INTRODUCTION

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Greetings and welcome to our material on stepper motor technology. There's just too much to say to have it all on the web page so we moved most of the details into this document.

Before we begin, you should understand that this document cannot cover everything you might need to know about stepper motors. We just can't cover it all here. That being said, here's how we've decided to cover the issues:

A stepper motor is distinct from other electric motors in several important ways.

First, the rotor of a stepper motor does not need electric power. This eliminates having to have brushes to make electrical contact between the rotor and the rest of the system. That's a good thing because brushes are a major source of wear and failure in servo-motors.

Second, a stepper motor has distinct, repeatable movements. This, generally, eliminates the need for a position feedback system. I say "generally" because certain mechanical systems can introduce positional variance into the system and you may need a position feedback system for that.

Stepper motors are simple but that's not to say they don't have their own unique set of technical gotchas. Without an understanding of the limits of stepper motors, you can get yourself into some trouble.

In the following I'll introduce you to the major concepts involved in implementing systems using stepper motors. I will try to avoid dipping into too much detail but you should be aware that the detail exists. If you want or need the detail, call us (or check out the engineering classes at a nearby university).

Also, you should know that experience counts. As a wise man once said:

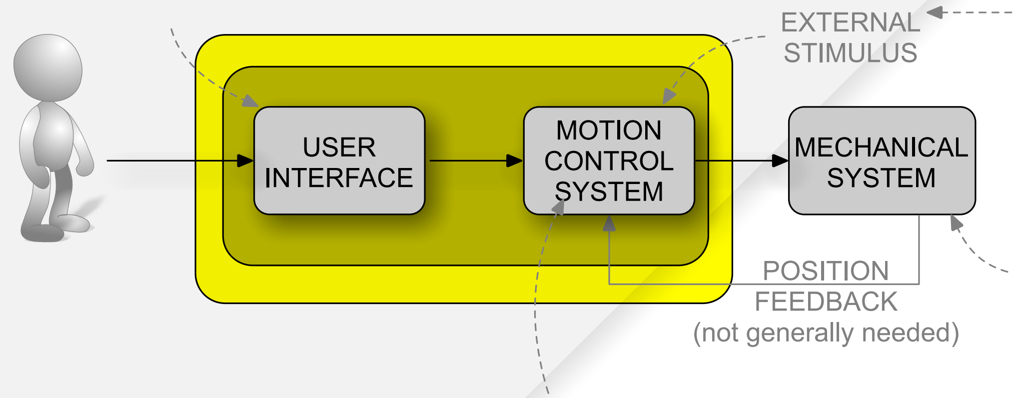
"In theory there is no difference between theory and practice. In practice there is."

Yogi Berra

This is Jamie, a.k.a. the user (our good friend, our customer).

A user interface can be a really wide variety of things. A small computer is probably the most common. Electromechanical interfaces (dials and switches) are not uncommon.

The user interface should be carefully selected. It's how the user interacts with the system and, assuming the system does what it's told, it's what determines what the system can (and can't) do and how easy it is to make the system do it.



It's common for systems to be designed to run without a user and without a user interface. At TMG, we call these systems "auto-start enabled". In the systems world, you might hear the terms "embedded" or "wholly embedded".

In an auto-start system, the system has an intelligent controller and it's taught what it's supposed to do (programmed). From then on, when power is applied, the system automatically starts executing its program.

Many systems execute instructions "live" (on user demand). You're using one now! A disk drive is a stepper motor control system. It gets commands from the computer software to read and write data.

The motion control system contains:

- a controller,
- a driver (with power supply) and
- one or more step motors

The job of the controller is to tell the driver when to take a step, and in which direction.

The driver's job is to apply power to the motor. It really only understands "take a step". Still, with modern step motors, that's not trivial. It's responsible for changing the current on all of the windings so that a single step is taken.

To get "motion" (not just steps) the controller tells the driver to take a step, take another step ...

The speed is determined by how fast the controller is issuing the commands.

It's common to have a few switches and/or sensors that tell an intelligent interface about things that are going on in the system. Physical limits (edges), temperature, opto-sensors, etc.

The mechanical system is what takes the rotational motion of the motor and translates it into motion that does some desired function.

That generally consists of belts or gears with things attached.

Typical systems include: CNC, linear actuators, linear stages, mirror mounts, floppy disks, scanners, printers, 3D printers, plotters, compact disks, video security systems, intelligent lighting and much, much more.

TMG provides a wide selection of equipment that covers everything except the user and the mechanical system.

While we really can't supply your users, we can help with everything else. We don't supply the mechanical systems but we do work closely with our customers who are designing them.

BASIC PHYSICS

All electric motors work because of magnets. I assume you have, at some time, played with magnets and you know that they attract and repel each other.

You also need to know about electromagnets. That is, flowing electricity (amperage) creates a magnetic field. When the current flows in one direction it creates a field in a North-South orientation. If we reverse the flow, the field changes and it's in a South-North direction.

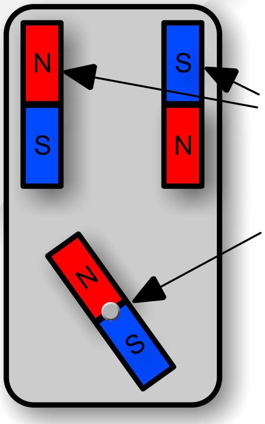
Knowing those two things, you can create an electric motor. I will focus on the characteristic elements of stepper motors.

Stepper motors (and, in fact, all electric motors) work because magnets pull and push on each other. It's a case of opposites attract so the "North" pole of one magnet is attracted (moves toward) the "South" pole of another magnet. In addition to that, like poles (north-north and south-south) push against each other.

There's only one more thing you need to know to understand how the motors work. That is, we can use electricity to create magnetism. When electrons (current) flow through a wire, they create a magnetic field and when we reverse the flow, we reverse the field.

So here's the situation. Let's take and glue a couple of electro-magnets (they can change their poles) to a board. Then let's mount a permanent magnet on a swivel nearby.

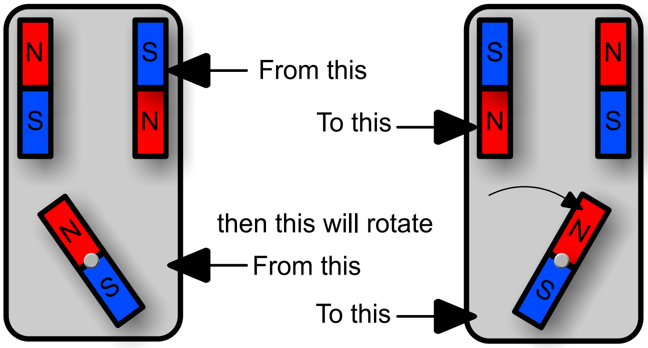
Like this:



Notice that the permanent magnet is pointing at the electromagnet with the opposite pole (opposites attract).

Now here's the trick:

If you change the poles (change the direction of the current) on these electromagnets



See, it's still pointing at the opposite pole!

That’s it. That’s how you make a motor out of magnets. You arrange the electromagnets in a circle around the rotating piece (rotor) and then just keep moving the poles around to make the rotor chase after them.

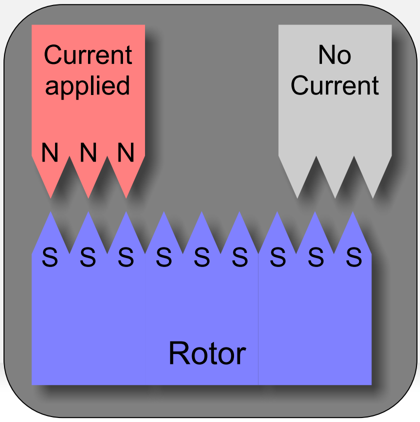
Of course, when you get into details, it gets a lot more complicated.

There are mechanical issues involving how you mount the magnets, what kind of bearings you use on the rotating part (the rotor), what materials you use, etc.

There are electrical issues involving how much power you use, what to do with the heat that, inevitably, results from using that power, how many electromagnets to use, etc.

Now we need a way to make a stepper motor take a **SMALL** step. What we went through on the previous page is okay but it won't tell you much about why a stepper motor looks like it does. It is, in fact, interesting.

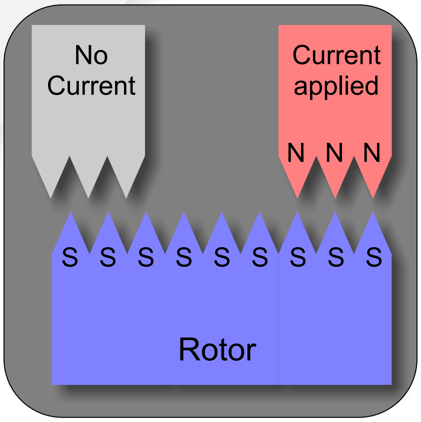
A stepper motor has "teeth". The teeth provide a way to move the motor in very small but predictable increments. Here's a very small segment of a motor. In reality, there are many more teeth on a rotor. I'm showing you a segment with 9 teeth.



In this case, the rotor (with the south pole magnets) is lined up with the electro-magnet (with the north poles). The teeth correctly line them up as close as they can get (point to point).

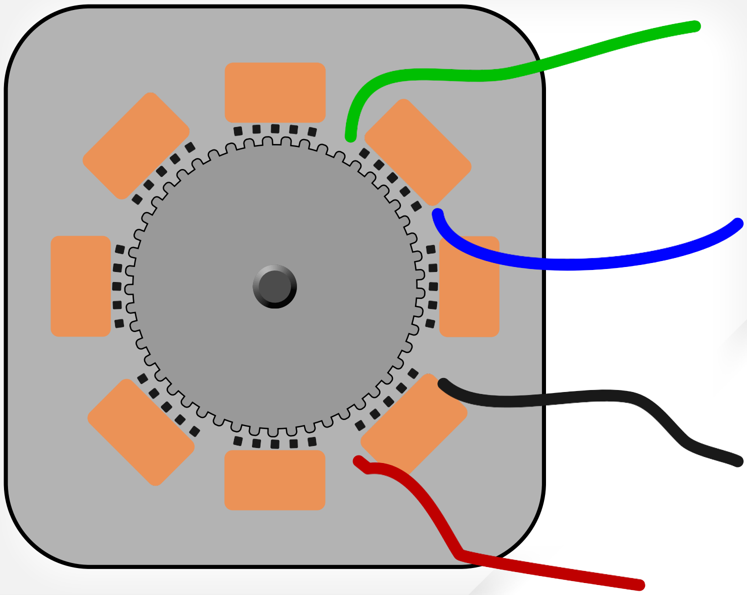
The electromagnet with no current is not magnetized so the rotor ignores it.

When we turn off current on the left electromagnet and turn on current on the right, the rotor will move just enough to line up under the other electromagnet.



To complete the picture, we make the rotor round and make a whole bunch of electromagnets and arrange them in a circle around the rotor.

Here's a simplified drawing of the inside of a stepper motor.



The large part (gray square) is the case. Everything is connected to the case and the case has mounting holes so that it can be bolted to your mechanical system.

The green, blue, red, and black lines are power connections. They're distributed to the windings.

The windings are the copper colored blocks and they are thinly insulated copper wire wound around a core. These are the electromagnets and they, on demand (when current is applied), become magnetic. The black dots are the ends of the electromagnets to which the rotor will align.

The large piece in the middle, with teeth, is the the rotor. The rotor is the part that spins and it's the permanent magnet (does not need electrical power).

And, finally, the dark dot in the middle is the shaft. It's part of the rotor and is mounted to the case with bearings so that it can spin freely.

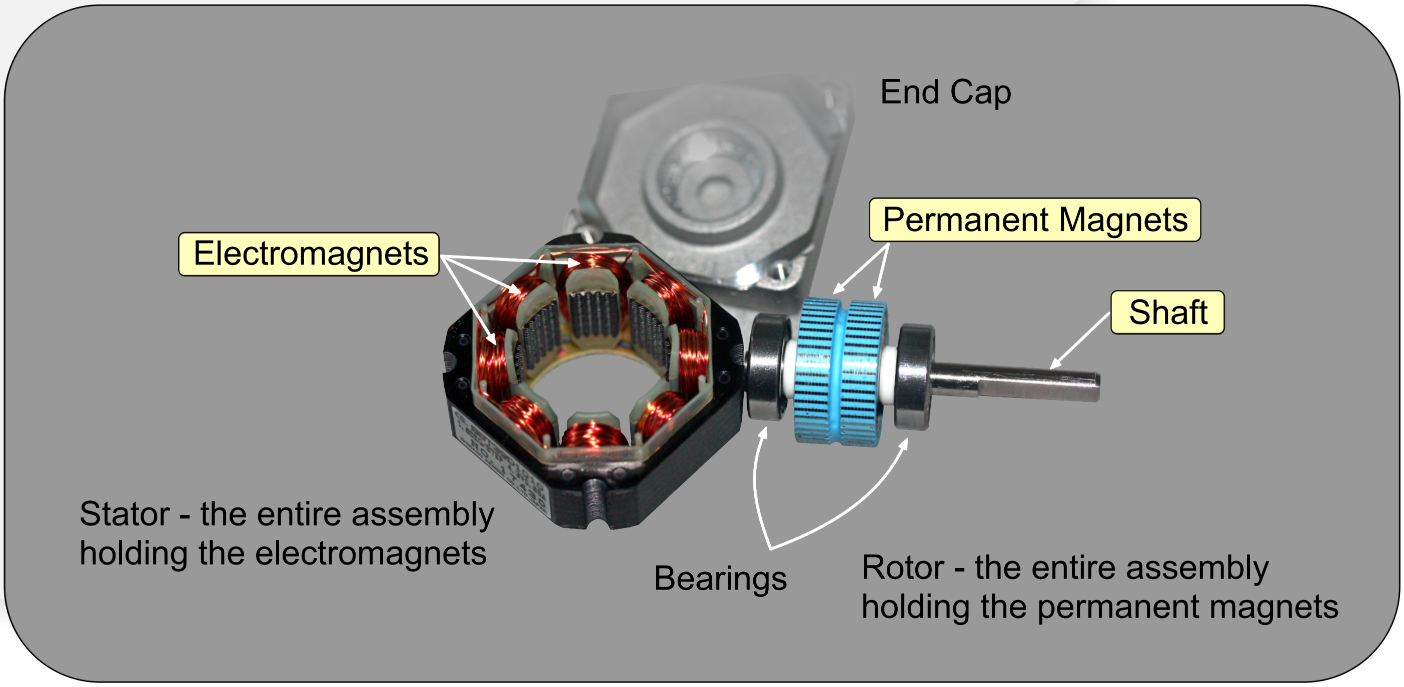
Look inside any stepper motor and you'll see similar objects. They may be larger, or smaller. There may be more, or fewer of them.

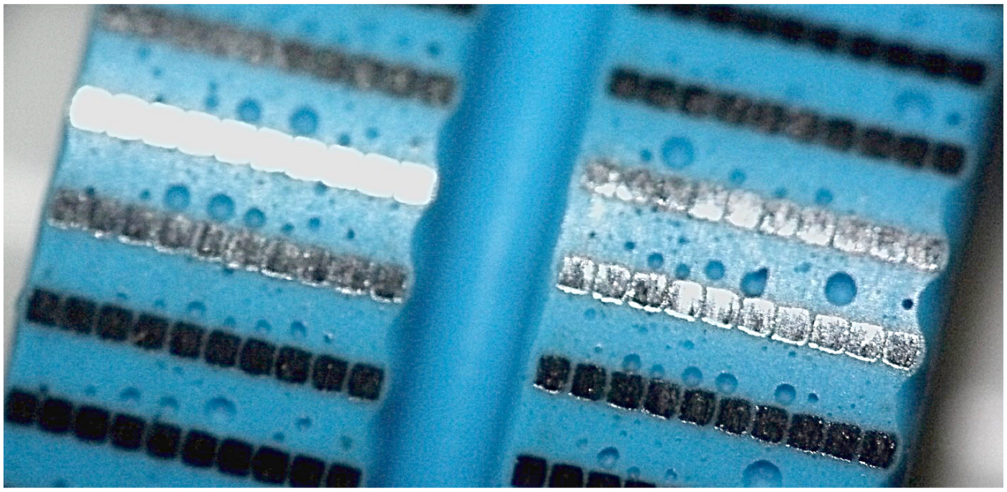
Some motors will have rotors with lots of teeth, some (where fine positioning isn't so important) may have fewer teeth.

There may be more, or fewer, electromagnets.

The right combination of all of these components is dependent upon the application.

Here's a real stepper motor that I've taken apart so that you can see the real thing.





Here's a closer look at the permanent magnets. You'll see that each "stripe" is actually composed of ten individual little magnets and that each stripe is offset from the other.

This assembly is made by placing the magnets in the retaining medium (it varies) BEFORE they're magnetized. If they were magnetized first, it would be very difficult to get this tight, orderly arrangement with all of them pushing against each other.

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A stepper motor system is an electro-mechanical rotary actuator that converts electrical pulses into unique shaft rotations. This rotation is directly related to the number of pulses.

The speed is synchronous to the rate of pulsing (the faster you pulse, the faster the motor moves).

The result is absolute speed and position. Stepper motors feature bi-directional control, built-in braking, variable torque, power control, high accuracy, high resolution, open-loop control, and direct interface to digital systems.

Compared to other servo systems, stepper motors exhibit an excellent power to weight ratio, minimum rotor inertia, no drift, no starting surge, and no cumulative errors.

General Description of Stepper Motors

A step motor converts electrical energy into discrete motions or steps. The motor consists of multiple electrical windings wrapped in pairs (phases) around the outer stationary portion of the motor (stator).

The inner portion (rotor) consists of iron or magnetic disks mounted on a shaft and suspended on bearings.

The rotor has projecting teeth which align with the magnetic fields of the windings. When the coils are energized in sequence, by direct current, the teeth follow the sequence and rotate a discrete distance necessary to re-align with the magnetic field.

The number of coil combinations (phases) and the number of teeth determine the number of steps (resolution) of the motor. For example, a 200 step per rev (spr) motor has 50 rotor teeth times 4 coil combinations to equal 200 spr.

There are no brushes (electrical connections) between the rotor and stator assembly; a stepper motor is a multi-pole (polyphase) brushless DC motor. The multiple coil pairs can be connected either positive or negative resulting in four unique full steps. When the coils are sequenced correctly, the motor rotates forward. When the sequence is reversed, the motor rotates in reverse.

When the sequence is held, the rotor locks (brakes) in place.

The amount of torque required to force the rotor from position is the holding or static torque. If the rotor slips (step loss), it will align with the next available coil combination; either four steps forward or four steps backwards.

Steppers can be stalled or held indefinitely without damage.

If the sequencing is faster than the rotor can move, the rotor will slip until sequencing is slowed enough for the rotor to again lock in to the sequence. The rotor requires a minimum settling time (ringing) to stop when held. This limits the minimum time for the motor to change direction successfully.

PM (permanent magnet) motors settle faster than hybrids. If the sequencing frequency (step rate) is close to the natural frequency of the coils, the motor will attempt to resonate at sub-multiples of this frequency; resulting in step loss and unusual noise (growling).

The low frequency resonant point of a typical motor is 100 full steps/second or slower; the mid-frequency point is between 900-1200 spr. Resonant behavior (electro-mechanical feedback phenomena) can be minimized by reducing the current (gain reduction), isolating the mechanical connection (de-coupling), reducing the step angle to half or micro step, and not operating the motor, continuously, in the resonant bands (ramping).

Electrical Types of Stepper Motors

Variable Reluctance (VM) motors have soft iron rotors with teeth and are mostly used for specialty applications.

Permanent magnet (PM) motors have magnet rotors with no teeth.

Hybrid motors are hybridization of both VR and PM and have magnetic rotors with teeth. mostly used for special applications.

Mechanical Types of Stepper Motors

Pressed Case (tin can or PC) motors are stamped, mated shells with sleeve bearings.

Machined case (MC) motors have cast aluminum end-bells with ball hearings; the bodies are stacks of laminations held together with screws.

A PC is generally the permanent magnet type and has a 7.5 or 15 degree step angle.

MC motors typically are 1.8, 0.9 or 0.45 degree and are accurate to 3 to 5%. Also the air gap (the space between the motor and the stator) is tighter and produces more torque.

PC motors because of their thin cases are more limited in the amount of heat they can handle. The torque of a stepper is a function of the magnetic field (Gaussian strength) produced by the direct current flowing in the coils. The subsequent heating of the coils limits the motor case to a wattage that the case can dissipate before the insulation is damaged (temperature rise).

Motor Case Sizes

Size 17, 23, 34, 42 There are NEMA standards for the MC case front view and the mounting flange holes. The most common are;

- size 17 (1.7 sq. or 40 mm), 5 mm shaft
- size 23 (2.3" dia. or 56mm), 1/4" shaft
- size 34 (3.4" dia. or 86 mm), 3/8" shaft
- size 42 (4.2" dia. or 107 mm).

Step Motor Windings

2-Phase, 4-Phase, 5-Phase

Common step motors have 2 sets of windings. Each winding can be energized positive or negative. The minimum number of connections (lead wires) is four.

Four wire motors are **2-phase (bipolar)**.

For electrical convenience (L/R driver) each winding is center tapped into two coils (bifilar winding). The result is a six wire or 4/1 phase motor (unipolar). A unipolar motor can also have the center taps in common creating a 5-wire motor.

An 8-wire motor is the most versatile.

5-phase motors have 5 coils (10 wires) and require a 5-phase driver.

Stepper Motor Driver Electronics

Unipolar and Bipolar

A stepper motor requires an electrical sequencer called a driver which is a specialized type of DC power supply. If the driver can reverse the polarity of its outputs, it is bipolar (4 leads). Simple, less expensive (but less effective and efficient) are drivers that cannot reverse polarity, called unipolar (6 leads). Bipolars can drive 4, 5, 6 or 8-lead motors.

To correctly connect a 5-wire to a bipolar drive, the center tap must be connected to the motor supply. To convert 6-wire to bipolar only the center tap and one leg are connected. Half of each winding is not used. 8-lead motors are connected as 6-wire in unipolar and in parallel for bipolar (more torque and efficiency). Bipolar motors use 8 transistors arrayed in 2 H-bridge arrays; unipolar motors use 4.

MICROSTEPPING

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Microstepping is a process of using the electromagnets to create “steps” that are between the natural full steps taken when only one electromagnet is on at a time. When, for example, two electromagnets are on at once, the rotor will take a position that’s dictated by the combined magnetic field strengths of both of the electromagnets.

If both coils are equally energized, the rotor rests at the resultant vector between two intersecting fields in the neutral (dead band) region. If one coil is de-energized (zero current), the rotor sweeps to a position in the center of the resulting energized field.

Alternately inserting this condition (one coil off) into the stepping sequence (half step) steps the motor a total of eight unique positions; four half and four full. By controlling the reference voltage, in a chop-per-drive, to both coil drivers with a dual D/A converter and subsequently stepping the output coil current from 100(full) to 0 (half) percent, the stepper motor microsteps between these two pole positions.

Microstep typically increases the resolutions of the stepper motor 4 to 64 times. The D/A table must match the Gaussian distributor of the step motor, a function of stepper motor quality and magnet style.

Microstepping is based simply on a sine/cosine function does not take equally spaced steps as a sine function is not a Gaussian curve. Also, microstepping does not improve the base accuracy of a stepping motor. That’s a function of the number of rotor teeth and the manufacturing quality.

You might think that a 256X microstepping driver will increase the accuracy of a stepper motor but microstepping is only accurate within limits.

Microstepping is most useful in making a stepper motor run smoother and quieter, but keeping the steps spaced evenly beyond 4X or 8X is very difficult and rarely done. So if you are looking for fine resolution in your application, your best bet is a mechanical solution (gears, belts, pulleys, etc.).

Stepper motors can be purchased that have 200, 400, or 800 steps per revolution. Combining 800 spr with 8x microstepping gives 6,400 steps per revolution (0.05625 degrees per step).

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Driver Types

L/R Driver

A stepper motor is nameplate rated to a voltage and current based on the resistance of the winding and the maximum power (torque) the case can dissipate.

The resistance and inductance produce a time constant for the charging of the coils to full torque. The voltage and the time constant determine the top speed of the stepper motor. If the step rate is faster than charge time, then the torque will diminish. If the rated voltage is applied, the step motor is said to be configured in L/R.

If dropping resistors, equal to the stepper motor resistance, are inserted in series with the coils, then the configuration is L/2R. Also twice the voltage is applied across the stepper motor. This will decrease the charge time (faster) and increase the torque at specific step rates. However, the resistors dissipate wasted energy equal to one stepper motor.

Bi-level unipolar drivers use two voltages. The higher voltage is turned on for a burst (kicker pulse) at the start of each step. The integrated bipolar driver circuit obsoleted the L/R and bi-level.

Switch Mode Stepper Motor Drivers

In switching drivers, current control circuits (sensing resistor and comparator) are inserted in series with the step motor coils and a higher than rated voltage is applied. They sense the coil and then rapidly turns the power circuit on/off continuously to regulate coil current (constant current). This technique is called chopping or switch mode. Two to fifty times the rated voltage is applied across the stepper motor. The resulting performance (speed) of the driver is the equivalent of L/2R to L/50R.

Switchers have a second preset for reduced current when the stepping motor is not rotating (parking). Without this, the motor rises to maximum temperature at standstill. Parking allows stepper motor running current (torque) to be increased (overdrive) based on the reduced duty-cycle of the system. The current of a switcher is easily adjusted by varying the reference voltage to the comparator.

A stepper driver (also commonly called an amplifier) controls the power going into the coils.

The driver receives commands from the controller, then sets the current to each coil in order to carry out the command. For example, the controller says “Take one step now” and the driver turns on coil A and turns off coil B. Or, the controller may say “Take one microstep now” and the driver sets coil A to 70% and coil B to 33%.

There are many ways that a driver may receive these commands. The simplest and most common is a “step and direction” configuration. This uses two binary (on or off) signals. The step signal tells the driver to make the motor rotate one step every time it pulses. The direction signal tells the driver which direction (clockwise or counter-clockwise). In its simplest form, a driver consists of transistors to turn the voltage to the coils on or off in turn. In this case, resistors regulate the current into the motor. This is called an L/R ("L over R") drive because the charge time of a coil is a function of the coil's inductance ("L") and the resistor value ("R"). The charge time limits how fast the motor can run, so an L/R driver is not used in high performance applications. The advantage of L/R of drives is that they are simple and inexpensive to build. Because of this, they have been popular with hobbyists. A more complex driver, called the "chopper drive". Chopper drives perform much better at high speeds. They are also more efficient because they do not use resistors to limit current, therefore they do not lose as much power as heat. In a chopper drive, transistors connect the motor coils directly to the power rails, but only for a brief moment. There is no resistor to limit current. The only significant resistance involved is the internal resistance of the motor coil. This reduces the charge time of the coil, allowing it to come up to full current much quicker and consequently creating the magnetic fields much more quickly and allowing the motor to run much faster.

Without a current-limiting resistor, a chopper drive must find another way to limit the current to the motor coil. It does this by turning the voltage to the coil on and off rapidly. To turn the voltage on and off at the appropriate times, the chopper drive must monitor the current running through the coil. This is the sequence the driver follows:

1. Switch the transistors on to connect the motor coil to the voltage line.
2. Monitor the current through the coil as it increases. The current rises quickly by our perception, but slowly enough that the driver can turn it off before it gets too high.

   When the current reaches a specific level, switch the transistors off, disconnecting power from the motor coil. Because the coil is an inductor, the current cannot instantaneously switch off without damaging something, so it is allowed to circulate through diodes while it decays.

3. Wait a specific amount of time, say 1/20,000 second.
4. Repeat steps 1 through 4 continuously. The only thing that changes is the current level the coil is regulated at. Each time the driver receives a step command, it will change this set point appropriately, but the process of switching the power on and off continues as long as the stepper system is on.

Parts of a driver

Interface to Controller

The interface provides an electrical connection between the controller and the driver. It also dictates the method that the controller will use to send command signals to the driver, including the voltage levels (3.3V, 5V, etc.) and the meaning of the signals. Classically, the voltage of a signal would be either 5V for on or 0V for off. Recently, more systems are using 3.3V, but I'll use 5V in our examples.

As mentioned before, there are many types of interfaces. Here is a brief explanation of the most common ones:

Step and Direction

This interface uses two digital (on or off) signals. The direction signal tells the driver which direction the motor will rotate on the next step. If the signal is high (5V), rotate clockwise. If the signal is low (0V), rotate counter-clockwise. The step signal is detected by the driver when it transitions from 5V to 0V. This is called a falling edge, and it tells the driver to "take one step now".

Quadrature (or Phase Drive)

A quadrature interface uses two signals called phases. The phases are named A and B. The driver expects to see a pattern between the two phases, where only one of the phases changes value at a time. There are four possible combinations, which are arranged in a table like the following. Each time one of the phases changes value, the driver steps the motor once. If the change advances down the table, the motor will rotate clockwise. If the values go up through the table in reverse, the motor will rotate counter-clockwise.

Quadrature drive has a couple of distinct advantages. First, the stepper motor itself has two phases, also called A and B. By switching the phase coils on and off (more accurately, plus and minus polarity) in the same pattern as the quadrature input, the motor will rotate one full step. The direction it rotates depends on the direction the signals are progressing through the table. This makes it easy to set up an L/R drive, where the interface signals are connected, with very few intermediate parts, to the transistors that turn the power on and off to the coils.

Another advantage of the quadrature interface is that it is the type of interface encoders use for their outputs. This means that you can control a quadrature driver directly with an encoder. This is useful if you want to control something manually, but remotely with a stepper motor. You can give the user an encoder to turn by hand and the stepper motor will mimic his movements at a remote location. You can also "cam" or "slave" motors together with an encoder mounted to the master motor.

Serial Interfaces

Some drivers have a little bit more intelligence built into them. These drivers can accept textual or coded commands over a serial communication interface. The most common standards for these types of interfaces are I2C and SPI. We will not expand on the electrical properties of serial interfaces here.

Drivers with serial interfaces can often accept configuration commands, which program the driver with valuable information about the motor it is driving, such as how much current it can handle and what its electrical properties are, and what the microstep angle should be. Sometimes they can also accept motion commands that are more complex than "take one step", such as "take 6000 steps clockwise with X acceleration and Y maximum speed". This begins to blur the distinction between a driver and a controller, since these drivers must have small controllers on them to perform these functions.

Translators

The phase polarity signals (step sequence) between driver and coils is based on the step function which can take the form of logic gates or memory (step table). If this logic is configured to increment from a single pulse (clock), the circuit is called a translated driver or step / direction driver. The direction input controls the direction of sequencing. A translated driver is easily connected to a source of clock pulses (pulse generator) called an indexer or controller.

Current Control

There is one current control for each motor phase. The current control does the following jobs:

- Convert the coded information from the translator into a reference voltage used to regulate motor current.
- Read the actual motor current via the feedback loop and compares the value with the reference voltage.
- Turn the transistors connecting the motor coils to power on or off as needed to regulate the current.

Traditional chopper drives have a preset lag time between switching a coil off and switching it back on. This lag time is set by a timer within the current control circuitry.

Feedback Loop

The current control relies on a feedback loop to read the actual current that is flowing through a motor coil. This is most simply done using a resistor with very low resistance, usually a fraction of an ohm, placed in series with the motor coil. The voltage across the resistor is directly proportional to the current through the coil, and is compared with the reference voltage by the current control.

Power Stage

The power stage consists of the transistors used to switch power to the motor coils on and off, as well as select the polarity of the power to the coils. While most of the circuitry in the driver runs at low voltage such as 5V, the power stage connects to the higher motor supply voltage, which is typically 12V to 80V depending on the driver and motor. Higher voltage charges the motor coils faster, which allows the motors to run faster.

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Basic Control

The word "controller", in this context, implies something that tells the driver when to send a pulse (a "take a step" command).

You'll hear about "intelligent" controllers and the difference, in whether or not a controller is "intelligent", is whether or not the controller ever makes motors move on its own.

TMG has a variety of intelligent controller systems starting with a simple native language (CY-5xx) single axis controller all the way up to our multiple axis, high level language system.

We also have systems tailored for CNC.

Our integrated systems are plug and play. You plug them in and they're ready to go.

Intelligent Motion Control

Intelligent controllers are logic or processor circuits (programmable motion) which accept command or switch inputs. The specific distance of rotation (number of steps), the speed at which the pulses are issued (rate), and a function of speed increments (slope) is preset or input to the controller.

The slope function (ramping) allows the stepper motor to accelerate to a speed greater than the instantaneous stop/start speed. In this case, a starting speed (first rate) and a top speed (slew rate) is input. The controller accelerates the stepper motor through the motion and decelerates to a stop after the present number of steps (target).

When using open loop operation (no feedback loop) the stepping motor initially steps backwards until a reference position (home) is detected and the position counter in the controller is set to zero.

The step motor is then moved to positions by incriminating or decrementing the position counter (absolute motion) or repeatedly cycling the counter a fixed amount (incremental).

In open loop control the load needs to be within the motor's speed and torque range. A positioning system, when successfully returned to the home sensor under command (slip detection), operates with plus or minus zero steps (no error).

Automated Systems

Systems that run without operator intervention are automated systems. You see them all the time. Vending machines, ATMs, Ticket Machines (like for mass transit), and toll booths are commonly automated.

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EMBEDDED SYSTEMS

You may hear this term but what constitutes an embedded system is fuzzy. What the phrase refers to is a system that does not have any direct user access. An embedded system performs a function within a larger system. Frequently, an embedded system has significant constraints. It may, for example, need to perform its function within a specific time.

It's pretty common to find motion control system that is either partially, or wholly embedded within some other equipment.

You, no doubt, are familiar with vending machines. These are machines with embedded motion control systems. Put in the right coins and motors spin and you get what you want out of the machine.

OTHER ISSUES

About Feedback

You'll see, over and over again, that we say that step motors don't require position feedback. That doesn't mean that they don't need any feedback.

A stepper motor, just because of the way it works, hits positions repeatedly and reliably without a **position** feedback loop.

There are, however, other types of feedback that you may want.

The most common is a home position sensor of some kind. A motion control system really doesn't know where it is when it just powers on, until it finds a home position.

The second most common feedbacks are "limit" switches. These are, generally, safety issues. A limit switch will halt motion, if that motion goes too far.

There are a lot of other kinds of feedback.

You might want a series of buttons that kick off individual programs so you can check on things between steps in a process.

You might want to have several programs in an intelligent system and use some sort of feedback to control which routine is run.

About "Closed Loop"

You'll hear the term "closed loop" a lot. Many motors need position feedback because they really can't tell how far they've moved.

Adding a sensor that measures movement and feeds that information back into the system is called a "closing the loop".

Mostly, stepper motor systems don't need this.

Special Motion Problems

Liquids

Moving things full of liquids (all sorts) can be tricky. They tend to splash and slosh and they fight changes in speed.

Motion control systems that deal with liquids frequently need to have excellent control over how they change speed. They ramp up to a speed and ramp down in specific ways (depending on the viscosity of the liquid).

Fine Positioning

There's no practical limit to how fine you can position things using a stepper motor motion control system. Many stepper motors have fine positioning built in. If that's not enough, your system may require a belt or reduction gearing. Stepper motion systems are really ideal for most fine position control systems.

Disk drives, DVDs, and medical devices are common applications for fine position control using stepper motors.

Speed

Stepper motors are fast. If you have an application that requires movement at high speed, a stepper motor may be just what you're looking for.

Torque (power)

Stepper motors can be very powerful. It's all a matter of how big of a motor you want to use. Many stepper motors use rare earth magnets (powerful yet small) to help keep the power up and the size down.

The problem with using a lot of electrical power is that it creates side effects that have to be managed.

Powerful electromagnets, for example, require lots of current ... lots of current tends to generate lots of heat.

You may be able to trade speed for power. It all depends on the application.

Choosing a Stepper Motor

Even though stepper motors are very capable, choosing the right stepper motor can be complicated. If you're new to stepper technology you might, for example, assume that more torque (turning force) is better. In many cases, too much torque can cause problems.

Here are some things to consider when picking a stepper motor.

Speed

The speed required for your application is one of the most important factors. All stepper motors have a harmonic vibration at a specific frequency. That frequency is determined by their construction. At certain speeds, the motors will resonate. That resonance can be severe enough to stall the motor, even if it's not under any load. Motors should be selected with resonance frequencies that aren't in the operating speed of your application.

Torque also tends to fall off with speed. The faster you go, the weaker it gets. This is more pronounced in "high-torque" motors. Often, a motor with lower advertised holding torque (torque at stand-still under full power) will have more torque at higher speeds.

Rotary Loads

Driving a load with large rotary inertia (such as a heavy turntable) can be tricky. Stepper motors move in a start-stop pattern. Even when they appear to rotate smoothly, they're starting and stopping.

The inertia of the load will resist the motor's start-stop nature, which can cause strange problems. Sometimes, the motor will run at twice the intended speed, run backward, or stall.

In cases like these, we recommend using worm gears or timing belts. However, since this is not always possible or cost effective, going up to a larger motor (frame size) say from NEMA 23 to NEMA 34, will often solve the problem, even if torque is not increased.

Larger motors have larger internal rotors and are physically constructed to handle more inertia.

Step Spacing

You might think that a 256X microstepping driver will increase the accuracy of a stepper motor but microstepping is only accurate within some limits.

Microstepping is most useful in making a stepper motor run smoother and quieter, but keeping the steps spaced evenly beyond 4X or 8X is very difficult and rarely done. So if you are looking for fine resolution in your application, your best bet is a mechanical solution (gears, belts, pulleys, etc.).

Stepper motors can be purchased that have 200, 400, or 800 steps per revolution. Combining 800 spr with 8x microstepping gives 6,400 steps per revolution (0.05625 degrees per step).

Existing Electronics

If you're replacing a motor in an existing system, you need to make sure the motor matches the electrical specifications and ratings as closely as possible.

When drivers and motors aren't matched, it can cause problems ranging from poor performance to physical damage.

For best results, select a motor with a current rating as close as possible to, but just over the current delivered by the driver.

The type of driver must also be considered. Unipolar drivers require a 6- or 8-wire motor. Bipolar drivers can drive 4-, 6-, or 8-wire motors. An L/R driver requires a motor with higher resistance, typically 20 to 50 ohms. A chopper or PWM (pulse width modulated) driver performs best with low-resistance motors, typically 5 ohms or less.

Other Factors Impacting Selection

- The mechanical components of your application
- Availability
- Price
- Environmental factors, such as temperature, moisture, pressure, etc.

It's very important to speak with an Application Engineer when selecting motors. We can help you select the best motor and advise you on the best way to use it in your application. We can even customize motors for your specific needs.