MAKER & ENGINEERING GUIDE

# Mecanum Wheels Explained.

> The complete guide to how omnidirectional wheels work, the math behind them, and how to build with them — for beginners and engineers alike.

| READING LEVEL | TOPICS COVERED | FORMAT |
|---|---|---|
| **Beginner → Advanced** | **Physics, Math, Build Guide** | **Illustrated Reference** |

@buildwithkalp

# Index

SECTION 01

# What Is a Mecanum Wheel?

A **mecanum wheel** is a normal wheel with a twist: instead of a smooth rubber tread, its outer edge is covered in a row of small angled rollers. Each roller can spin freely on its own axle, and every roller is mounted at exactly **45 degrees** to the main wheel's axle.

That one small change turns an ordinary wheel into something completely different. A robot built on four mecanum wheels doesn't just drive forward and turn like a car — it can slide sideways, glide diagonally, spin in place, or move in any direction at all **without ever turning the wheels themselves**. The wheels always point the same way. Only the combination of speeds and spin directions changes.

> **IN ONE SENTENCE**
>
> A mecanum wheel converts the wheel's forward spin into a sideways-pushing force, using free-spinning angled rollers instead of a single grippy tread.

## Why This Matters

Regular wheels are great at one thing: rolling forward and backward. To move sideways, a car-like robot has to stop, turn its wheels, and reposition — the classic three-point turn. Mecanum wheels remove that limitation entirely. This is why they're called **omnidirectional** — "omni" meaning "all," as in all directions.

| 4 | 45° | 1973 | 3 |
|---|---|---|---|
| WHEELS TYPICALLY USED PER ROBOT | ROLLER MOUNTING ANGLE | YEAR OF INVENTION | DEGREES OF FREEDOM (X, Y, ROTATION) |

## A Little History

The mecanum wheel was invented in **1973** by Bengt Ilon, an engineer at the Swedish company Mecanum AB — which is where the name comes from. It was originally designed to help forklifts and material-handling equipment move in tight warehouse spaces where turning radius was a real problem. Today the same idea shows up in robotics competitions, wheelchairs, warehouse robots, and countless maker projects — including the kind you've probably just seen in a reel.

> **QUICK NOTE**
>
> You'll sometimes see these called "Ilon wheels" after their inventor, though "mecanum wheel" is the name that stuck worldwide.

SECTION 02

# Anatomy of the Wheel

Before diving into the physics, it helps to know the parts. A mecanum wheel looks complex, but it's really just three simple components working together.

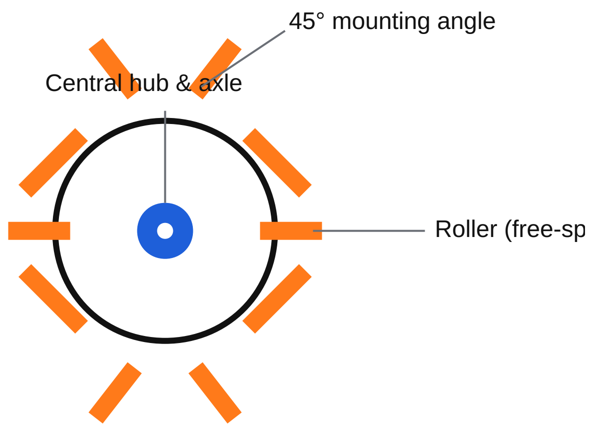



Figure 2.1 — **Exploded view of a mecanum wheel:** a central hub carries a ring of free-spinning rollers, each angled 45° to the hub's own axis.

### 1. The Hub

This is the main body of the wheel. It bolts onto the motor shaft just like a normal wheel and is what actually receives the driving torque from the motor.

### 2. The Rollers

A set of small barrel-shaped or tapered wheels (usually 9–15 of them) sit around the hub's rim. Each one spins completely freely on its own tiny axle.

### 3. The 45° Offset

Each roller's spin axis is tilted 45° relative to the hub's axle — never parallel, never perpendicular. This offset is the entire secret of the design.

### 4. Contact Point

At any moment, only one roller touches the ground. As the wheel turns, the next roller rotates into contact, keeping motion smooth.

> **BEGINNER TIP**
>
> Try spinning a mecanum wheel by hand while holding the axle still. You'll feel the rollers rotate independently — that free rotation is what allows force to "leak out" sideways instead of just rolling forward.

SECTION 03

# The Core Trick: Force Vectors

This is the single most important idea in this entire guide. Everything else — the math, the layouts, the movement charts — is just a consequence of this one piece of physics.

## Splitting a Force Into Two Directions

When a motor spins a mecanum wheel, it pushes the roller that's currently touching the ground forward, exactly like a normal wheel. But because that roller is mounted at 45°, the ground pushes back on it at 45° too — not straight backward.

Any force at an angle can be split into two components: one along the roller's own rolling direction, and one perpendicular to it. Since the roller is **free to spin**, the component along its rolling direction is "absorbed" — the roller just spins and cancels it out. But the perpendicular component has nowhere to go. It pushes straight into the robot's frame as a net sideways force.

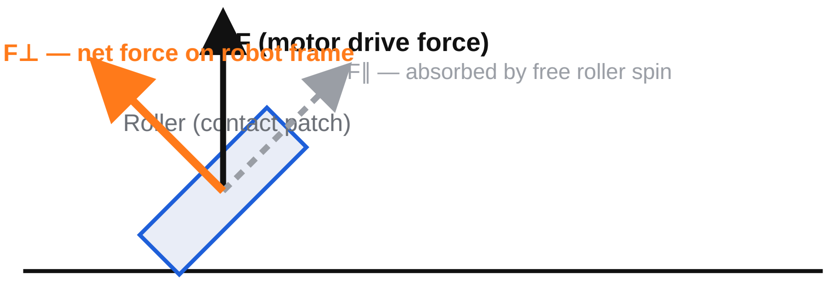



Figure 3.1 — **The wheel's drive force F splits into two parts** at the 45° roller contact. The parallel part spins the roller uselessly; the perpendicular part actually pushes the robot's frame.

**THE KEY INSIGHT**

A single mecanum wheel spinning on its own just rolls diagonally — part forward, part sideways. It's only when **four** wheels combine their diagonal pushes in different directions that the sideways parts add up and the forward parts can cancel (or vice versa).

## Why One Wheel Alone Isn't Useful

A single mecanum wheel by itself will just roll off at a diagonal — not particularly useful. The real power comes from combining four of them, each contributing its own diagonal push, so that the unwanted components from each wheel cancel each other out while the wanted components stack up. That's the subject of the next two sections.

SECTION 04

# Why Exactly 45 Degrees?

It's a fair question — why not 30°, or 60°? The answer comes down to symmetry between the robot's two directions of travel: forward/backward and left/right strafing.

## The Geometry, Simply

At 45°, the roller's rolling direction and its "blocked" direction are perfectly balanced — each contributes equally to forward motion and sideways motion. This means a mecanum-drive robot can move sideways **just as fast** as it can move forward, using the exact same motor speeds, just recombined differently.

If the angle were smaller (say 20°), the wheel would be very good at rolling forward but weak at generating sideways force — strafing would be sluggish. If the angle were larger (say 70°), the opposite happens: strong sideways force, weak forward drive. 45° is the exact midpoint that gives the robot balanced performance in every direction.

> **THE MATH IN ONE LINE**
>
> At angle θ, the sideways-force fraction is sin(θ) and the forward-force fraction is cos(θ). These two are equal only when θ = 45°, since sin(45°) = cos(45°) ≈ 0.707.

## What Happens At Other Angles?

| ROLLER ANGLE | FORWARD ABILITY | SIDEWAYS ABILITY | RESULT |
|---|---|---|---|
| 20° | Strong | Weak | Feels like a normal wheel, barely strafes |
| **45°** | **Balanced** | **Balanced** | **Equal performance in all directions** |
| 70° | Weak | Strong | Strafes well, poor forward drive |
| 90° | None | Maximum | Becomes a simple free-rolling caster wheel |

This is also why real-world mecanum wheels are remarkably consistent across manufacturers — nearly every commercial and hobbyist wheel uses the 45° standard, because any other angle simply trades away balance for no real benefit in a typical robot.

> **FUN FACT**
>
> Because sin(45°) = cos(45°), a mecanum-drive robot's theoretical top strafing speed equals its top forward speed. In practice, friction and roller losses make sideways motion slightly slower.

SECTION 05

# Omnidirectional Movement

Engineers describe a mecanum-driven robot as **holonomic**. It's a precise technical word worth understanding, because it explains exactly what makes this drive system special.

## What "Holonomic" Actually Means

A robot has three degrees of freedom on a flat floor: it can move along the X axis, move along the Y axis, and rotate. A regular car-like robot can control all three — but not independently. To move sideways, it must first rotate. Its *controllable* freedom at any instant is less than its total freedom. That's a **non-holonomic** system.

A mecanum-drive robot can control all three degrees of freedom **at the same time, independently**. It can move sideways while also rotating, while also moving forward — all in one continuous motion. That full independence is what "holonomic" means.

**NON-HOLONOMIC (E.G. A CAR)**

Must reposition to change direction. Parallel parking exists because of this limitation. Fewer wheels can be actively steered at once.

**HOLONOMIC (MECANUM DRIVE)**

Can translate and rotate simultaneously. No repositioning needed. Can "crab-walk" directly into a parking spot sideways.

## Three Independent Controls

- **Vx** — forward / backward velocity
- **Vy** — left / right (strafe) velocity
- **ω (omega)** — rotational velocity around the robot's own center

Every possible motion of the robot is just some combination of these three numbers. Section 08 shows exactly how they translate into four individual wheel speeds.

**REAL-WORLD PAYOFF**

Holonomic motion is why mecanum-wheeled forklifts can slide directly sideways into a narrow aisle, and why competition robots can shoot a ball while simultaneously driving toward the opposing goal.

SECTION 06

# The Roller Orientation Pattern

Four mecanum wheels don't all point the same way. To make forces cancel and combine correctly, the rollers must form an **"X" pattern** when viewed from above — and getting this wrong is the single most common mistake beginners make.

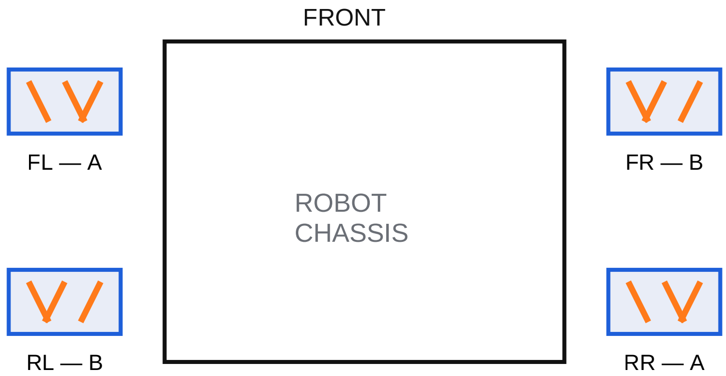



Figure 6.1 — **Top-down "X" roller pattern.** Front-left and rear-right wheels share one roller type (A); front-right and rear-left share the other (B) — diagonal pairs match.

## The Rule of Thumb

Look down at the robot from above. The rollers on all four wheels should visually form a rough **"X"** or an **"O"** shape across the chassis — never a plain box shape where all rollers tilt the same way. Diagonally opposite wheels (front-left & rear-right, front-right & rear-left) always use matching roller-type wheels; adjacent wheels use the opposite type.

> **THE #1 BEGINNER MISTAKE**
>
> Mounting all four wheels identically (same type on every corner). The robot will still drive forward and backward fine — but strafing will do nothing, or worse, make the robot spin uncontrollably. If your robot won't strafe, check this first.

## How To Tell Left-Handed From Right-Handed Wheels

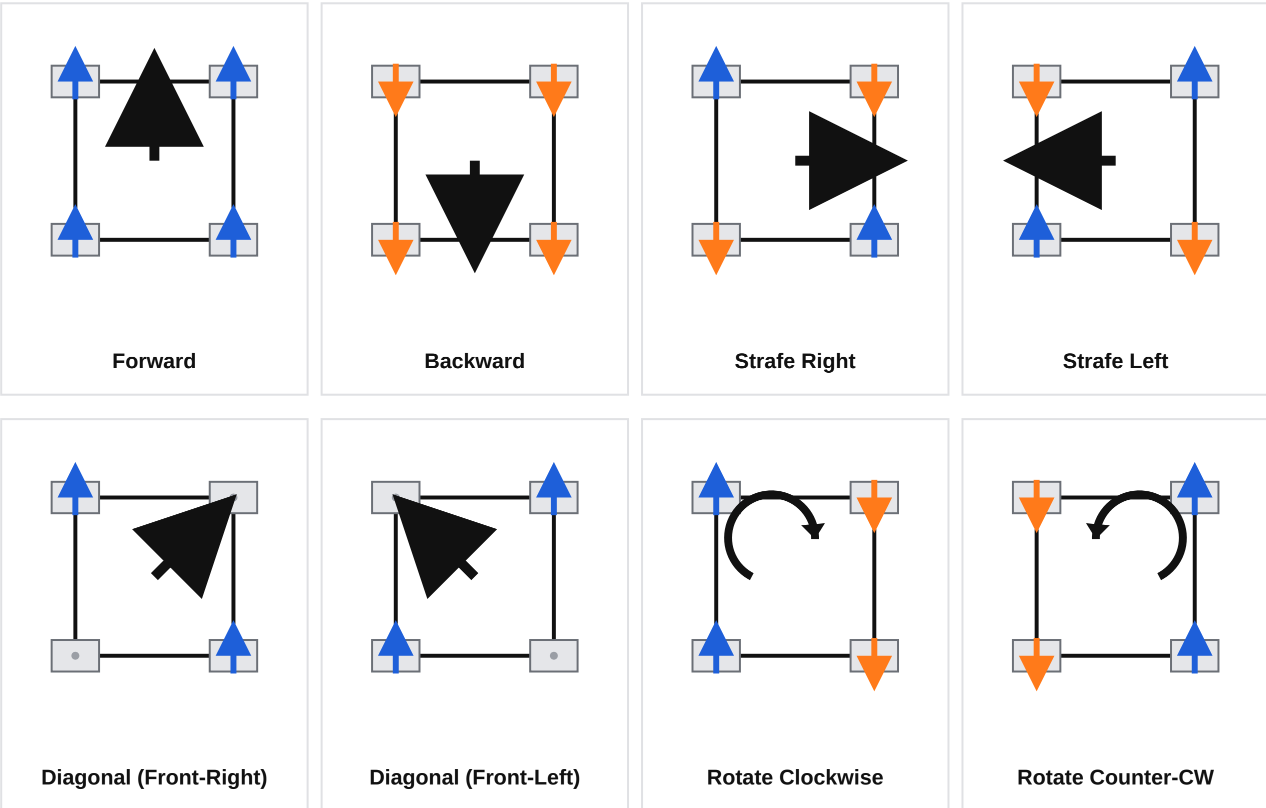
Mecanum wheels are sold in mirrored pairs, often labelled **A / B** or **Left / Right** by the manufacturer. Run your finger along a roller from the outside edge toward the hub — on a "Type A" wheel the roller line tilts one way, and on "Type B" it tilts the other. Always check the manufacturer's diagram before mounting; the labels are not standardized across all brands.

SECTION 07

# Every Direction of Motion

Here is the complete picture: every basic motion a mecanum-drive robot can perform, and exactly what each of the four wheels is doing to make it happen. **F** = wheel spins forward, **R** = wheel spins reverse, and a grey dot = wheel stays still.

Forward spin  Reverse spin  Stopped




**READING THE DIAGRAMS**

Each small square is one wheel, viewed from above. The arrow inside it shows that wheel's own spin direction. The bold black arrow (or curved arrow) in the middle shows the direction the **whole robot** actually travels as a result.

## The Pattern Behind The Chart

Notice that strafing sideways uses all four wheels — just with diagonal pairs reversed relative to each other. Pure diagonal motion only needs **two** wheels active, with the other two idle. And rotation in place uses all four wheels, with each side spinning opposite to the other. Every other direction — any angle at all — is simply a blend of these basic patterns, achieved by scaling each wheel's speed proportionally. That blending is exactly what the kinematic equations in Section 08 calculate automatically.

SECTION 08

# The Kinematics

This section turns everything so far into usable equations. If you're a maker who just wants working code, you can skip to the boxed formula and the worked example in Section 09. If you're an engineer who wants the reasoning, read on.

## Setting Up the Problem

Every motion of the robot is described by three numbers: **Vx** (forward speed), **Vy** (sideways/strafe speed), and **ω** (rotation rate). The goal of the kinematics is to convert these three numbers into four individual wheel speeds — one for each motor.

Because of the 45° roller geometry from Section 04, each wheel's contribution to sideways motion depends on both Vx and Vy combined, plus a rotational term that depends on the robot's physical dimensions: half the wheelbase length **L** (front-to-back distance from center) and half the track width **W** (side-to-side distance from center).

STANDARD INVERSE KINEMATICS EQUATIONS

For a robot with the standard "X" roller layout from Section 06:

```
Front-Left  = Vx − Vy − ω(L+W)
Front-Right = Vx + Vy + ω(L+W)
Rear-Left   = Vx + Vy − ω(L+W)
Rear-Right  = Vx − Vy + ω(L+W)
```

## Reading the Equation Intuitively

- **Vx term** — same sign on all wheels; it's what makes every wheel spin the same way for pure forward motion.
- **Vy term** — alternates sign in the "X" pattern; this is what generates the sideways push that cancels on the forward axis and adds on the sideways axis.
- **ω term** — one side gets added, the other subtracted, so the left and right wheels spin in opposite directions, spinning the robot on the spot.

Each of the eight small diagrams in Section 07 is simply this formula evaluated at specific values of Vx, Vy, and ω (for example, pure strafing is Vx=0, ω=0, and only Vy non-zero).

## Forward Kinematics (Odometry)

The reverse direction — figuring out how the robot is actually moving based on the four wheel encoder readings — is just the same relationship solved backward. This is what lets a robot track its own position on the floor, a technique called **odometry**, useful for navigation and autonomous driving.

**UNITS MATTER**

Keep Vx, Vy, and $\omega$ in consistent units (e.g. all in meters/second and radians/second) and L, W in the same length unit before you scale the result to actual motor PWM or RPM values.

SECTION 09

# Worked Example

Let's plug in real numbers so the formula stops being abstract. Say you want your robot to drive **diagonally forward-right** while also **rotating slowly clockwise** — a combined motion that would be very hard to describe with a normal drivetrain.

> **GIVEN**
> $V_x = 0.5$ | $V_y = 0.5$ | $\omega = 0.2$ | $(L + W) = 1.0$

**1 Front-Left wheel speed**

$Vx - Vy - \omega(L+W) = 0.5 - 0.5 - 0.2(1.0) =$

**−0.2**

→ spins slowly in reverse

**2 Front-Right wheel speed**

$Vx + Vy + \omega(L+W) = 0.5 + 0.5 + 0.2(1.0) =$

**1.2**

→ spins fastest, forward

**3 Rear-Left wheel speed**

$Vx + Vy - \omega(L+W) = 0.5 + 0.5 - 0.2(1.0) =$

**0.8**

→ spins forward, moderate

**4 Rear-Right wheel speed**

$Vx - Vy + \omega(L+W) = 0.5 - 0.5 + 0.2(1.0) =$

**0.2**

→ spins slowly, forward

| WHEEL | FORMULA RESULT | DIRECTION | RELATIVE SPEED |
|---|---|---|---|
| Front-Left | −0.2 | Reverse | Slow |
| Front-Right | 1.2 | Forward | **Fastest** |
| Rear-Left | 0.8 | Forward | Moderate-fast |
| Rear-Right | 0.2 | Forward | Slow |

Notice none of these four numbers match each other — which is exactly the point. That's what allows one motion command to smoothly produce a diagonal-plus-rotating path, using ordinary motors that only know "spin faster" or "spin slower," "forward" or "reverse."

**IN CODE**

In a real robot, Vx, Vy, and ω usually come from a joystick, and this calculation runs continuously — often 50-100 times per second — inside the motor control loop, feeding each result straight into a motor speed controller.

SECTION 10

# Types & Roller Designs

Not all mecanum wheels are built the same way. Roller shape, count, and material all affect how smoothly the robot rides and how much sideways force it can actually generate.

## Barrel Rollers vs. Tapered Rollers

**BARREL (CYLINDRICAL) ROLLERS**

Simple, cheap, common on hobby-grade wheels. Contact patch changes slightly as the roller turns, which can create a light "bump" at low speed. Great for learning and most maker projects.

**TAPERED (HOURGLASS) ROLLERS**

Curved profile designed so the effective wheel radius stays nearly constant through the whole rotation. Smoother ride, used in higher-end and industrial wheels, more expensive to manufacture.

## Roller Count

Wheels typically have **9 to 15 rollers**. More rollers mean smaller individual rollers, smoother transitions between them, and a more continuous ride — but also more moving parts that can wear out or collect debris. Fewer, larger rollers are more robust for rough outdoor terrain but feel "bumpier" on hard floors.

| ROLLER COUNT | RIDE SMOOTHNESS | DURABILITY | BEST FOR |
|---|---|---|---|
| Low (6–9) | Bumpier | **Higher** | Outdoor, rough terrain, load-bearing |
| Medium (9–12) | Balanced | Balanced | General robotics, hobby projects |
| High (13–15+) | **Smoothest** | Lower | Indoor, precision, flat floors |

## Materials

- **Polyurethane rollers** — the most common choice; good grip, reasonably quiet, decent wear resistance.
- **Rubber rollers** — softer, better grip on smooth floors, but wear faster under heavy load.
- **Nylon / hard plastic rollers** — very durable and cheap, but noisier and less grippy, common on budget hobby kits.
- **Aluminum hub with plastic rollers** — the standard for most mid-range and competition-grade wheels, balancing strength and weight.

**SIZING TIP FOR MAKERS**

Common hobbyist sizes are 60mm, 80mm, and 100mm diameter. Bigger wheels roll over small obstacles and carpet more easily but demand more motor torque — check your motor's torque rating before committing to a larger wheel.

SECTION 11

# Advantages & Limitations

Mecanum wheels are impressive, but they are not automatically the "best" choice for every robot. Here's an honest, balanced look.

## Advantages

- **True holonomic motion** — move in any direction and rotate simultaneously, no repositioning needed.
- **Compact footprint** — no steering mechanism needed, unlike swerve drive, which saves space and complexity.
- **Mechanically simple** — just four motors, no servos or steering linkages to maintain.
- **Excellent in tight spaces** — ideal for warehouses, narrow aisles, and cluttered indoor environments.

## Limitations

- **Needs a hard, flat, low-friction floor** — performs poorly on carpet, gravel, grass, or uneven outdoor terrain.
- **Lower energy efficiency** — the rollers constantly scrub sideways against the floor, wasting energy as friction and heat compared to plain wheels.
- **Reduced traction and payload capacity** — smaller contact patch per roller means less grip and a lower practical load limit than standard wheels of the same size.
- **More points of wear** — every roller is a small bearing that can wear out, collect dust, or jam over time.
- **Higher cost** — precision-machined rollers cost noticeably more than a simple rubber tire.

> **THE HONEST TRADE-OFF**
>
> You're trading traction, efficiency, and durability for maneuverability and omnidirectional freedom. Choose mecanum wheels when tight-space agility matters more than raw efficiency or rough-terrain capability.

SECTION 12

# Mecanum vs. Omni vs. Swerve

Mecanum wheels are one of three common ways to achieve omnidirectional or highly maneuverable motion in robotics. Each has real trade-offs.

| SYSTEM | HOW IT STEERS | COMPLEXITY | EFFICIENCY | TYPICAL USE |
|---|---|---|---|---|
| **Mecanum Drive** | Angled roller geometry, no moving steering parts | **Low** | **Lower** | Warehousing, indoor robots, maker projects |
| **Omni Wheel Drive** | Perpendicular free rollers (90°), usually 3-wheel triangle layout | **Low** | Medium | Small robots, competition bots, light loads |
| **Swerve Drive** | Each wheel individually steered by its own servo/motor | **High** | **Higher** | Competitive robotics, heavy-load precision platforms |

## Mecanum vs. Standard Omni Wheels

Omni wheels use rollers mounted at 90° instead of 45°, and are usually arranged three-per-robot in a triangular layout rather than four in a square. They're mechanically similar cousins of mecanum wheels, but the 90° geometry and triangular arrangement give a different balance of forces — often simpler to build, but slightly less common in four-wheeled rectangular chassis designs.

## Mecanum vs. Swerve Drive

Swerve drive achieves omnidirectional motion completely differently: instead of clever wheel geometry, each wheel physically rotates on its own turret to point in any direction, driven by a second motor per wheel. This gives excellent efficiency and traction — full grip is always available since the wheels are normal tires — but doubles the motor count and adds real mechanical and software complexity.

> **CHOOSING BETWEEN THEM**
>
> Pick **mecanum** for simplicity and tight-space maneuvering on flat floors. Pick **swerve** when traction, efficiency, and rough terrain matter more than mechanical simplicity. Pick **omni wheels** for lightweight, low-cost, small-scale robots.

SECTION 13

# Real-World Applications

Mecanum wheels show up in far more places than robotics demos — many of them industrial and highly practical.

### Warehouse & Logistics

Automated guided vehicles (AGVs) use mecanum drive to slide sideways into narrow shelving aisles and reposition pallets without needing a turning radius — a major space saver in dense warehouses.

### Forklifts

The original 1970s application. Mecanum-equipped forklifts can approach a pallet from an angle and then slide directly sideways to align — no repeated back-and-forth maneuvering.

### Robotics Competitions

FIRST Robotics, VEX, and similar competitions widely use mecanum drivetrains because they let a robot drive and reposition freely while another mechanism (like an arm or shooter) operates independently.

### Assistive Wheelchairs

Some advanced power wheelchairs use mecanum wheels so users can move sideways in tight indoor spaces — hallways, elevators, and cluttered rooms — where turning is difficult or impossible.

### Maker & Hobby Robots

A favorite among hobbyists precisely because of what you may have shown in your reel — the sideways "crab walk" motion is visually striking and relatively simple to build with off-the-shelf wheel kits.

### Mobile Platforms in Manufacturing

Factory floor robots use mecanum drive to navigate cluttered production lines, docking precisely with machines and workstations from any approach angle.

> **WHY MAKERS LOVE THEM**
>
> Beyond function, mecanum wheels are simply satisfying to watch — a robot gliding sideways looks almost magical to anyone who hasn't seen the mechanism up close. That's exactly the kind of "how does that work?" moment that makes for a great reel.

SECTION 14

# Building Your Own

Ready to build a mecanum-drive robot? Here's a practical checklist covering the decisions that actually matter.

## Design Checklist

- **Buy wheels in a matched set of four** — two Type-A and two Type-B, confirmed against the manufacturer's mounting diagram, never mixed randomly.
- **Use four independently controlled motors** — one per wheel is non-negotiable; you cannot share a motor across two mecanum wheels and still get holonomic motion.
- **Pick motors with encoders** if you want reliable, repeatable movement — open-loop speed control makes precise strafing much harder to tune.
- **Keep the chassis rigid and square** — the kinematics in Section 08 assume a fixed geometric relationship between wheels; a flexing frame throws off every calculation.
- **Choose a motor driver that supports all four motors independently** — a dual H-bridge driver typically handles two motors, so most builds need two driver boards or one four-channel driver.
- **Test on a hard, flat surface first** — carpet will make strafing look broken even with a correctly built robot; always validate on tile or a smooth floor before troubleshooting further.

## A Simple Motor Mixing Algorithm

PSEUDOCODE

```
FL = clamp(Vx − Vy − ω, −1, 1)
FR = clamp(Vx + Vy + ω, −1, 1)
RL = clamp(Vx + Vy − ω, −1, 1)
RR = clamp(Vx − Vy + ω, −1, 1)
```

Feed Vx, Vy, and ω from a joystick's X, Y, and twist axes (each normalized between −1 and 1), run this every control loop cycle, and send each result to its motor's speed controller. Clamping keeps values within the motor driver's valid range when combined inputs would otherwise exceed it.

## Recommended First Build

1. **Start with a kit**
   — a pre-made aluminum or acrylic chassis with matched 4-wheel mecanum sets removes a huge source of alignment error for a first build.
2. **Use a microcontroller with PWM outputs**
   — an Arduino or ESP32 with a 4-channel motor driver is a common, well-documented starting point.

3 **Test each wheel individually first**
— confirm every motor spins the correct direction before combining them, using the direction table in Section 07 as a reference.

4 **Add the mixing algorithm last**
— once individual wheels behave correctly, layer in the Vx/Vy/ω formula to unlock full omnidirectional control.

SECTION 15

# Common Mistakes & Troubleshooting

Most mecanum-drive problems trace back to one of a handful of root causes. Here's how to diagnose them quickly.

| SYMPTOM | LIKELY CAUSE | FIX |
|---|---|---|
| Robot spins instead of strafing | Wheels mounted in wrong orientation (not the "X" pattern) | Re-check each wheel against Figure 6.1 and manufacturer's A/B labeling |
| Strafes, but drifts diagonally | One motor's speed doesn't match the others | Calibrate motor speed scaling per wheel; check for uneven battery voltage sag |
| Very weak sideways force | High-friction floor surface (carpet, rubber matting) | Test on a hard, smooth floor; mecanum wheels need low lateral friction to work |
| Jerky or bumpy ride | Low roller count or worn/ damaged rollers | Check for cracked, flat-spotted, or seized rollers; consider a higher roller-count wheel |
| Robot pulls to one side driving straight | Uneven wheel wear or misaligned chassis | Verify chassis squareness and confirm all four wheels are the same size/diameter |
| Rollers feel stiff or don't spin freely | Debris jammed in roller bearings | Clean roller axles; add a drop of light lubricant if the design allows it |

**FIRST THING TO CHECK, ALWAYS**

If strafing doesn't work at all, 90% of the time it's the roller orientation. Go back to Section 06 before checking anything else.

## A Simple Diagnostic Routine

1. Lift the robot off the ground so wheels spin freely.
2. Command pure forward motion — all four wheels should spin the same direction at the same speed.
3. Command pure strafe right — check each wheel's direction against the "Strafe Right" diagram in Section 07.
4. If any wheel doesn't match the diagram, that wheel is either wired backward or physically mounted with the wrong roller orientation.

SECTION 16

# Glossary of Terms

### Holonomic

A drive system that can control all of its degrees of freedom (forward/back, left/right, rotation) independently and simultaneously.

### Roller

A small free-spinning wheel mounted around the rim of a mecanum wheel's hub, angled at 45° to the hub's own axle.

### Hub

The central body of a mecanum wheel that mounts to the motor shaft and carries the ring of rollers.

### Strafe

Sideways motion — moving left or right while facing the same direction the whole time.

### Vx, Vy, ω (omega)

The three control inputs of a holonomic robot: forward/back speed, left/right speed, and rotational speed, respectively.

### Inverse Kinematics

The math that converts a desired robot motion (Vx, Vy, ω) into the four individual wheel speeds needed to produce it.

### Odometry

Estimating a robot's position and movement over time using wheel encoder data — the reverse of inverse kinematics.

### Omni Wheel

A close cousin of the mecanum wheel using rollers at 90° instead of 45°, typically arranged in a 3-wheel triangular layout.

### Swerve Drive

An alternative omnidirectional drive system where each wheel is independently steered by its own motor, rather than relying on angled rollers.

### Type A / Type B Wheel

The two mirror-image variants of a mecanum wheel, distinguished by which way their rollers tilt; a matched robot needs two of each.

### Contact Patch

The small area where a single roller touches the ground at any given moment — the point where all driving force is actually transferred to the floor.

### Wheelbase / Track Width

The front-to-back distance (wheelbase) and side-to-side distance (track width) between wheel centers — both used directly in the kinematic equations.

SECTION 17

# Further Learning

This guide covers the full picture from first principles to a working build — but there's always more to explore as you go deeper.

## Next Steps By Level

**BEGINNER / MAKER**

Buy a small mecanum wheel kit, wire it to a basic microcontroller, and get pure forward/backward/strafe working before attempting combined motion.

**INTERMEDIATE**

Implement the full inverse-kinematics mixing algorithm from Section 14 and add joystick control for smooth, real-time holonomic driving.

**ADVANCED / ENGINEER**

Add wheel encoders and build an odometry system to track the robot's exact position, then explore closed-loop path following.

**EXPERT**

Study slip compensation, traction control across uneven floors, and compare real-world performance against swerve drive for your specific payload and terrain.

## Topics Worth Exploring Next

- PID control loops for smoother, more accurate motor speed control
- Field-oriented vs. robot-oriented driving (does "forward" mean the robot's front, or a fixed compass direction?)
- Slip and traction modeling for mecanum wheels on different floor surfaces
- Sensor fusion — combining wheel odometry with IMU data for more accurate position tracking

**KEEP BUILDING**

The best way to truly understand mecanum wheels is to build a small robot and watch the equations in Section 08 come alive as real, physical motion.

THANK YOU FOR READING

# Now you know exactly how it rolls sideways.

From a single angled roller to a full four-wheel holonomic drivetrain — you've now got the complete picture: the physics, the math, the build advice, and the troubleshooting know-how.

If this helped you understand what you saw in the reel, that's exactly the goal. Building something with your own hands is the next best step.

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