

Crash Course in Conduit

After buying a fixer-upper north of San Francisco, a carpenter friend of mine wanted to install a workbench in the garage to tackle some projects. The problem was, there weren't enough outlets to make efficient use of the space. When he asked me for help, one solution immediately came to mind: surface-mounted boxes connected by electrical metallic tubing, referred to as EMT.

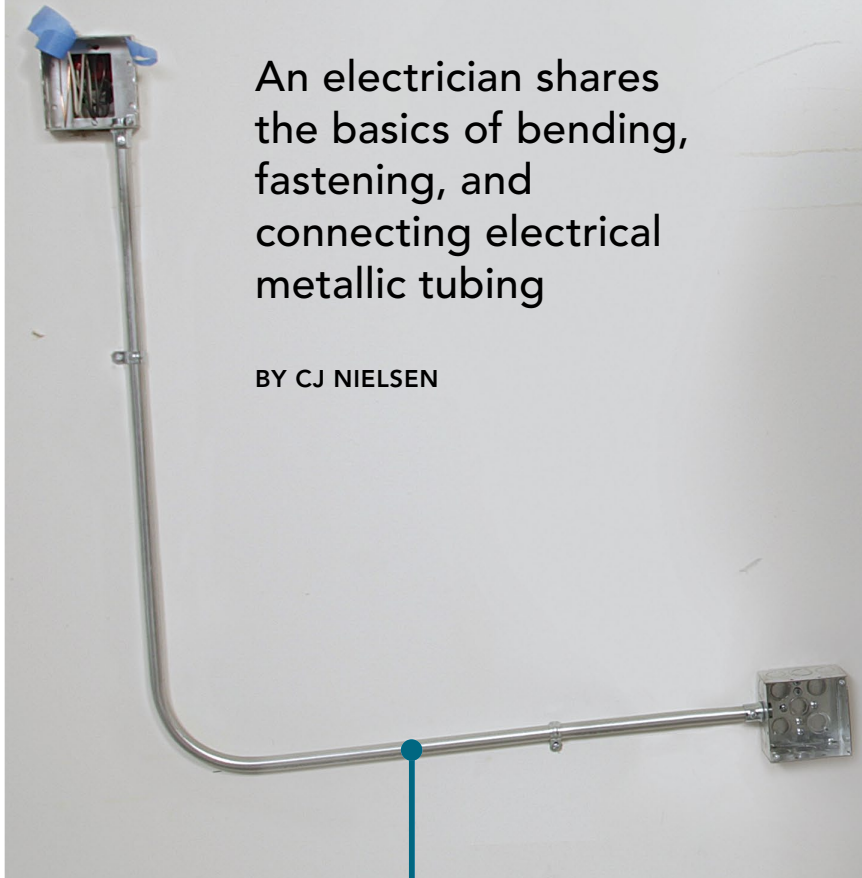
Although the sleek, industrial look of EMT is finding a niche in industrial interiors, where it's used as a design element to add interest to a room, it's mostly called upon for its low cost, durability, and ease of installation. It has become a standard for garages or workshops, where it's tough thin-walled steel or aluminum construction can take a beating. It's often used to retrofit new electrical outlets, switches, and other devices onto existing walls. It's especially useful on concrete or block walls, and in other situations where obstructions don't allow wiring to run in the walls.

In my friend's garage, the wiring is typical of residential homes—nonmetallic sheathed cable hidden behind drywall. While there are no obstructions, using EMT meant I didn't have to open up the walls (or patch the drywall afterward), and it'll be easy to run additional electrical devices off of it in the future.

Laying out surface-mounted EMT

Before bending any conduit, install all your electrical boxes—both the new boxes and the extension rings on the existing boxes that you're going to tap. All measurements will reference off these.

When deciding where to put new boxes, envision how the conduit is going to get there from existing boxes. It's best to avoid putting new boxes in places that require lots of bends. The electrical code only allows 360° worth of bends between



An electrician shares the basics of bending, fastening, and connecting electrical metallic tubing

BY CJ NIELSEN

WHAT IS EMT CONDUIT?

Several types of conduit are used to create “raceways”—the industry term for an enclosed channel that holds wires—but all share the same basic form and purpose: They're all tubes that protect wiring. EMT is among the most affordable and simple types of conduit to work with, and can be used both indoors and out. EMT is produced in diameters from 1/2 in. to 4 in., and usually comes in 10-ft. lengths. It's typically made of zinc-coated steel, but also comes in aluminum, which weighs less. Despite its rigidity, EMT is easily bent around obstacles and connects to boxes with fittings—a little like plumbing, but easier.

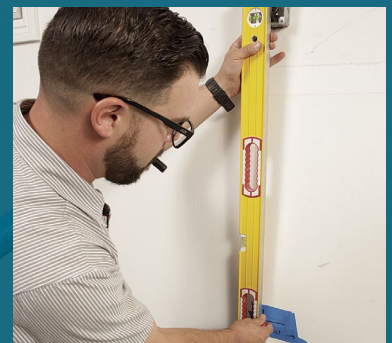


LAY IT OUT

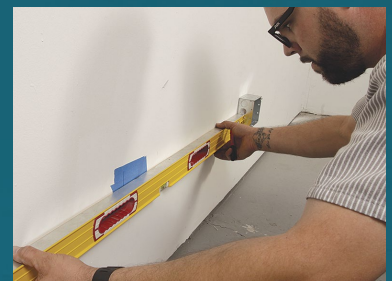
When laying out electrical boxes for conduit runs, keep in mind that you can only have 360° worth of bends between pull points (openings through which you can feed and pull wires). Use painter's tape and a level to accurately locate and mark plumb and level lines for box and bend locations. Measure tight to the boxes, keeping your accuracy within about 1/16 in.



Level boxes. When attaching the boxes to the wall, use a torpedo level to ensure that they're plumb and level before tightening. Crooked boxes look off, and they can stress the conduit, making it difficult to mount to the wall and more likely to pop off in the future.



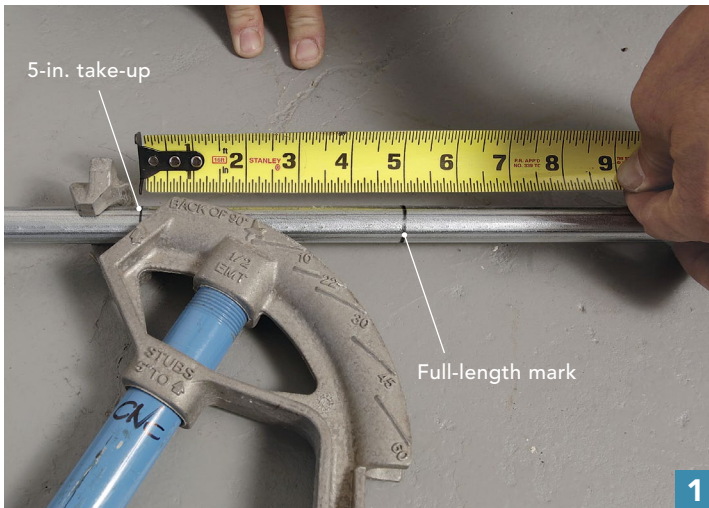
Mark plumb lines. Hold the level to the edge of the box's knockout that's in line with the outside of the 90° stub bend.



Mark level lines. Hold the level to the edge of the other box's knockout that's in line with the outside of the 90° stub bend.

BENDING BASICS

Bending conduit is more science than art. There's a formula to determine the distance between bends for offsets (see drawing p. 79), and simple math for determining where to bend for stubs. Some people guesstimate where to make bends, but doing it by the book gets solid results every time.



1 Subtract the take-up. Conduit benders indicate the take-up dimension (5 in. for 1/2-in.-dia. EMT) used to make 90° bends. After marking the total distance from a box to the outside of a bend (or one bend to the next) on the EMT, subtract the take-up and mark it on the EMT as well. For example, if you're using 1/2-in.-dia. EMT and the distance from box to bend is 20 in., measure 20 in. from the end of the EMT and mark it, then subtract 5 in. (to 15 in.) and mark that spot as well. This is the mark you'll use to align the bender.



3 Measure to length. After bending a stub, the leg you measured should be the proper length; now the other leg needs to be cut to length. Lay the bent EMT on the floor, and lay a bender or other straight edge along the stub as a reference. With the end of the tape measure butted against this straight edge, measure and mark the length of the other run.

“pull points.” Pull points are openings in the conduit system that you can pull wires through (see photos p. 81). It's possible to add pull points to allow for more bends, but this adds time, complexity, and cost.

If you're working on a finished stud wall, it's helpful to locate the boxes directly over the studs for easy attachment. When going into drywall between studs, hollow wall anchors are the only option. I like to use Snap toggles because they hold strong and are easier to use than standard toggle bolts.

To mark the layout, I put painter's tape where boxes and bends will go. Then I can draw various measurements, level and plumb lines, and fastener locations on the tape without marring the wall. If I want to move something, it's easy to remove the tape and start over.



2 Bend slowly. With the EMT on the floor, align the bender's arrow (across from its hook) with the second (take-up) mark, and bend toward the first (full-length) mark. Pull the bender handle toward you slowly (foot pressure on the bender shoe helps get it started) until the bend reaches 90°. Check for accuracy with a level or large square.



4 Cut it square. Cut the conduit using a saw with a metal-cutting blade, or use a specialty conduit cutter.

Think about future needs when doing the layout. If your boxes have a lot of knockouts (the metal discs that pop out to allow wires to run in and out), choose the one that will make future additions easier. For example, if your conduit run is going down and to the right, use the knockout on the bottom right.

Before adding extensions to existing boxes, make sure the circuits are off, and test all devices in the box before you open it up.

Bends are often unavoidable

Often, the easiest and fastest way to achieve a change in direction in conduit is to bend it. For consistently good results, get accurate measurements and use simple formulas to calculate where to mark and

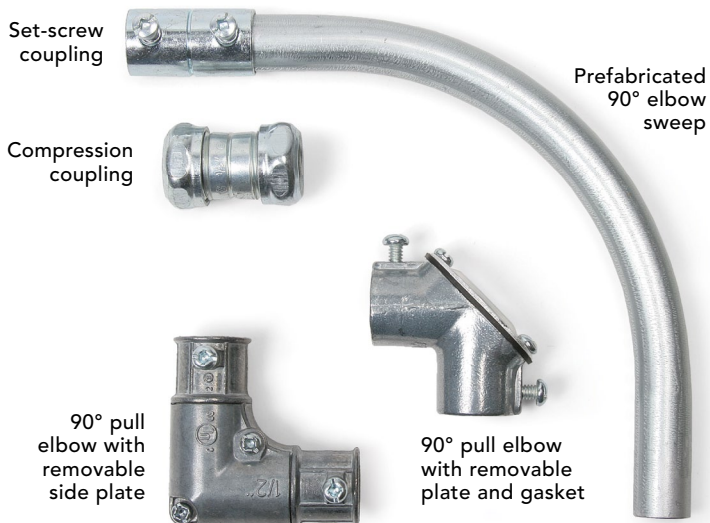


Check for fit. After bending a stub and cutting it to length, check that it fits well between the boxes. If it's too short, start over. If it's too long, trim as necessary.

STORE-BOUGHT BENDS

There's more than one way to get to 90°

Bending isn't the only way to change direction in conduit. Fittings can be used in place of some bends. Prefabricated EMT elbows attach to straight lengths of EMT with couplings, while various pull elbows can make it easier to fit into tight corners and to pull wires.



bend the conduit (a couple are provided here; others are easily found online or in bender instructions).

Manual EMT benders come in different sizes for different diameters of conduit up to 1 1/4 in., and are the standard tool of the trade. Manual benders all have marks for various angles and to align conduit for bends. Each size bender has a different bending radius that is taken into account when making bends. The "take-up"—the number of inches a 90° bend (called a "stub") will account for in the overall distance from a box to a bend location—is usually marked on the bender.

For example, with 1/2-in.-dia. EMT, the take-up is 5 in. So, if there are 20 vertical inches from the box to the bend location, there are just

Calculating offsets

A simple formula is all it takes

Offsets are used to avoid obstructions or make transitions from one height or wall plane to another, and are made up of two bends of the same angle. Among the most common offset bends is the "box offset," which is comprised of two 10° bends—one to kick the conduit out from the wall or ceiling, and another to bring it back parallel to the surface and square into the box.

Step 1 Measure the distance between the two planes you want to connect (e.g., the distance from the wall to the box knockout).

Step 2 Choose an appropriate angle for the offset. Shallow bends make pulling wires easier, but steeper bends take up less space. The angle chosen determines the multiplier

Common multipliers for bending conduit

Degrees of bend	Multiplier
10°	6
22°	2.6
30°	2
45°	1.4
60°	1.2

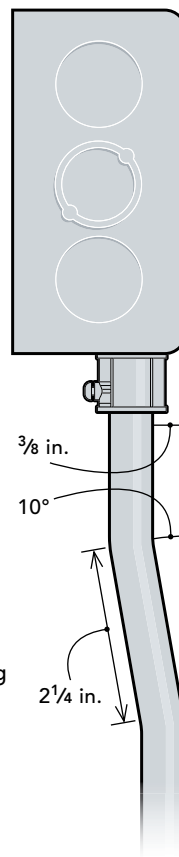
used to figure out where to mark the conduit for bending (see table left).

Step 3 Calculate the distance between bending marks. To do this, multiply the depth of the obstruction by the multiplier from Step 2. For a 3/8-in. box offset, a 10° angle is typical, and the

multiplier for that angle is 6. The math works out to 3/8 in. x 6 = 2 1/4 in. This is the distance between bending marks.

Step 4 Mark the first bend in the conduit, extending the line all the way around the tube. If doing a box offset, I make the first mark 2 1/4 in. from the end (this is arbitrary, but it works). For other types of obstructions—say, a step down—measure to the edge of the step. From this first mark, add the distance computed from Step 3 and mark it on the conduit, again drawing the line all the way around.

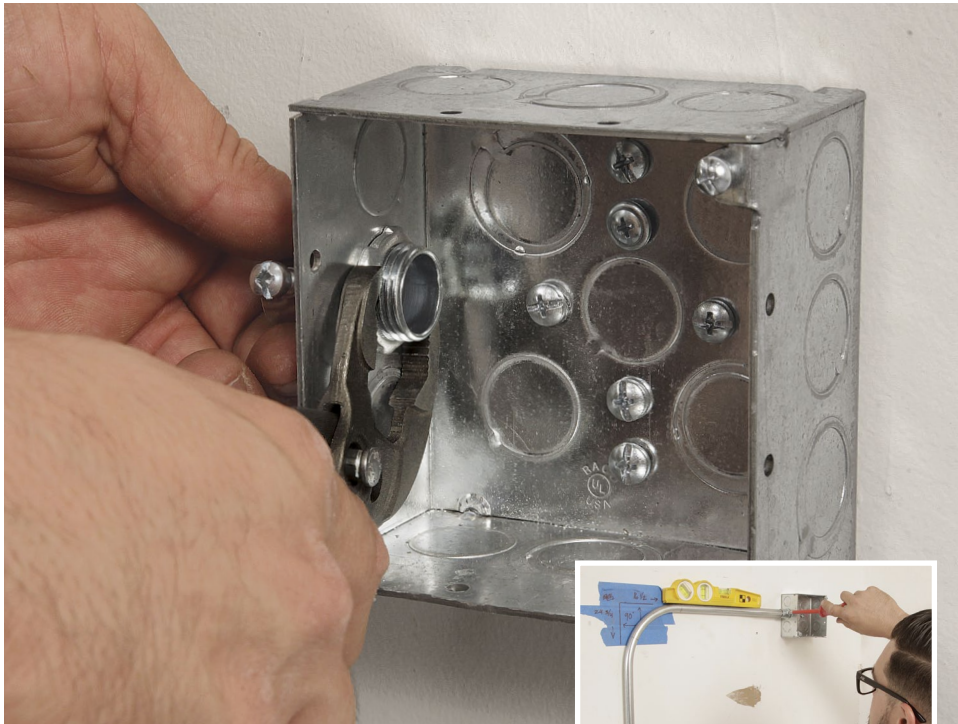
Step 5 Make the bend closest to the end first, then rotate the EMT 180°, slide it to the second mark, and make the next bend.



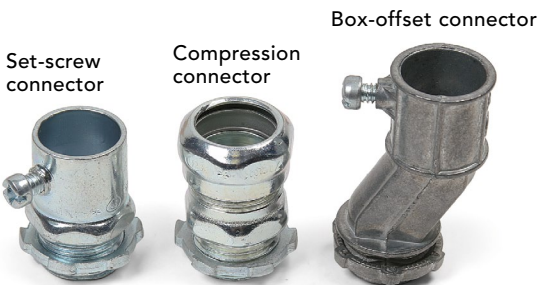
Offset for boxes. Offset bends are used to bring the conduit from the wall to the plane of the box knockouts, which are typically 3/8 in. out from the wall. I use a special offset bender (about \$250), but a manual bender can do the job as well.

MAKING CONNECTIONS

All EMT connections are made with fittings. Set-screw fittings, which are inexpensive and easy to install, are only allowed in dry, indoor locations. Compression fittings, which are a bit more expensive, are required in wet and outdoor settings, but are also used in dry areas—usually for their sleeker aesthetics.



Install connectors. Before installing the conduit, attach the connector fittings to the boxes, tightening the lock nuts securely with adjustable pliers.



Connect the conduit. Slide the conduit ends into the connectors, and tighten the set screws or compression rings to secure the conduit to the fittings.



Strap it up. Straps are required every 10 ft. along conduit runs, and within 3 ft. of boxes. In hollow walls, use anchors to hold the straps' screws securely.



Screw on bushings. Before running wires, screw plastic bushings onto the box connectors to protect the wires' insulation.

15 in. of conduit running perfectly vertically; the other 5 in. are taken up in the bend.

By code, all bends must have an even radius with no kinks. The relatively large radii of EMT benders helps prevent kinking, but proper technique is also important. Always keep pressure on the conduit as close to the bender as possible for good results.

Cut square and deburr

I like to use a portable bandsaw to cut EMT because it makes quick work of the conduit without binding, but a reciprocating saw with a sharp metal-cutting blade works too, as does a good old hacksaw. When using a hacksaw or reciprocating saw, secure the con-

duit in a vise first. Regardless of the tool, always be sure to cut the conduit square.

Even if done with sharp blades, cutting EMT leaves burrs, which can nick wire insulation. To remove burrs, I use a reamer that hits all of the conduit edges at once, but files and other tools also work. However you deburr, carefully check the edges with your finger to make sure they're smooth.




Don't fight it

When fitting conduit to boxes, the conduit should bottom out in the fittings and lay flat against the wall without putting pressure on it. If you have to fight it, something's not right. Assuming the lengths

RUNNING WIRE

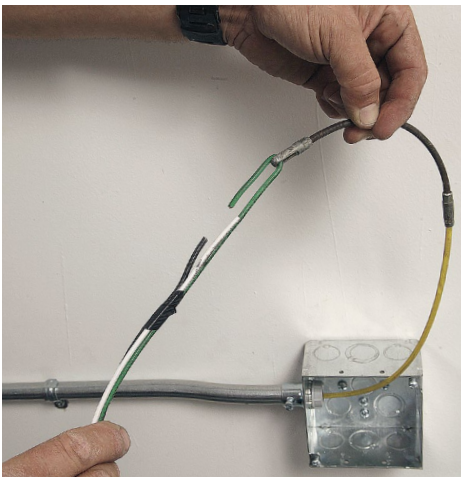
Running wires through conduit isn't hard, but fish tape can help on long runs or runs with lots of bends. Lots of electricians have their own techniques for attaching wires to the fish tape. When pulling wires, it helps to have an assistant feed them into the conduit to keep them from getting hung up.

EMT-conduit fill tables can tell you how many wires of a given gauge you can run through various sizes of conduit. Here I show some common wire gauges used in 1/2-in.-dia. EMT, but expanded charts are widely available online.

WIRE SIZE	14-ga. wire	12-ga. wire	10-ga. wire
Maximum number of THHN wires	 12 wires	 9 wires	 5 wires



Fish-tape anatomy. My fish tape has an eyelet end, rather than a leader, as some tapes have. I prefer this because it's a solid piece that can't spring apart. My Ideal S-Class fish tap costs about \$175.



Tape it up. Wrap electrical tape around the wires, starting about 8 in. down and working your way to the fish tape, finishing with a few loops over the joint between the tips of the wires and a few more over the eyelet and up the fish tape's leader.



Stagger the wires. After running the fish tape between pull points, prepare the wires by staggering their ends. One should be about 3 in. longer than the rest. Feed this long wire through the fish tape's eyelet, and bend it back until it's just shy of touching the tip of the next-longest wire.



Mount devices. Devices installed in surface-mounted boxes are attached to the faceplate rather than the box. Break the ears off the device with pliers and attach the cover to the device with the provided screws.

are correct, tweaking bends and checking the boxes for plumb can often get things where they need to be. If you try to force a length of conduit into position, it'll fight the straps as long as it's on the wall or ceiling. Eventually, it could spring loose.

Straps are required every 10 ft. or less, and within 3 ft. of any box or enclosure. For a neat look, try to space the straps evenly.

Working with wires

Different numbers and sizes of wires are allowed in different sizes of conduit (see "Running Wire," above). It's possible to run solid wire with conduit, but I typically use stranded wire because it's easier to pull it through, especially on long runs and runs with lots of bends. On

short runs with minimal bends, it's usually possible to push the wires through. On longer runs, use a fish tape—a flexible line that can be pushed through the conduit and pulled back with the wires attached to it. Whether fishing or pushing, run all of your wires at the same time to keep them from hanging up.

When attaching your switches, outlets, or other devices to surface-mounted boxes, remove the device's ears and screws first and then mount the device to the cover plate, which includes its own set of hardware for easy attachment. □

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