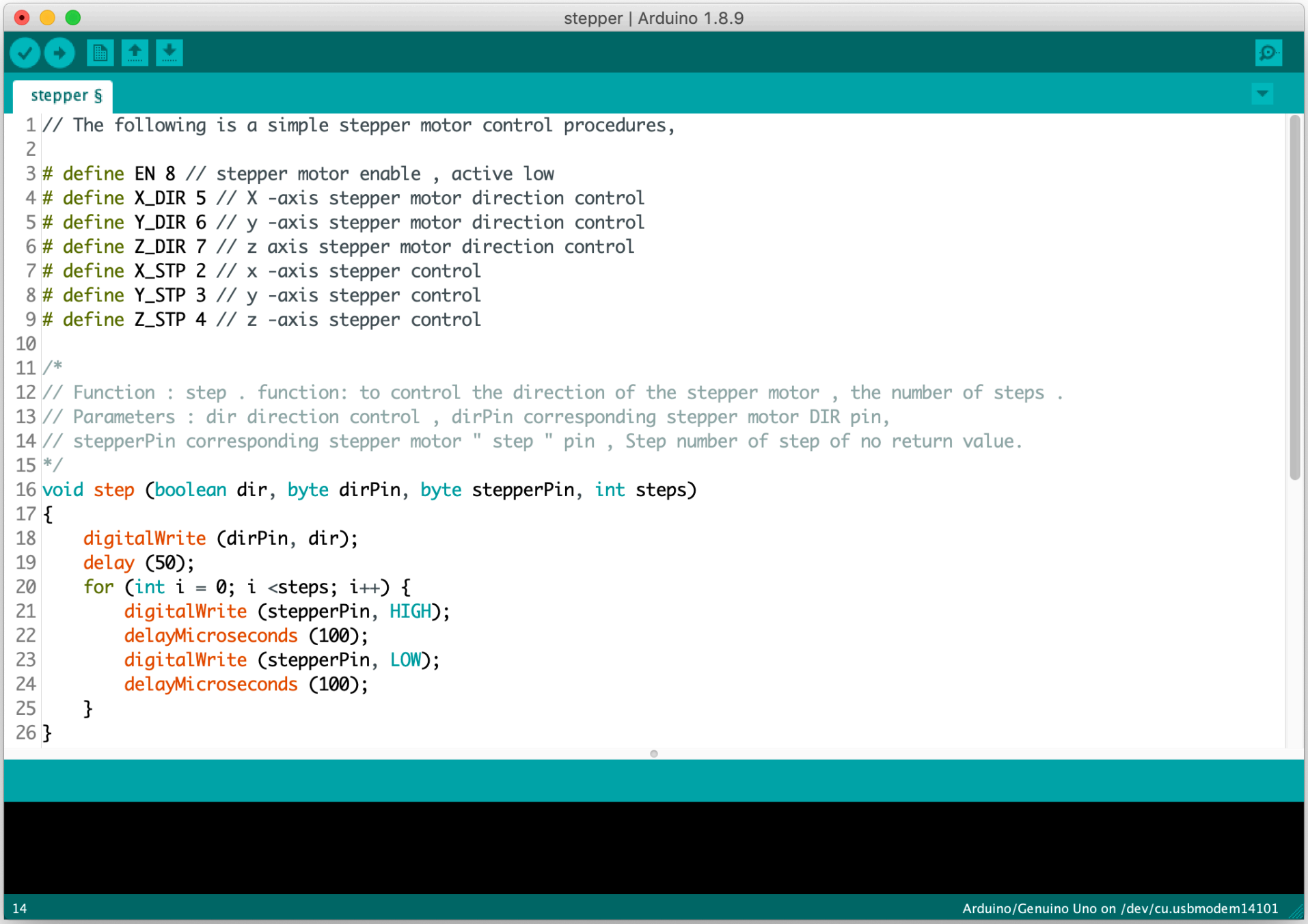


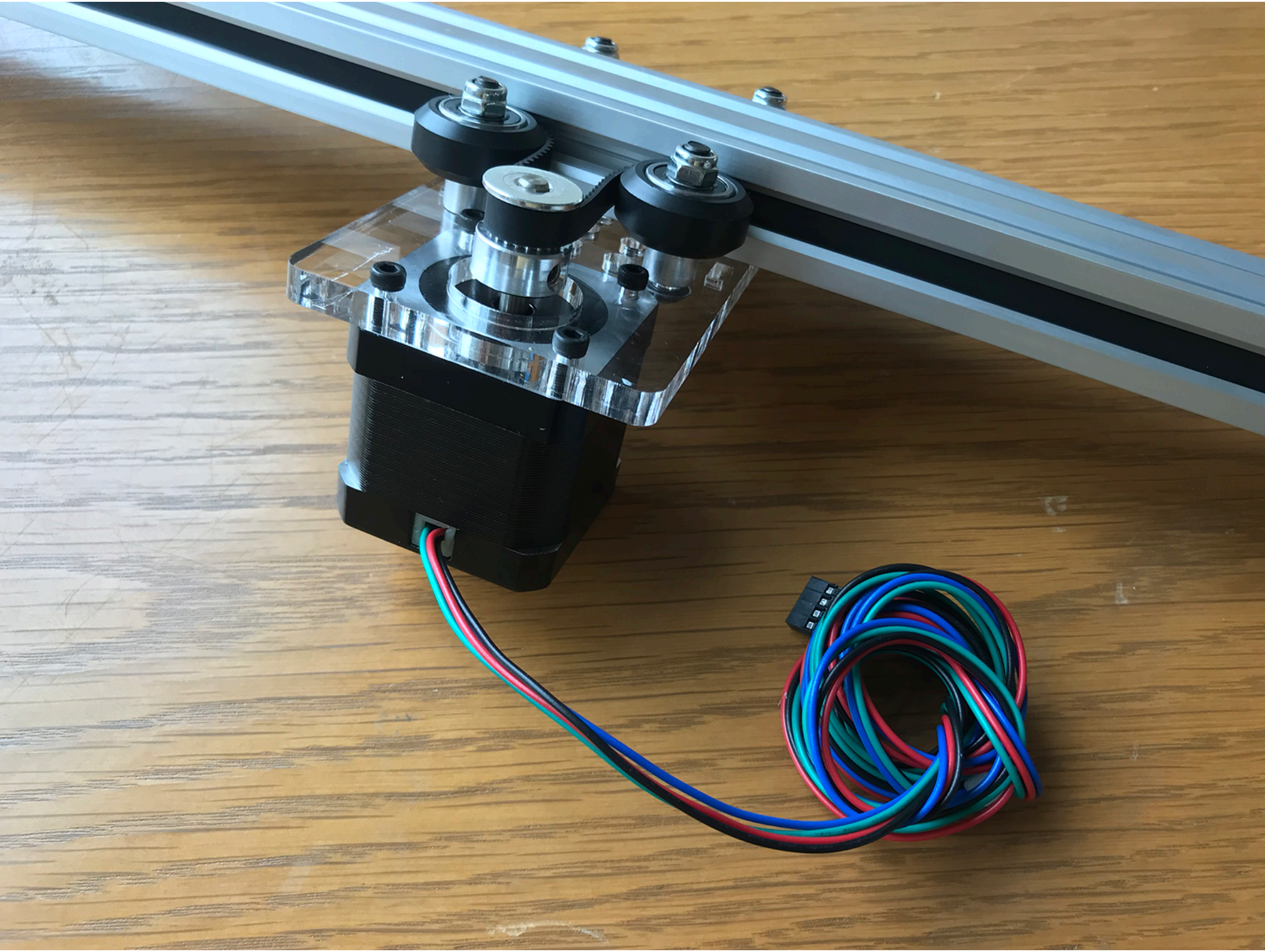
MS0	MS1	MS2	Microstep Resolution
Low	Low	Low	Full step
High	Low	Low	Half step
Low	High	Low	Quarter step
High	High	Low	Eighth step
High	High	High	Sixteenth step

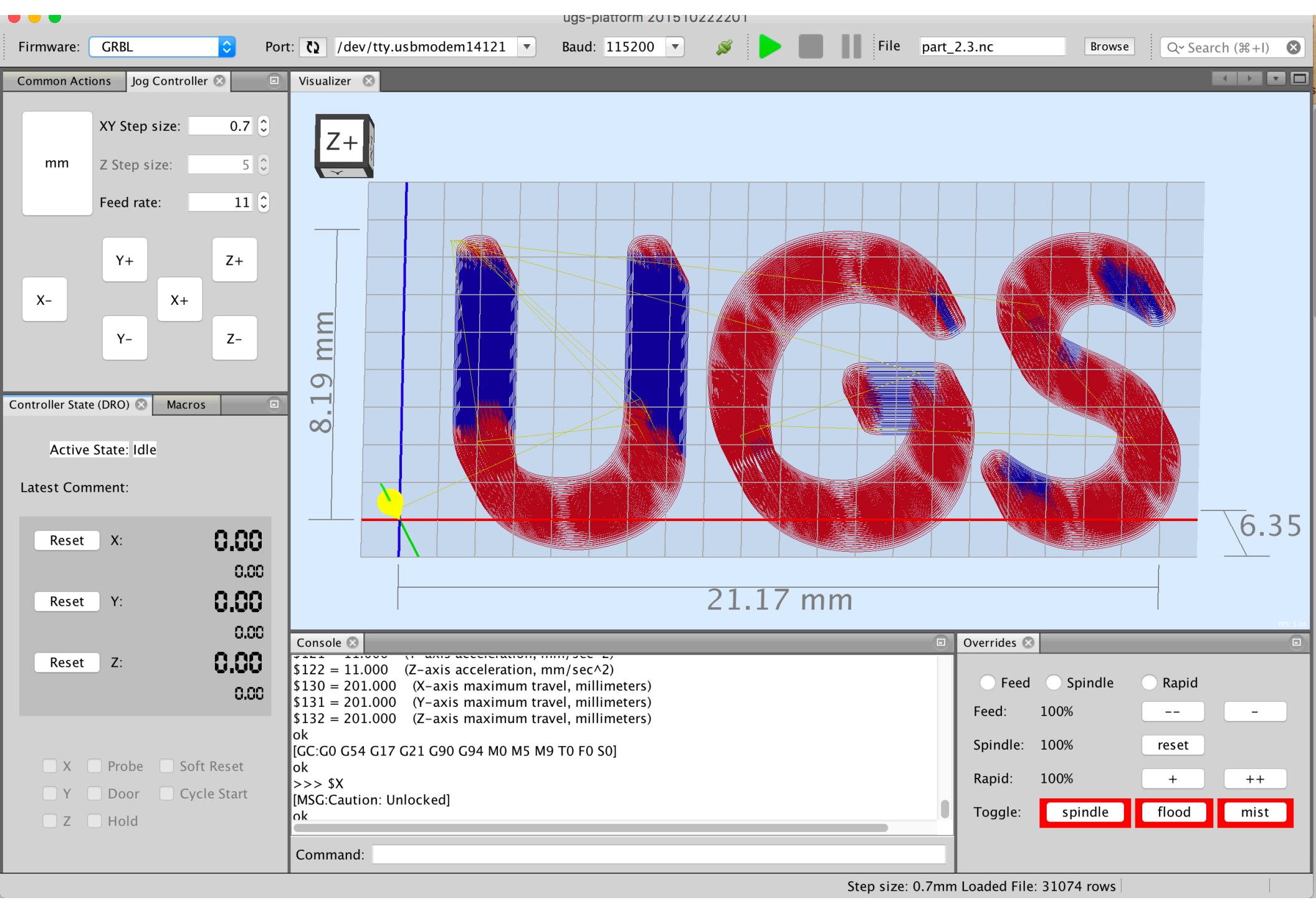

GND
ES_Select
5V
K6
CONN_3
Coolant
SpinDir
SpinEnable
K1
K3
ExtCont-GND
Z-EndStop
Y-EndStop
X-EndStop
P1
P2
P3
P4
P5
P6
ZStop
YStop
XStop
X-STEP
Y-STEP
Z-STEP
A-STEP
X-DIR
Y-DIR
Z-DIR
A-DIR
P11
P12
CONN_6
RST
PWRButton1
E-STOP
EStop1
Disable Drivers
R1
10K
EN
SHIELD1
ARDUINO_SHIELD
AREF
GND3
GND1
GND2
V_IN
3V3
AD0
AD1
AD2
AD3
AD4
AD5
Z-DIR
Y-DIR
X-DIR
D1
D0
K2
K4
GRBL_CTRL_GND
GRBL_CTRL
A4
A5
K5
RST/GND/SDA/SCL
RX/TX1
3V3/5V/RX/TX
Hole1
Hole2
EXT-V
Ext-V1
12-36V
Jpr-Z-5V1
Jpr-Z1
Jpr-Y1
Jpr-Y-5V1
Jpr-X1
Jpr-X-5V1
Jpr-A-5V1
Jpr-A1
CONN_3
EN
MS1
MS2
MS3
RST
SLP
STEP
DIR
VMOT
GND
2B
2A
1A
1B
VDD
MotorDrv
C3
C2
C1
C4
GPSMALL
SZ1
SZ2
SZ3
SZ4
SY1
SY2
SY3
SY4
SX1
SX2
SX3
SX4
SA1
SA2
SA3
SA4
SMLZ1
Z-MTR
SMLY1
Y-MTR
SMLX1
X-MTR
SMLA1
A-MTR
Z-Axis1
Y-Axis1
X-Axis1
A-Axis1
P7
P8
P9
P10
CONN_4



* - Indicates input pins. Held high with internal pull-up resistors.


stepper | Arduino 1.8.9
stepper §
// The following is a simple stepper motor control procedures,
define EN 8 // stepper motor enable , active low
define X_DIR 5 // X -axis stepper motor direction control
define Y_DIR 6 // y -axis stepper motor direction control
define Z_DIR 7 // z axis stepper motor direction control
define X_STP 2 // x -axis stepper control
define Y_STP 3 // y -axis stepper control
define Z_STP 4 // z -axis stepper control
/*
// Function : step . function: to control the direction of the stepper motor , the number of steps .
// Parameters : dir direction control , dirPin corresponding stepper motor DIR pin,
// stepperPin corresponding stepper motor " step " pin , Step number of step of no return value.
*/
void step (boolean dir, byte dirPin, byte stepperPin, int steps)
{
digitalWrite (dirPin, dir);
delay (50);
for (int i = 0; i <steps; i++) {
digitalWrite (stepperPin, HIGH);
delayMicroseconds (100);
digitalWrite (stepperPin, LOW);
delayMicroseconds (100);
}
}
14
Arduino/Genuino Uno on /dev/cu.usbmodem14101





universal gcode sender

GRBL Settings

Specification

$$

Calculation of grbl settings for GT2 belts

$100=80 // x steps per mm = 16 * 200 / 40

$101=80 // y steps per mm

GCODE (NIST RS-174)

G0 - rapid motion

G1 - linear motion (e,g, G1 X40 F1000)

G20 - set units to inches

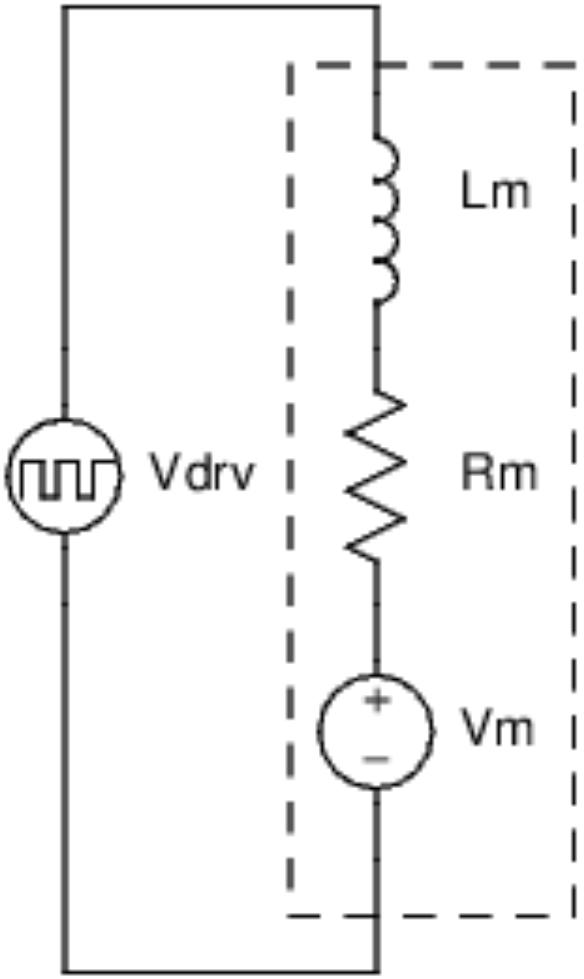
G21 - set units to millimeters

G28 - return to home

G90 - use absolute coordinates

G91 - use relative coordinates

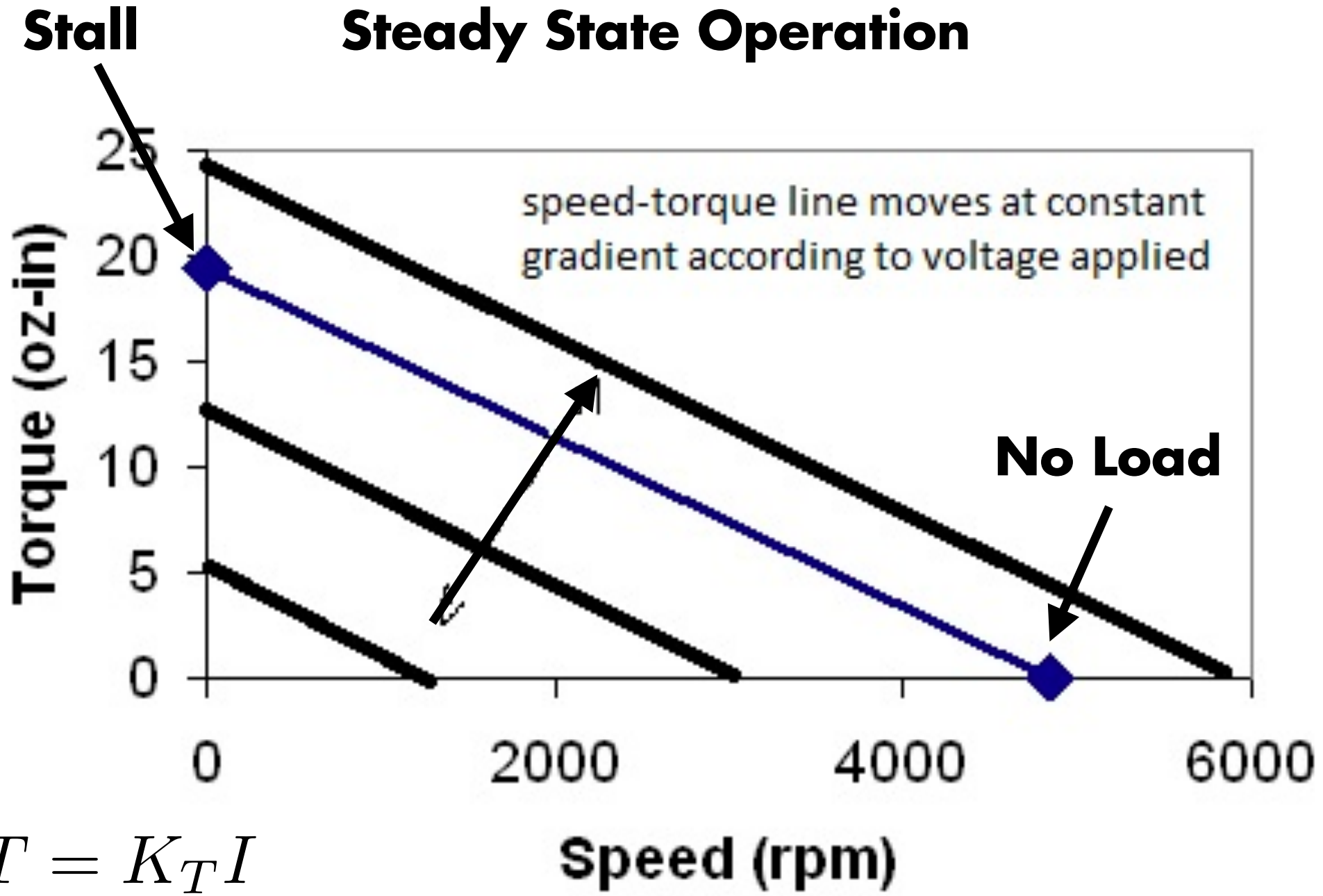
\



$$V_L = -L_m \frac{dI}{dt}$$ **Inductance**

$$V_R = I R_m$$ **Resistance**

$$V_m = -K_m \omega$$ **Back EMF**


Stall
Steady State Operation
speed-torque line moves at constant gradient according to voltage applied
No Load
Torque (oz-in)
25
20
15
10
5
0
0
2000
4000
6000
Speed (rpm)

$$T = K_T I$$

Torque Curve

Torque vs Speed

- Torque proportional to current
- Speed proportional to voltage

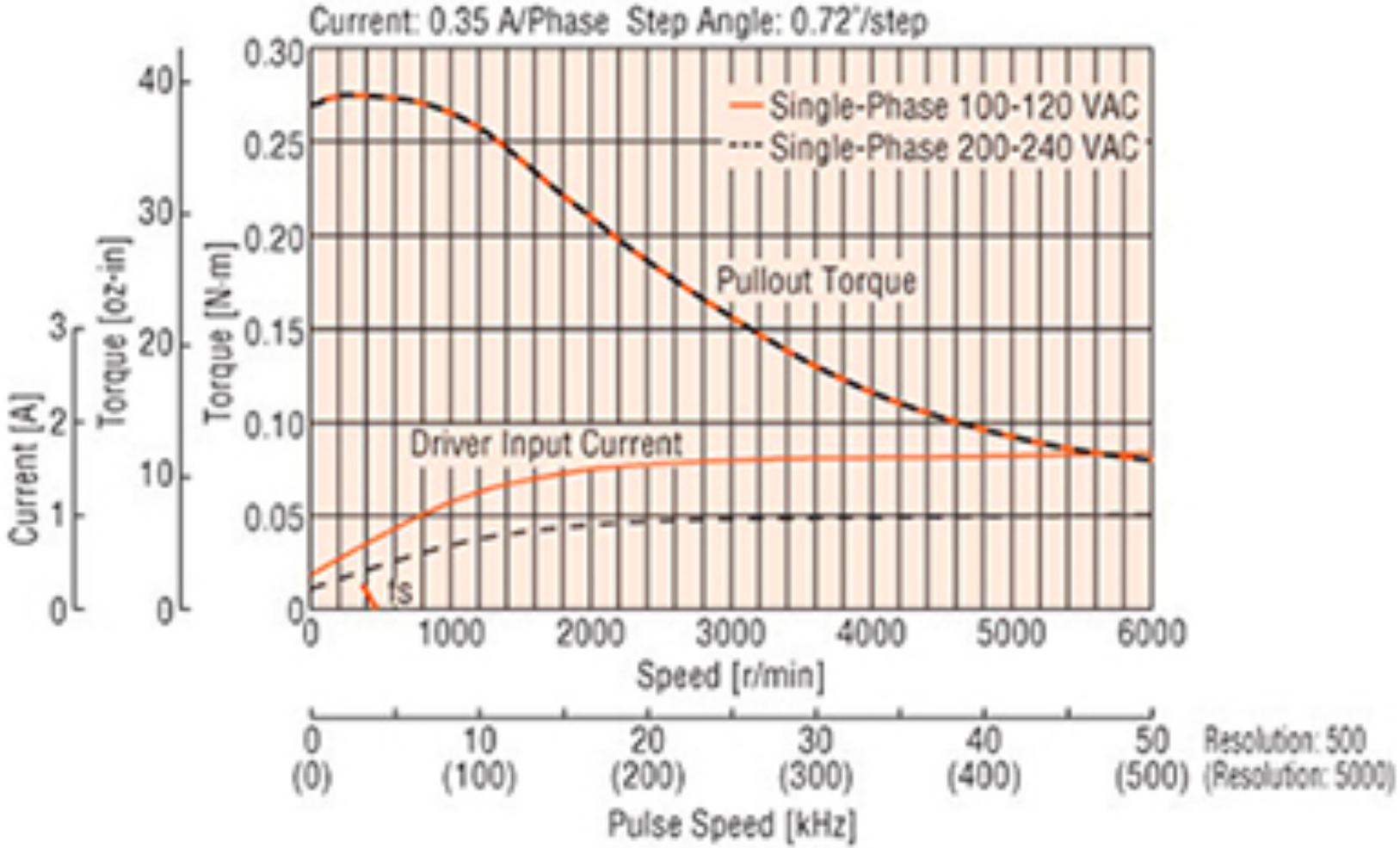
Theoretical curve

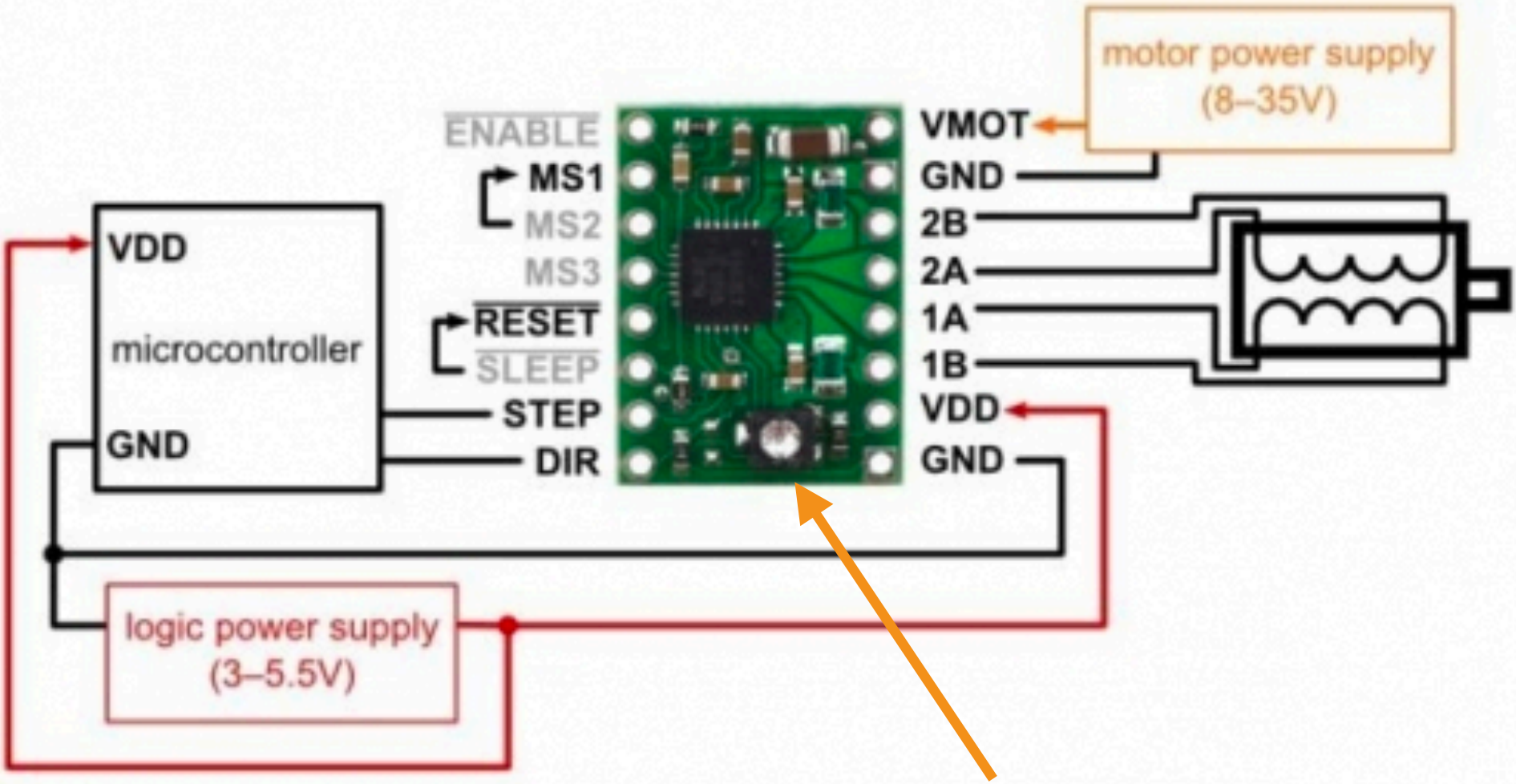
- Stall torque / current
- Speed under no load

Speed – Torque Characteristics

fs: Maximum Starting Frequency

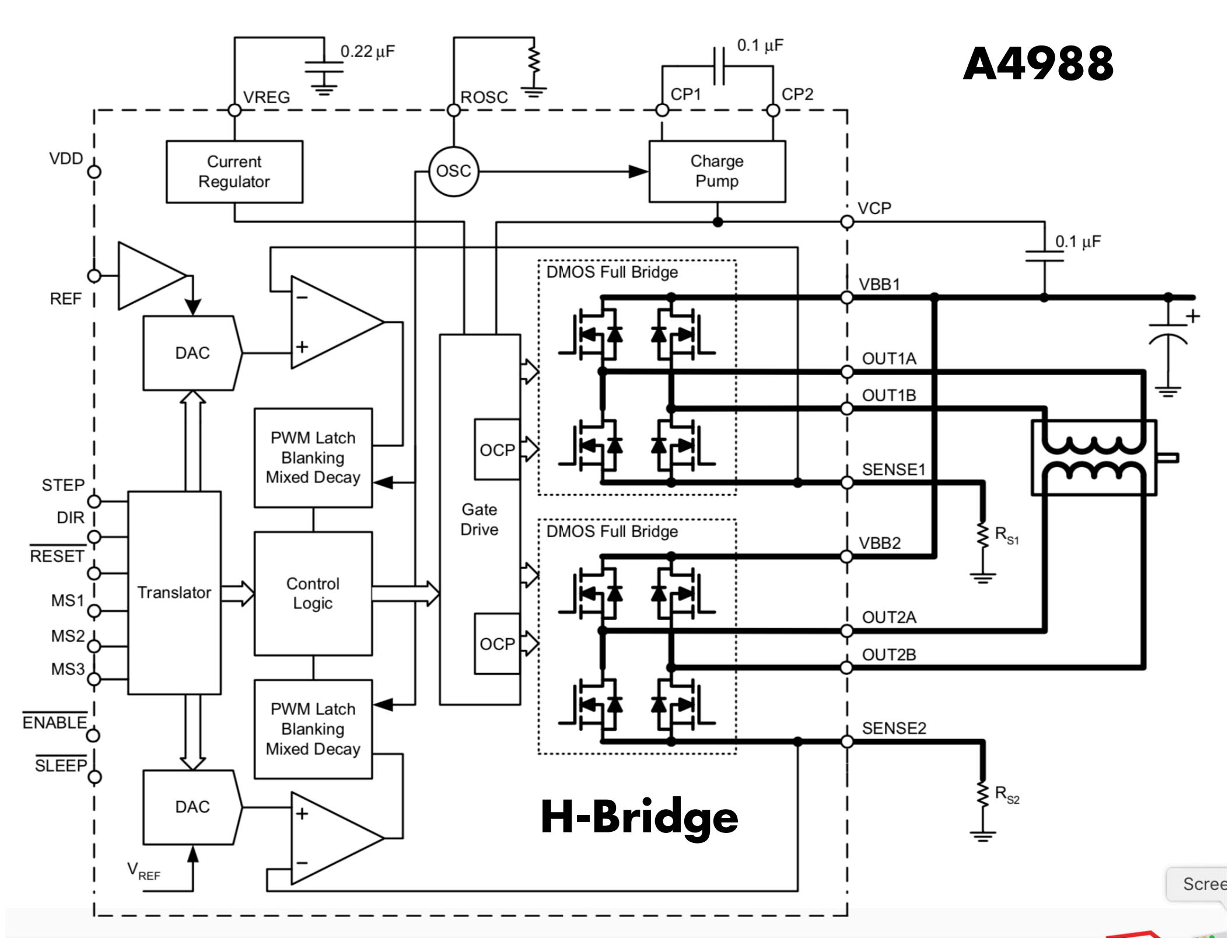
RKS545

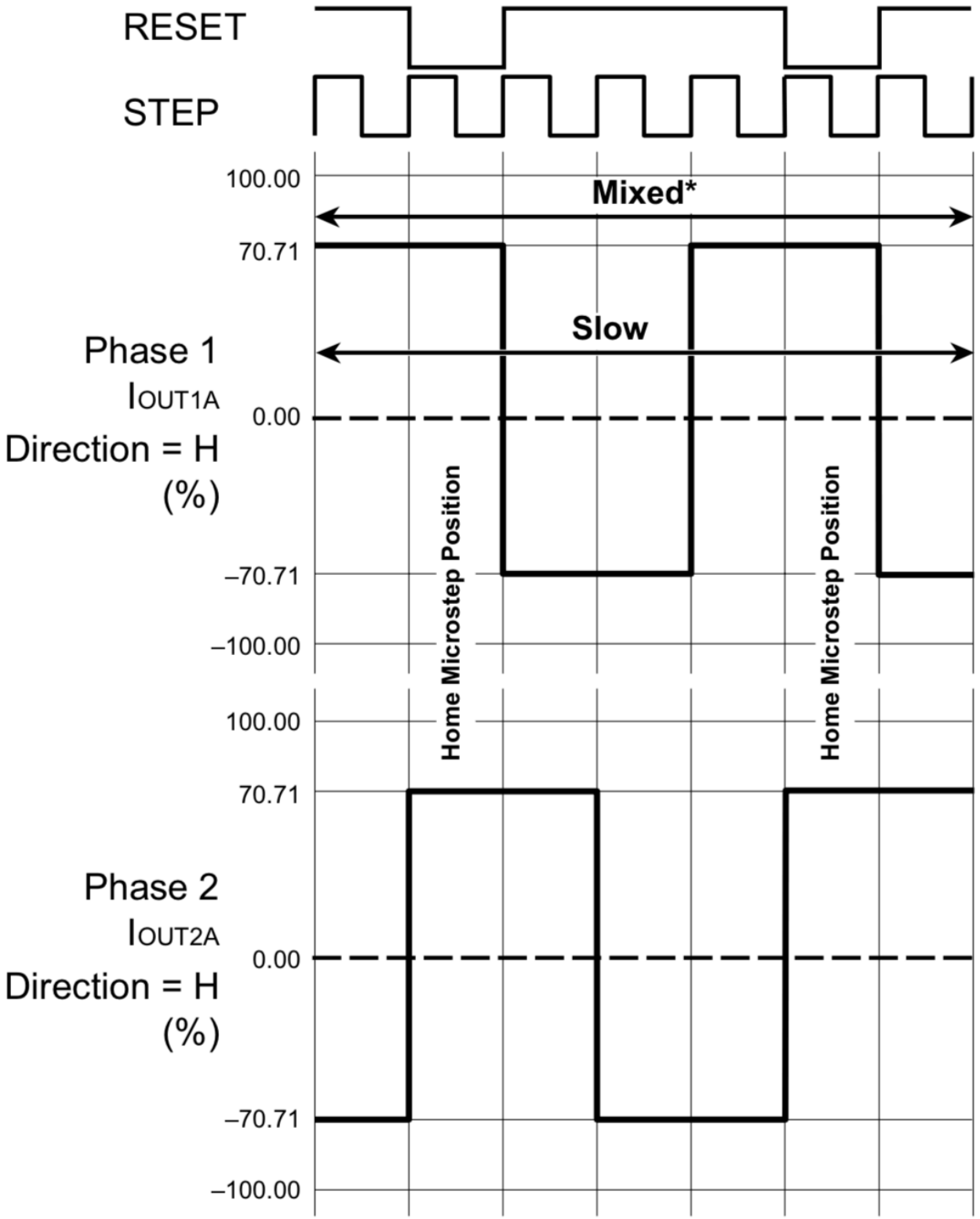




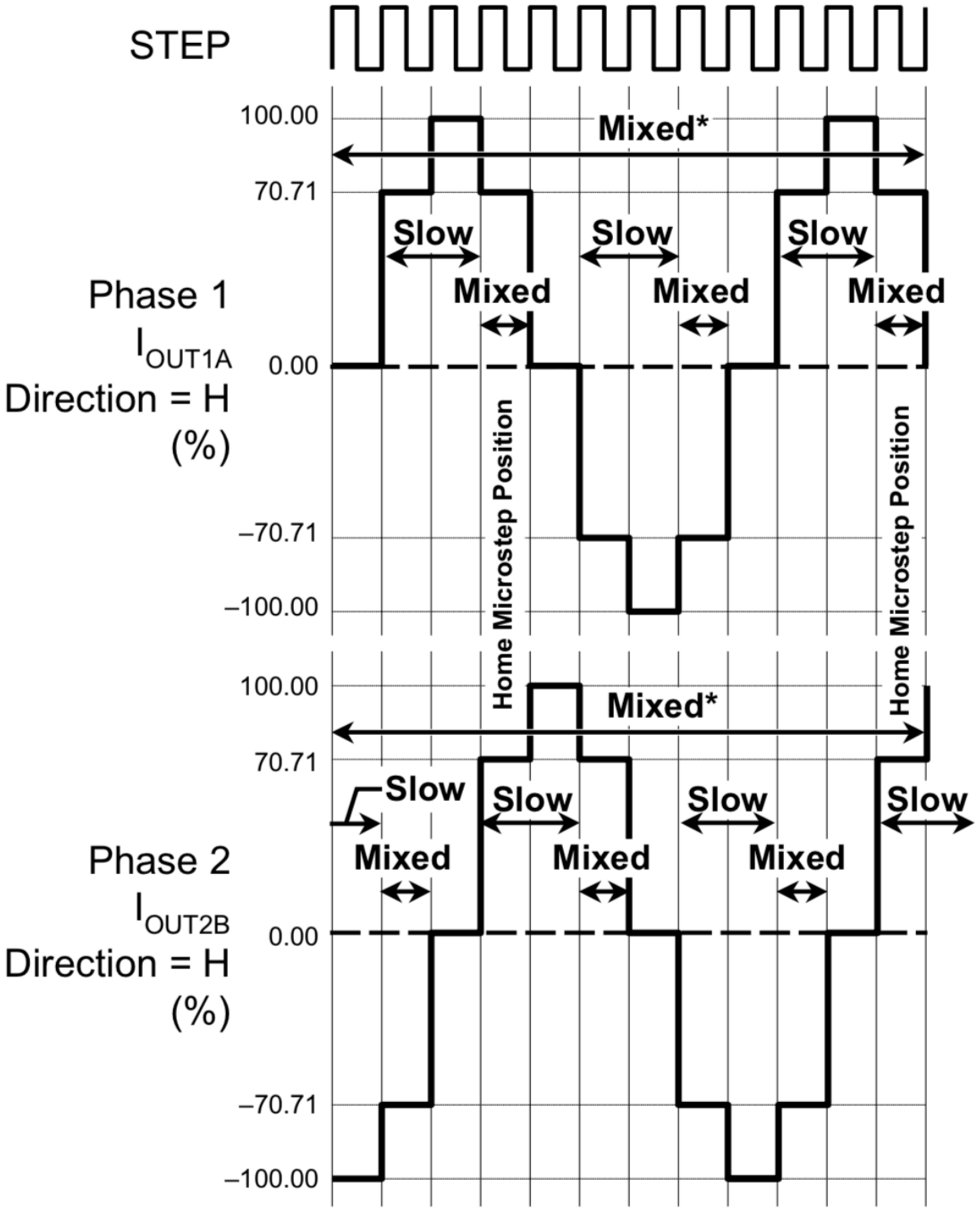
Potentiometer sets current

Vref = I * 8 * Rsense
Rsense=100 milliohms(?)

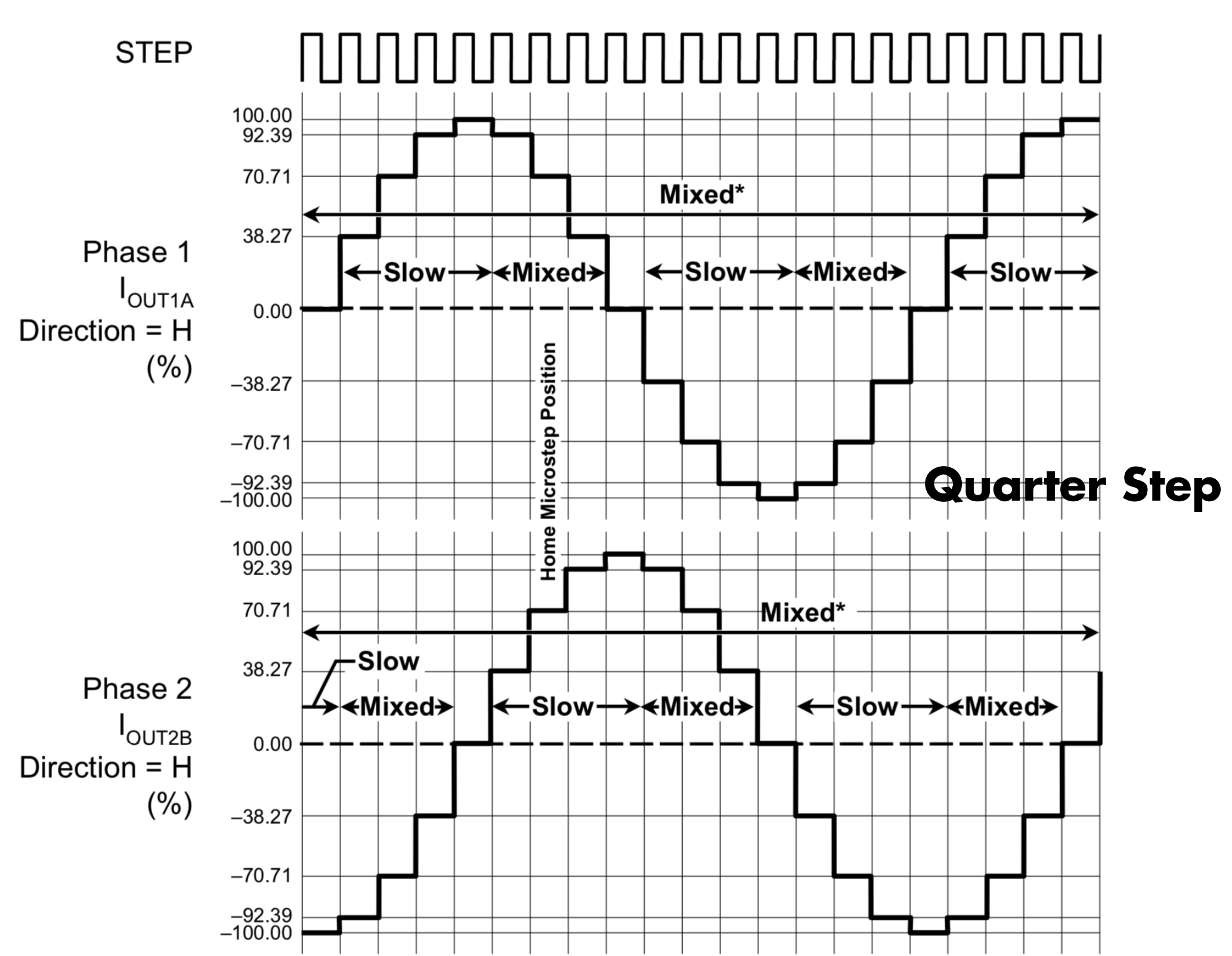

A4988
0.22 µF
VREG
ROSC
0.1 µF
CP1
CP2
VDD
Current Regulator
OSC
Charge Pump
VCP
0.1 µF
REF
DAC
DMOS Full Bridge
VBB1
OUT1A
OUT1B
SENSE1
PWM Latch Blanking Mixed Decay
OCP
Gate Drive
STEP
DIR
RESET
MS1
MS2
MS3
Translator
Control Logic
DMOS Full Bridge
VBB2
OUT2A
OUT2B
SENSE2
OCP
PWM Latch Blanking Mixed Decay
ENABLE
SLEEP
DAC
V_{REF}
R_{S1}
R_{S2}
H-Bridge

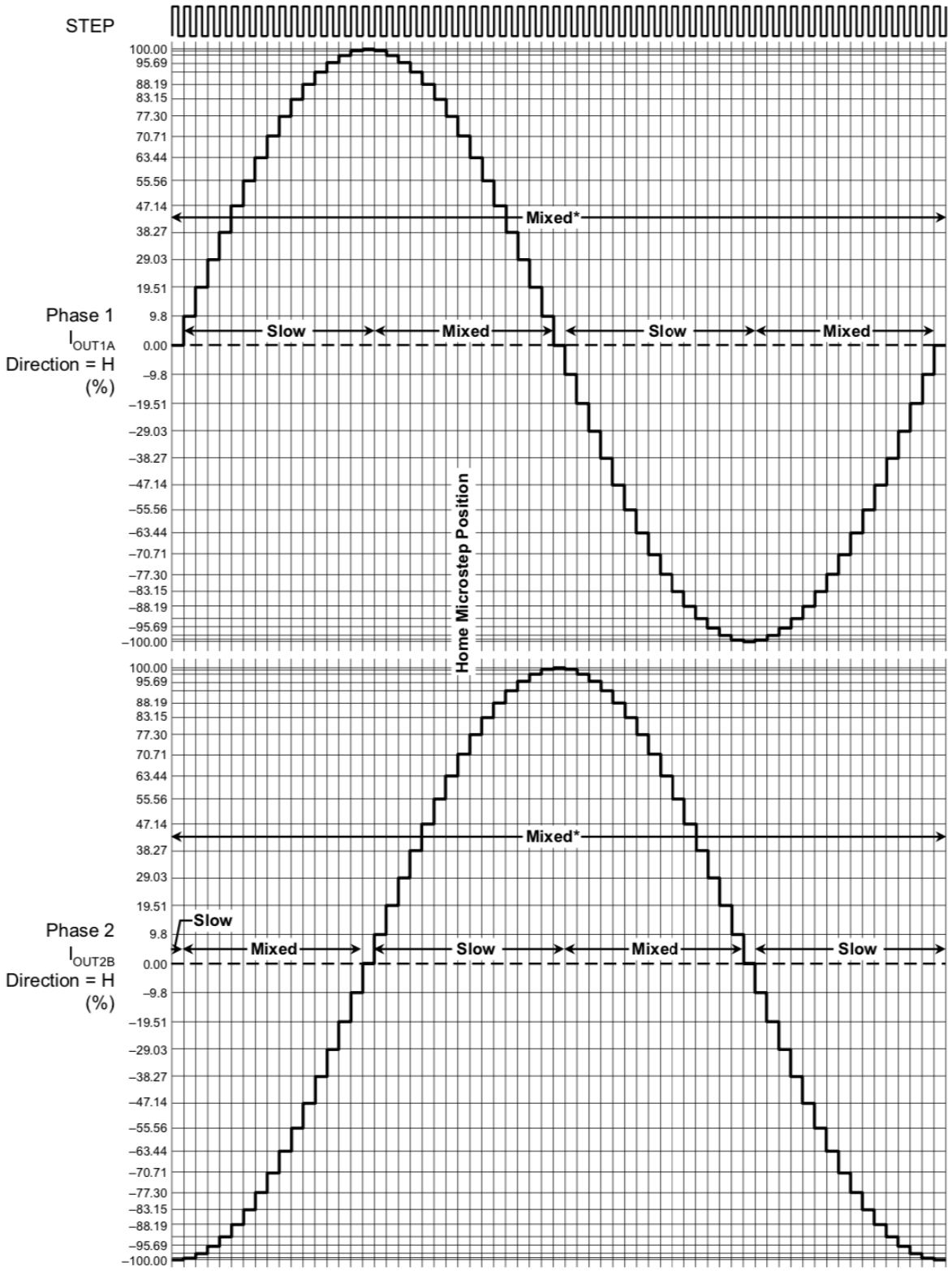

RESET
STEP
100.00
Mixed*
70.71
Slow
Phase 1
IOUT1A
0.00
Direction = H
(%)
–70.71
–100.00
Home Microstep Position
Home Microstep Position
100.00
70.71
Phase 2
IOUT2A
0.00
Direction = H
(%)
–70.71
–100.00

Full Step


STEP
100.00
70.71
0.00
–70.71
–100.00
Mixed*
Slow
Mixed
Home Microstep Position
Phase 1
I_{OUT1A}
Direction = H
(%)
Phase 2
I_{OUT2B}
Direction = H
(%)

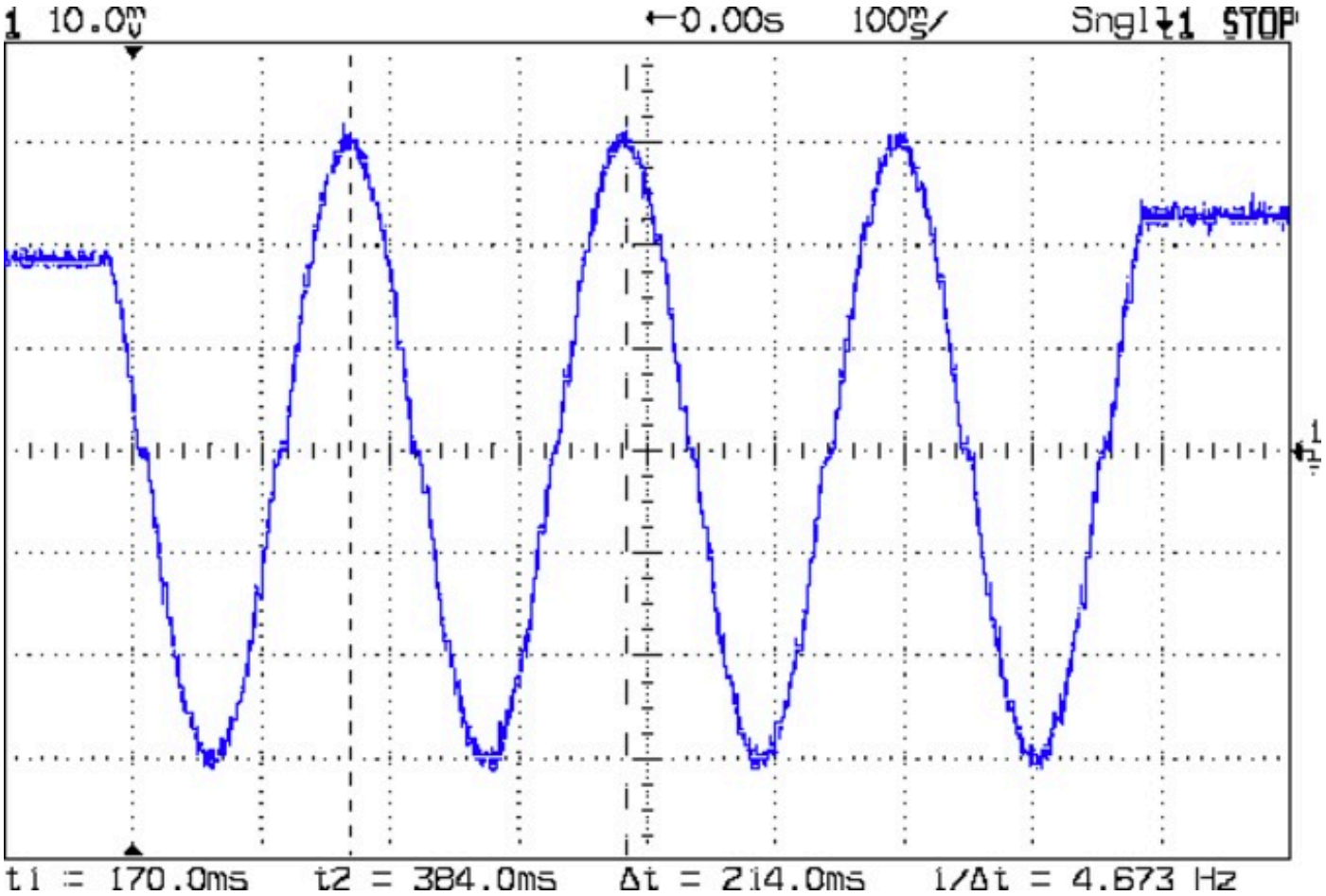
Half Step


STEP
Phase 1
I_{OUT1A}
Direction = H
(%)
100.00
92.39
70.71
38.27
0.00
–38.27
–70.71
–92.39
–100.00
Mixed*
Slow
Mixed
Slow
Mixed
Slow
Home Microstep Position
Quarter Step
Phase 2
I_{OUT2B}
Direction = H
(%)
100.00
92.39
70.71
38.27
0.00
–38.27
–70.71
–92.39
–100.00
Mixed*
Slow
Mixed
Slow
Mixed
Slow
Mixed


STEP
100.00
95.69
88.19
83.15
77.30
70.71
63.44
55.56
47.14
38.27
29.03
19.51
9.8
0.00
–9.8
–19.51
–29.03
–38.27
–47.14
–55.56
–63.44
–70.71
–77.30
–83.15
–88.19
–95.69
–100.00
Mixed*
Slow
Mixed
Slow
Mixed
Phase 1
I_{OUT1A}
Direction = H
(%)
Home Microstep Position
Mixed*
Slow
Mixed
Slow
Mixed
Slow
Phase 2
I_{OUT2B}
Direction = H
(%)

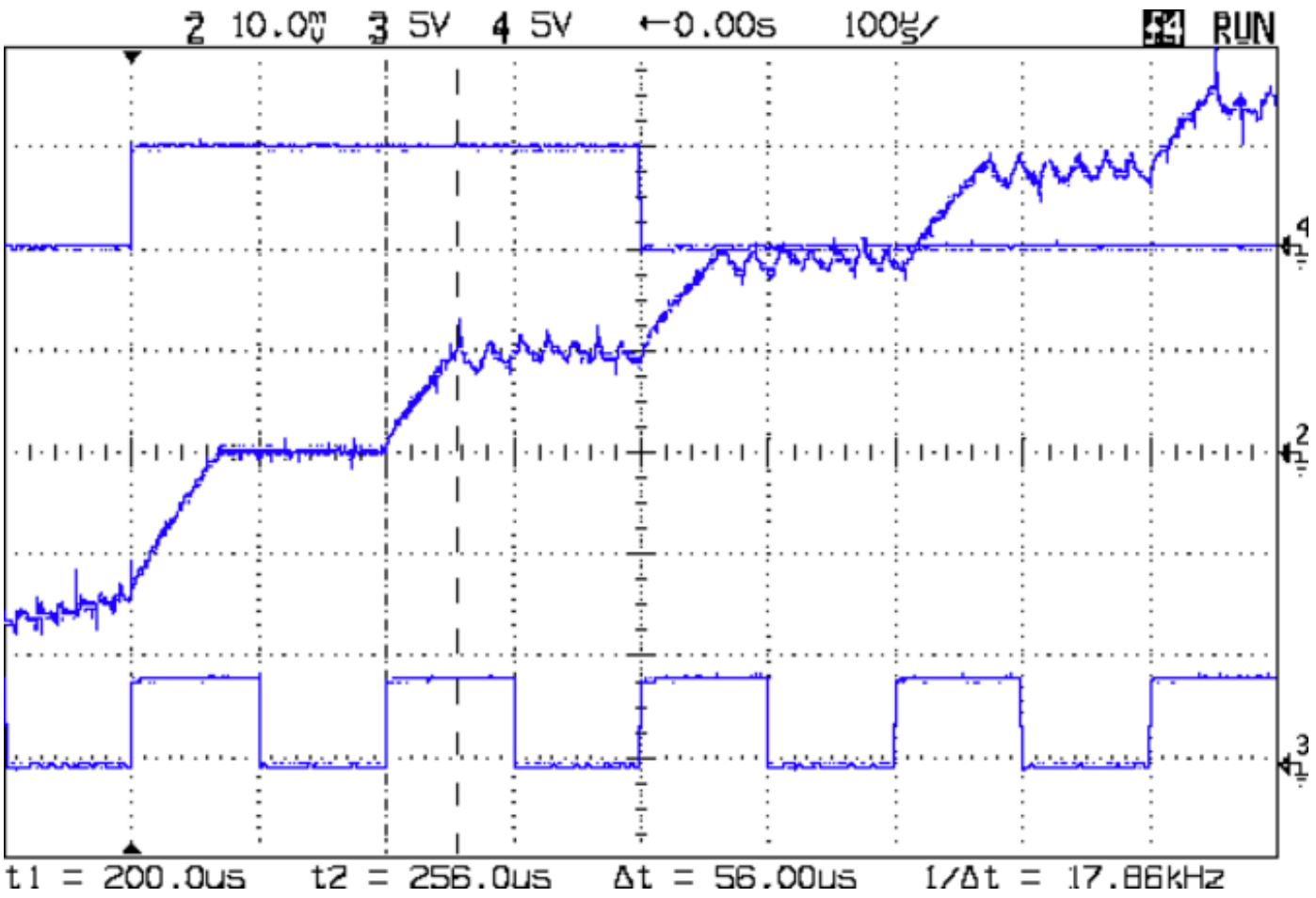
16 Step

4988 - 16 microsteps

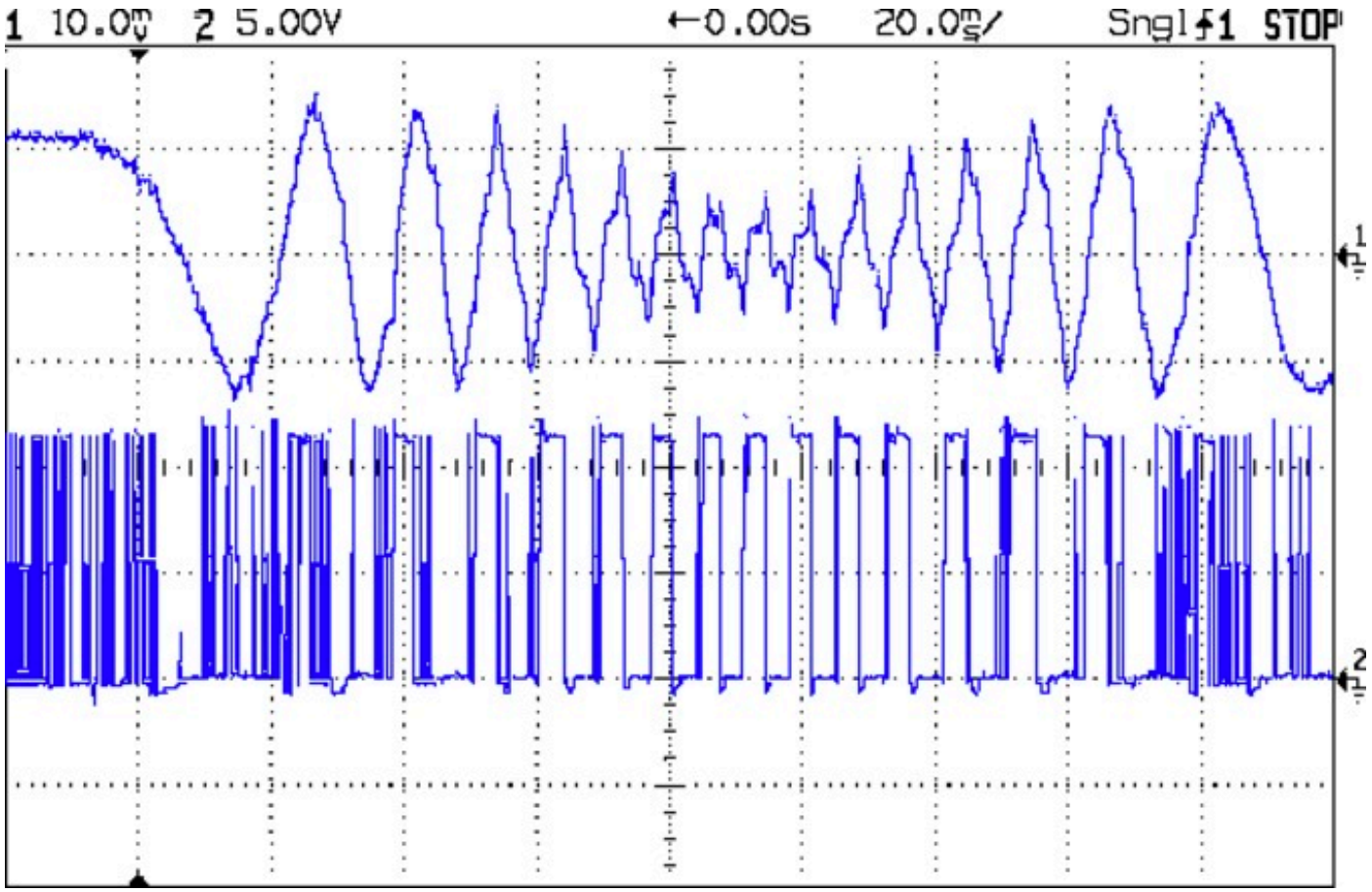


https://softsolder.com/2017/12/05/mpcnc-a4988-driver-microstep-waveforms/

4988 - 16 microsteps



https://softsolder.com/2011/06/20/stepper-sync-wheel-current-waveform-first-light/

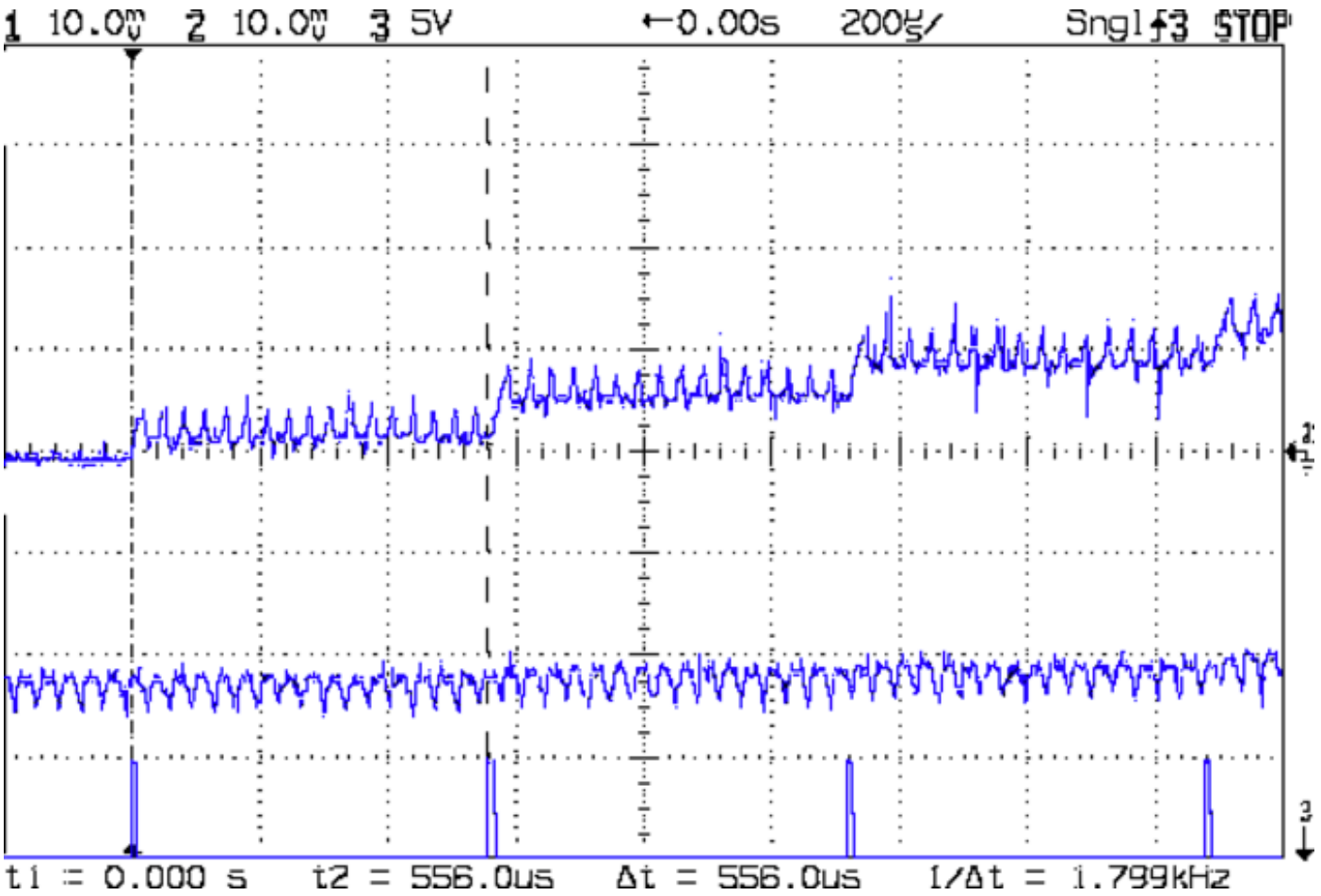


https://softsolder.com/2017/11/29/mpcnc-12-v-supply-vs-stepper-current-vs-axis-speed/

4988 - 16 microsteps

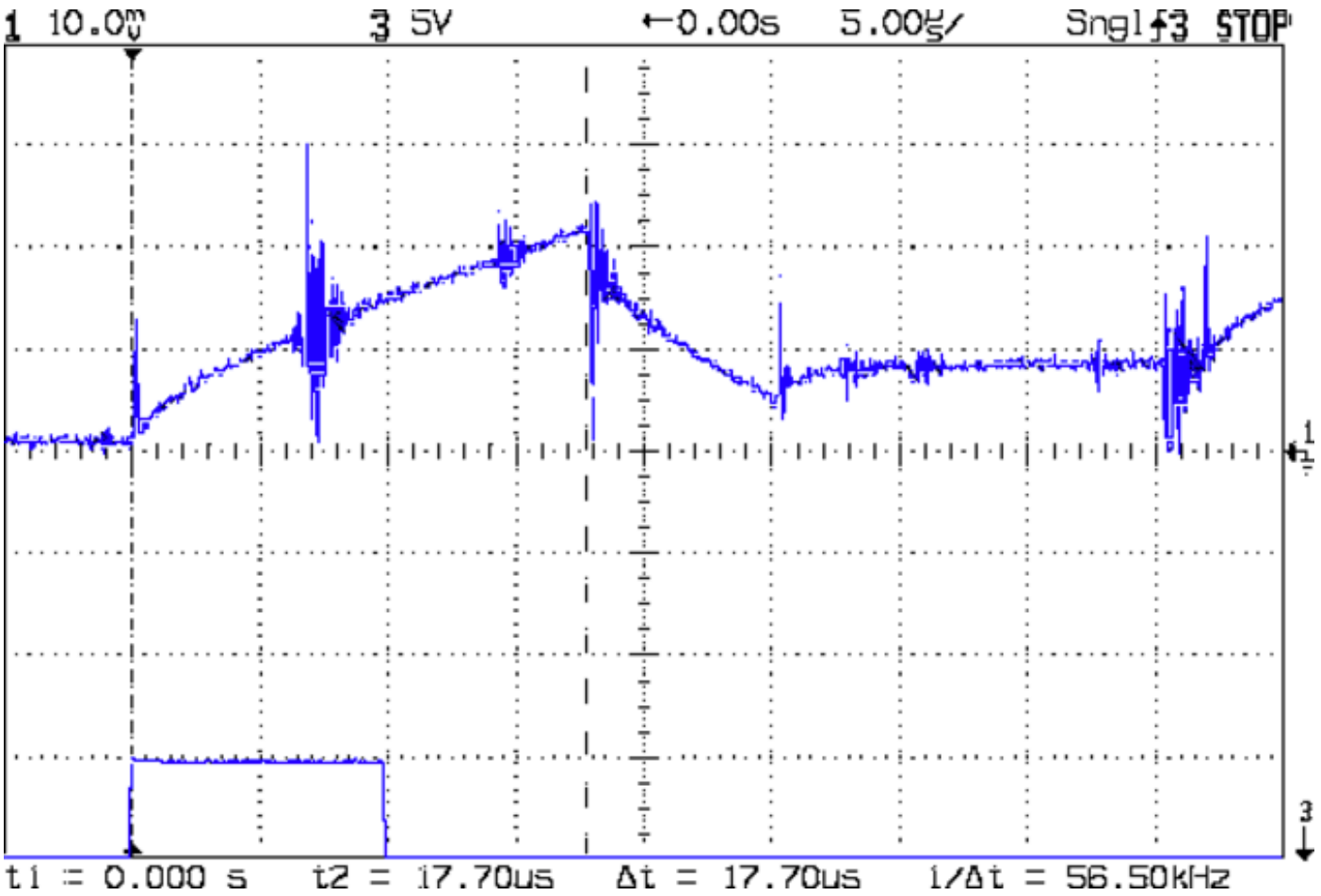
A

B



PWM - 20 KHz

http://circuitcellar.com/cc-blog/stepper-motor-back-emf/



http://circuitcellar.com/cc-blog/stepper-motor-back-emf/

Chopper Driver

Drive motor with 20 Khz PWM at 24V

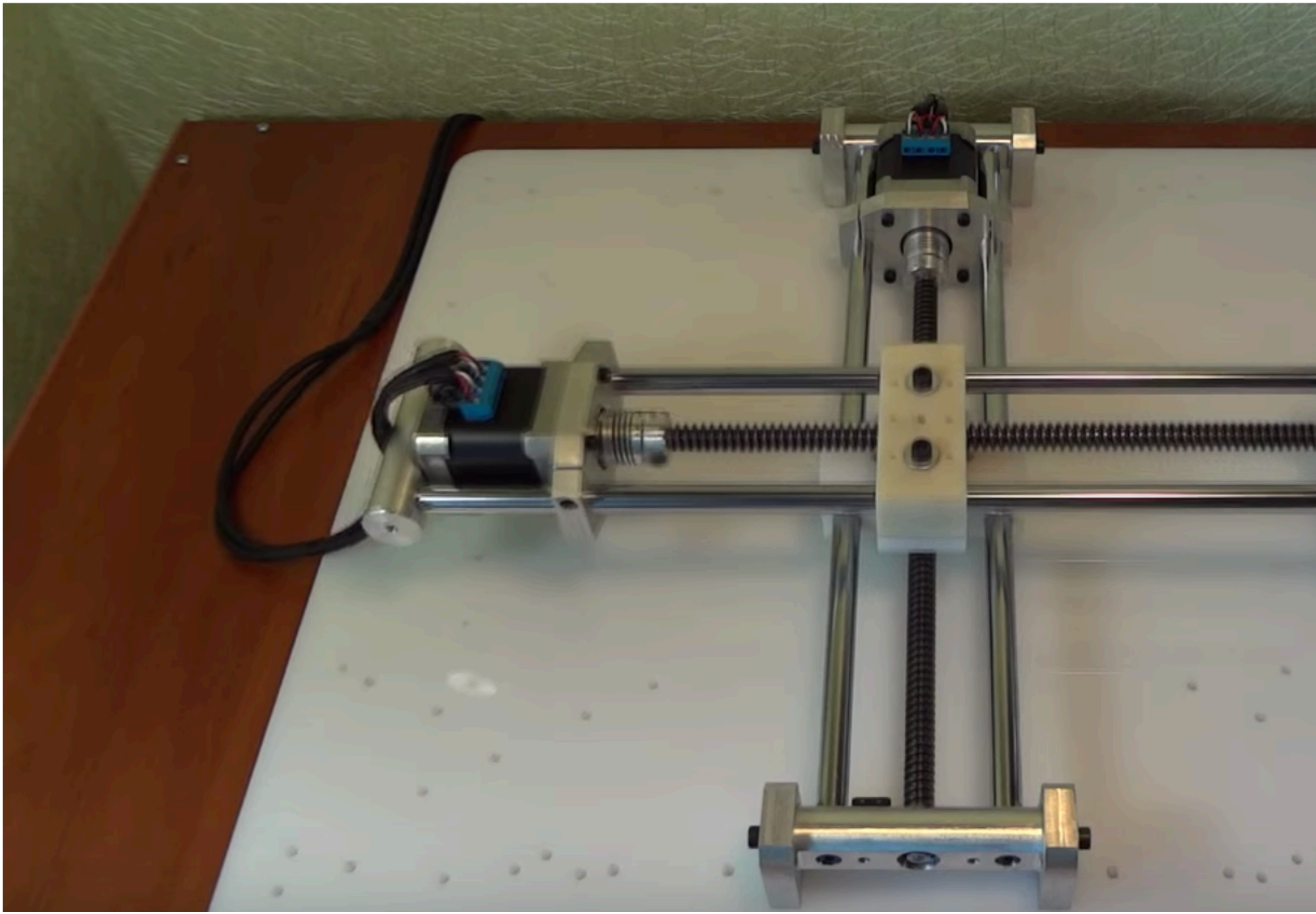
Current sense resistor

Feedback loop to adjust pulse width to set current (too much, decrease width, etc.)

Notes:

- **Current controlled, voltage doesn't matter**
- **Inductance can changes waveform**

Modular Machines

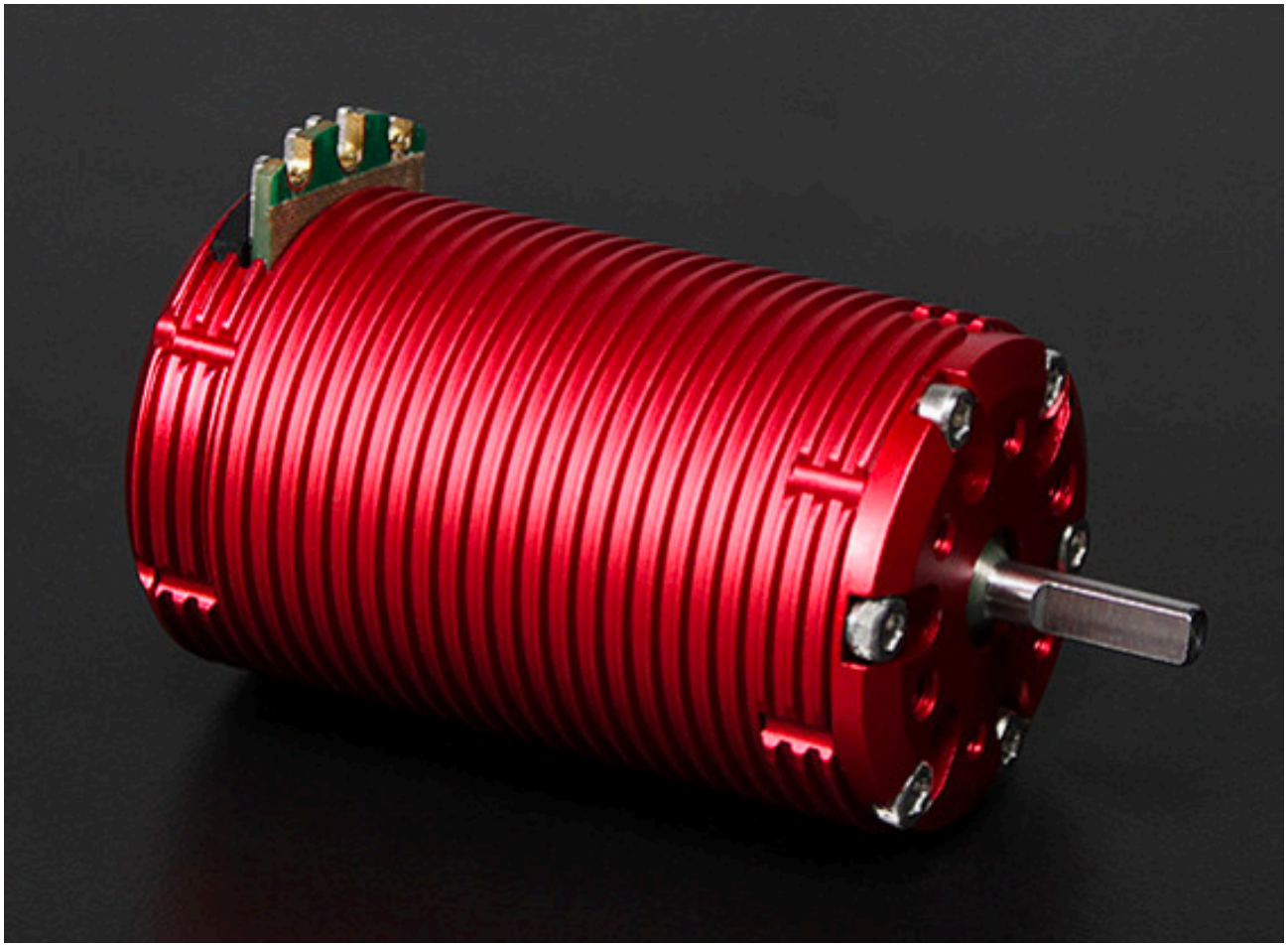


Types of Motors

Servo

SG90

Brushless DC



Turnigy TrackStar Sensored Brushless Motor 1900KV

Precision Gear Motor

Servocity