STEP MOTOR BASICS

TERMINOLOGY:

Step = Pulses	Distance, where 1 pulse could be 1.8º if full-stepping, 0.9º if half-stepping.
Hz = pps (pulses/sec) = frequency = steps/sec	Speed of rotation in terms of steps or pulses.
Microstepping	Dividing the motors natural full step by smaller increments, for example, a 1.8º step motor microstepped at 64x will mean that 1 pulse is now 1.8º/64 = 0.028º. Now, speed is 64 times slower and you must send the motor extra steps just to have it perform the same as when it was in full step mode.
Torque	Typically in oz-in, lb-in, ft-lb, Nm, a measurement of rotational force.
Inductance	Amount of time current will flow in and out of motor coils (less inductance is better for higher speeds.)
Resistance	The impedance that slows down current flow.
Inertia	Level of difficulty creating an angular rotation of an object about that axis. (Load inertia should not exceed 20x the rotor's inertia for fast acceleration applications.)

1.8º Step Motors have 200 steps/revolution
0.9º Step Motors have 400 steps/revolution
0.45º Step Motors have 800 steps/revolution

- This is because 360° are in a circle, or, 360°/revolution.
- To find steps/revolution, take (360°/revolution) / (1.8°/step) = 200 steps/rev

CALCULATING MICROSTEPS:

Example: A customer has a 0.9º stepper and is running at 256x microsteps. They would like to achieve 3 RPS. How many pulses should they send to their drive?

$$\frac{\text{Pulses}}{\text{Second}} = \frac{3\ \text{revolutions}}{\text{second}} \cdot \frac{400\ \text{pulses}}{\text{revolution}} \cdot 256\ \text{microsteps}$$

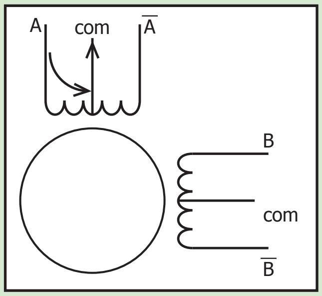
= 307200 pulses/sec

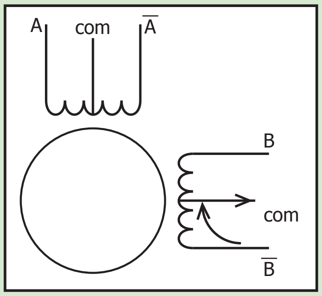
Or the reverse situation, a customer has a 1.8º stepper running at 64x microsteps and is running 42240 pps. What's the RPS?

- First calculate how many microsteps are in a revolution (200 x 64 = 12800 steps/rev)
- Take the number they gave you and divide: 42240 pps / 12800 steps/rev = 3.3 RPS

UNIPOLAR VS. BIPOLAR:

- **Unipolar** motors use 6 wires and require a unipolar driver. In addition to the A and B phases, there are two extra wires called the common wires:

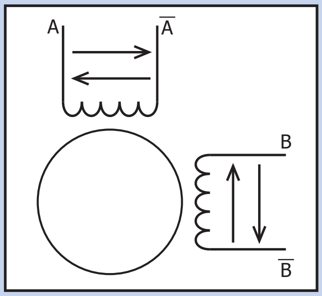




- Current always flows in **one** direction: from the phases, through the common wires. In addition, only **one** portion of the motor is energized at a time.

By energizing A then B this will cause the motor to step from one step to the next.

- **Bipolar** motors use 4 wires and require a bipolar drive. Common wires are not used.



- Current can flow in **two** directions. In addition, **two** phases can be energized at one time.

	Pros	Cons
Bipolar Motors	More efficient. Up to 40% more torque.	Could heat up faster.
Unipolar Motors	Generally run at lower heat.	Generally produce less torque.

EXPLANATION OF FULL STEPPING:

- During full stepping, both phases are always on, meaning, 100% current is being sent to both coils A & B, creating a vector sum of 1.4 times more current than the phase currents.
- If a motor is rated at 1 Amp/Phase, the driver will actually ouput an overall current of 1.4 Amps. Below shows what happens when A and B are both energized with 1 Amp of current.

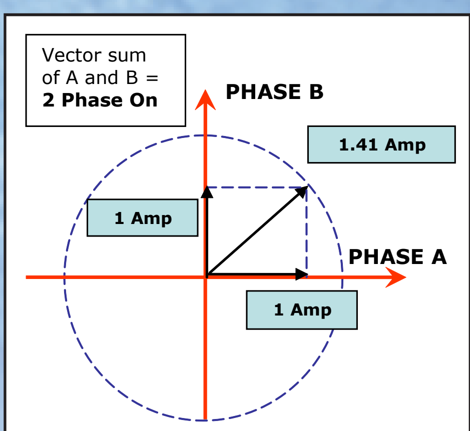


Figure A: this phase diagram depicts when Phase A is "on" and when Phase B is "on".

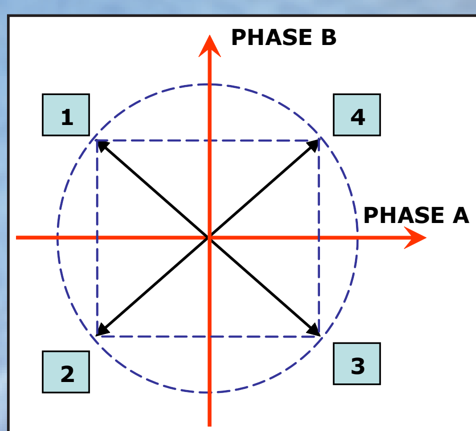


Figure B: Phase diagram for full stepping.

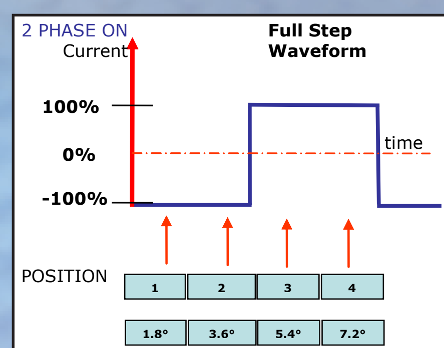


Figure C: Full Stepping Waveform and Position.

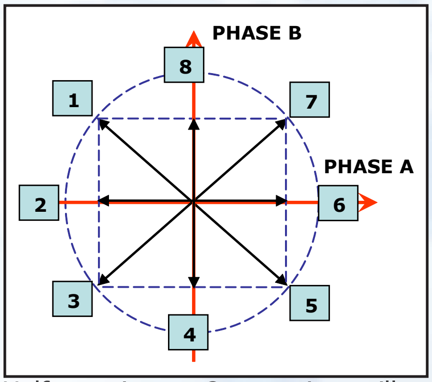
Notice in Figure B, position 2 shows that both Phase A and b are on, but the values are negative. **Negative current** simply means that current is flowing in the opposite direction.

By continuously following the step sequence 1-2-3-4, it will rotate the step motor. Each pulse entering the driver equals one step. The faster the pulses, the faster the rotational speed.

BASICS OF MICROSTEPPING:

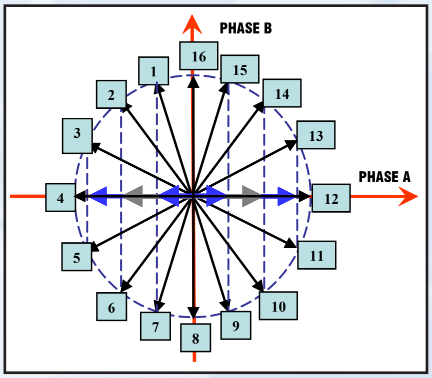
All step motors can be microstepped (microstepping is a function of the driver).
By sending different amounts of currents to each phase, it forces the motor to make a step in between its natural full step positions.
In order to half step a motor, instead of sending 100% current to both coils, it switches off and sends A Phase 100% and B Phase 0% current or vise versa (positions 2, 4, 6 and 8):

Figure D: Half Stepping Phase Diagram



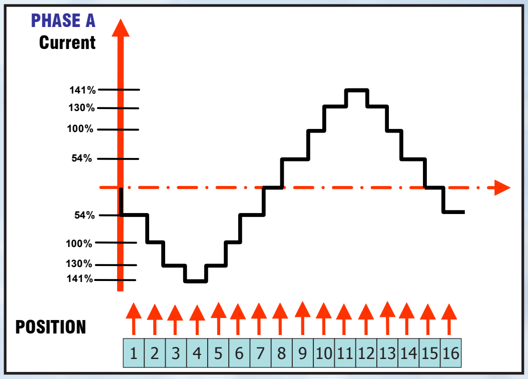
Half stepping, or 2x stepping, will force a 1.8° step motor to step every 0.9°, now there are 400 steps/revolution where 1 step = 0.9°.

Figure E: 1/4 Microstepping Phase Diagram



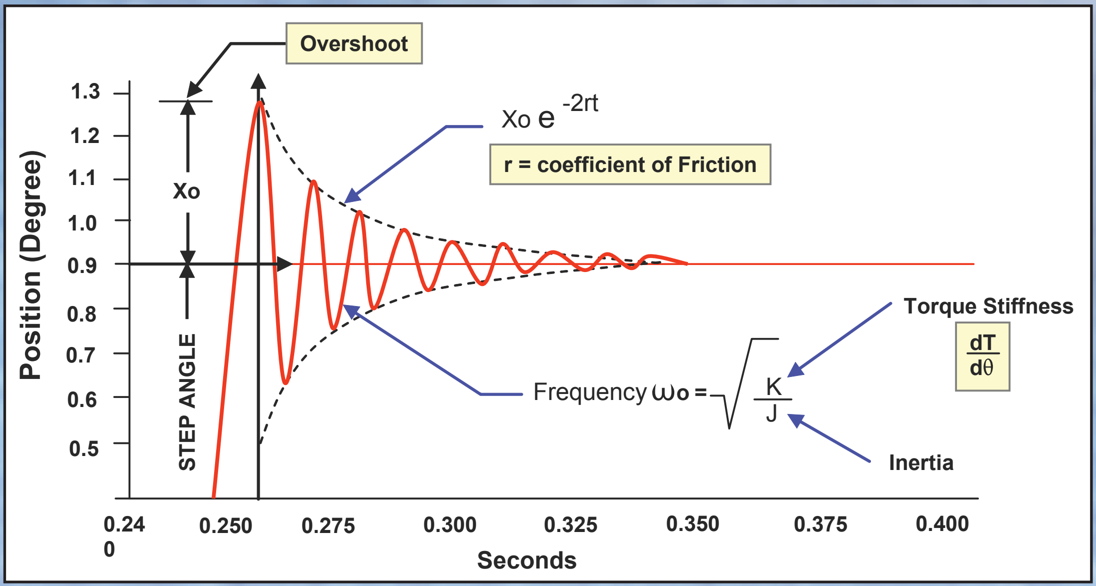
1/4 microstepping divides the currents into even smaller increments, and eventually the increments become sinusoidal because it changes so much, forcing the step motor to make small microsteps:

Figure F: 1/4 Microstepping Current Waveform



RESONANCE:

Each step creates an oscillation and then settles into the step, shown below.
Therefore, if oscillations from each step become the same frequency as the step rate, resonance will occur.



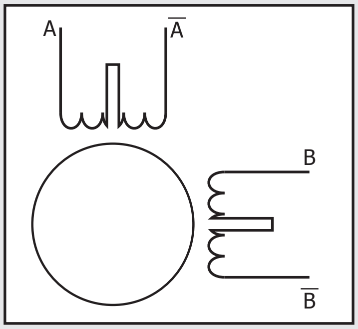
Overshooting can occur if oscillations build up with each step and the momentum of the load carries the motor to the next few steps beyond it's desired position.

To overcome resonance you must shift the resonance point away from the operating point. Resonance will always be there, it is a matter of manipulating the system so that it goes away.
Change the following parameters in order to shift resonance:

- Current
- Voltage
- Rotor Inertia
- Inertia load reflect to the Motor

SERIES VS. PARALLEL:

- Bipolar motors can be connected in several ways.
- A series connection uses the four wires shown below, ignoring the common wires.

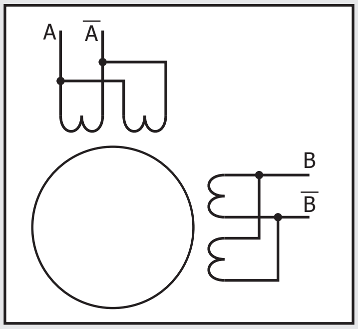


Series:

- Resistance is now 2xR compared to unipolar.
- Current is 0.707x compared to unipolar (less current.)
- Inductance is now 4x, because Inductance is proportional to the # of turns squared:

$$L \ \alpha \ N \ 2$$
$$2L \ \alpha \ (2N) \ 2$$
$$2L \ \alpha \ 4N \ 2$$

- Since Inductance means the amount of time current will flow in and out of motor coils, a series connection generally works only at low speeds.



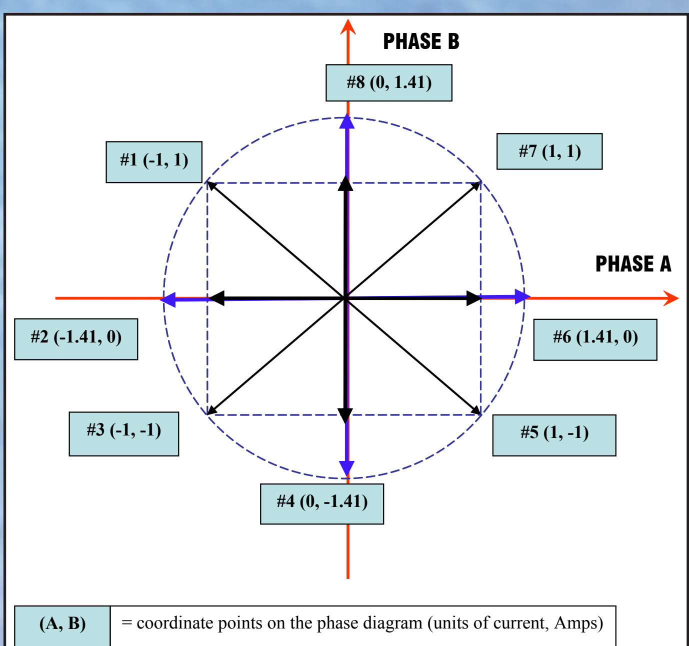
Parallel:

- Resistance is now ½ R compared to unipolar (or 4 times less than series.)
- Current is 1.4x compared to unipolar.
- Inductance is still the same, coils are wound in parallel, therefore the # of turns is not changed.
- Generally, a parallel connection runs at higher speeds, but will require more current.

AMPS/PHASE VS. AMPS PEAK:

- Amps/Phase and Amps RMS is the same value. Since current (Amps) is continuously changing, we need to define an "average", an RMS value to state what is the motor's rated current. (RMS = Root Mean Square).

- Peak current is defined as √2, or 1.41 times more than the RMS current. Peak current is the maximum amount of current the motor coils will reach at one point and time during the continuous change of current. Below gives us a better idea of what values each phase will see, and clearly the max is 1.41 Amps, if the Amps/Phase is 1 Amp.



- In setting up the current on a driver, many times we need to set it to the Peak Current value because the driver typically energizes one coil, usually at position #8 above. Therefore, we are measuring peak current.

For example: a motor is rated at 1.0 Amp/Phase. If you set the driver to 1.0 Amps, in reality, you are setting the position #8 values to be (0, 1). Therefore, everything will adjust to a lower current value.
i.e., position #1 will now be (-0.707, 0.707).

- Therefore, the motor is not receiving the maximum amount of current allowed. Instead, you must already calculate peak current when you set the driver. The correct amount should be 1.41 Amps Peak.