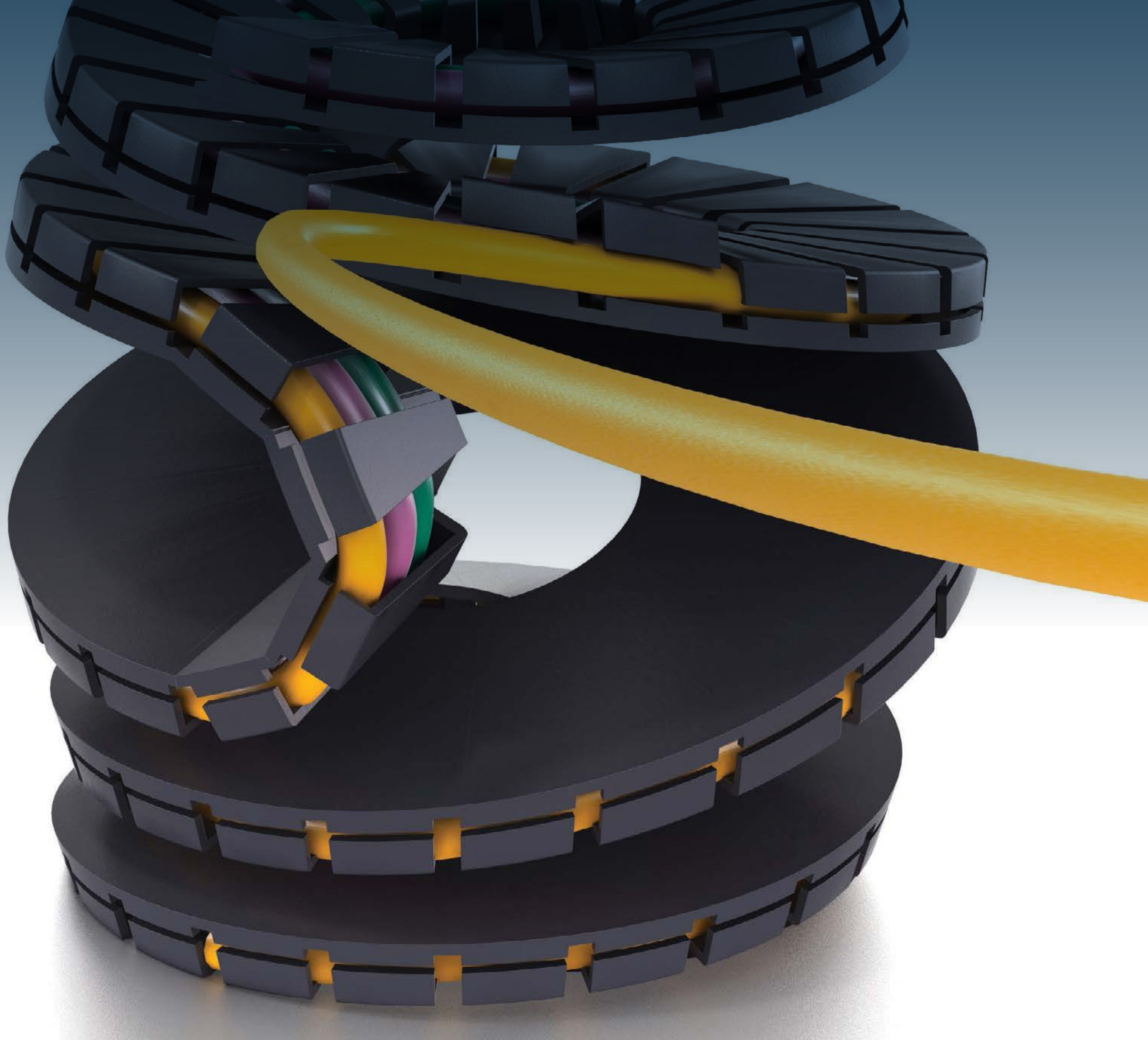
MOTION DESIGN GUIDE

CABLE CARRIERS



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Motion control systems can vary from simple, straightforward single-axis direct-drive systems with little wiring to large and complex multi-axis robotic systems with a hornet's nest of cables. This is usually where cabling, which was an afterthought, now takes center stage.

Especially where there are lots of cables and wiring, cable management becomes an issue. A simple form of cable management uses twist-tie type bundlers that tie together groups of wires and cables. These are low cost and easy to use. The problem is that with more and more cabling, they become impractical. Also, if the wiring and cabling have to be suspended, bundling them together may pose weight problems which cause sagging and put undue strain on the cables. Using cable carriers is another option. In this Design Guide, we detail cable carrier subtypes as well as the different designs into which cable carriers integrate.

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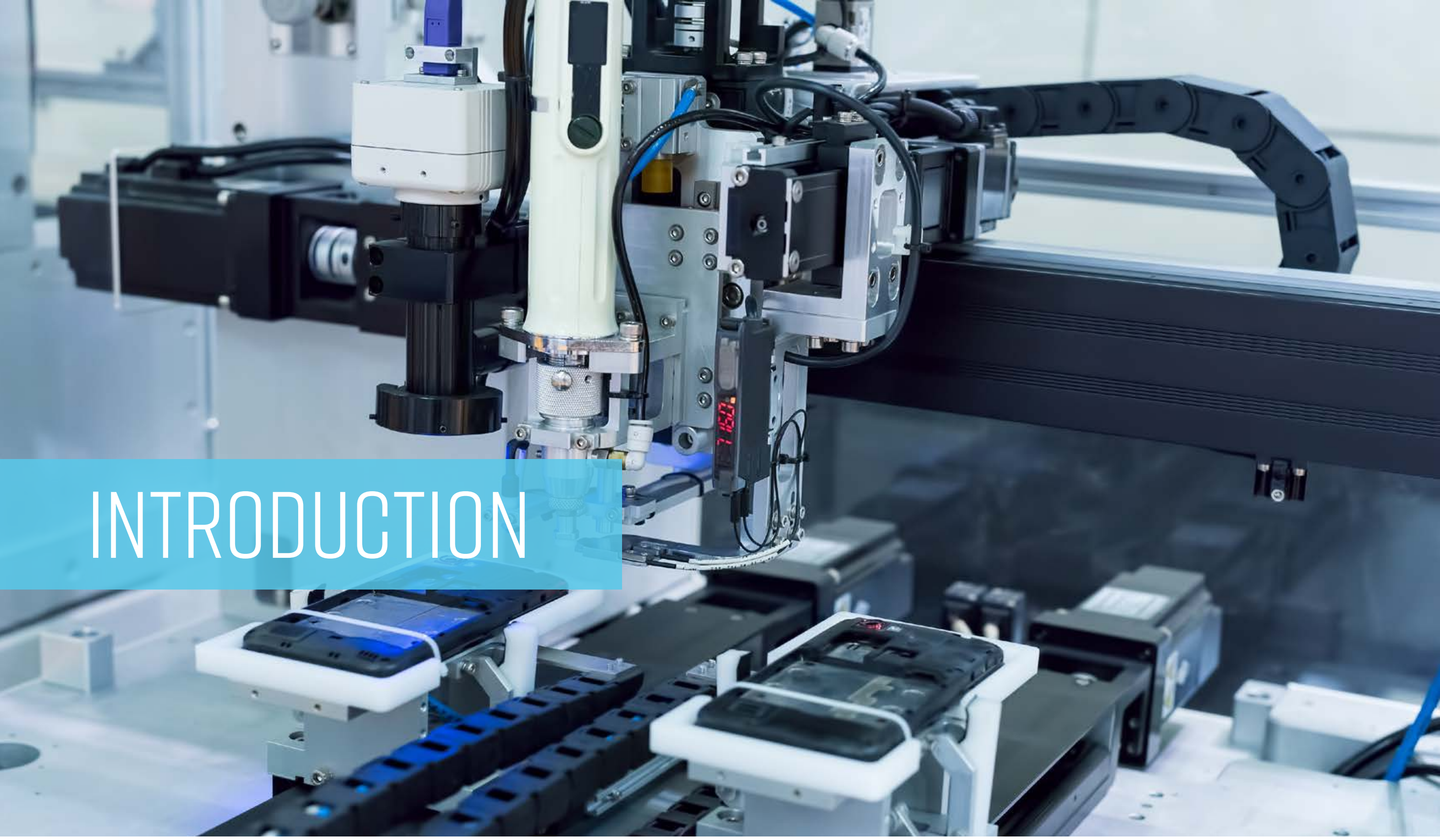


INTRODUCTION

Motion control systems can vary from simple, straightforward single-axis direct-drive systems with little wiring to large and complex multi-axis robotic systems with a hornet's nest of cables. This is usually where cabling, which was an afterthought, now takes center stage.

Especially where there are lots of cables and wiring, cable management becomes an issue. A simple form of cable management uses twist-tie type bundlers that tie together groups of wires and cables. These are low cost and easy to use. The problem is that with more and more cabling, they become impractical. Also, if the wiring and cabling have to be suspended, bundling them together may pose weight problems which cause sagging and put undue strain on the cables.

Using cable carriers is another option. Cable carriers are essentially structures designed to house cables. The structures themselves can be made of many materials such as plastic, steel, or a metal alloy. Cable carriers are used to protect cables and hoses on moving machinery. They prevent tangling and increase safety by not having cables susceptible to getting caught in moving parts of a machine. Applications for cable carriers can range from machine tools and robotics to cleanroom applications and large industrial equipment like cranes and other construction machinery.

Carriers can house a large volume of cables and wires and support the weight of them all without sagging or putting stress on the cabling. They also make managing and routing the cables through a machine or factory much simpler and provide easy access for troubleshooting or maintenance as well.

Selecting the right kind of cable carrier for an application starts with a few simple guidelines. The most important points to consider are the specifics of the application. These include the length of travel, the number of cables or hoses, the size and weight of the cables, the required speed and acceleration and environmental factors such as exposure to any debris, excessive heat or chemicals. Knowing the weight of the cables ensures that the carrier won't fail by snapping in two.

Cable carrier styles can be either open or closed. Open varieties allow for easy access to the cables and visible access as well, whereas closed carriers seal off the cables from the environment to protect from environmental contaminants such as metal filings.

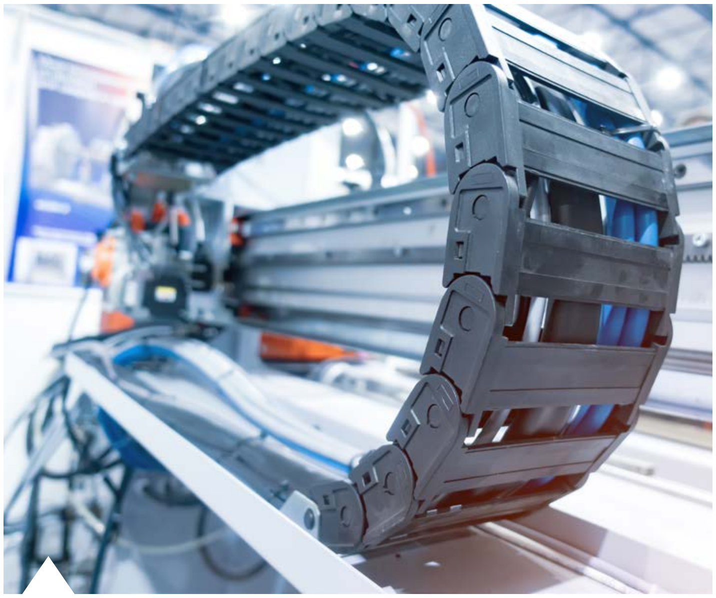
Environmental conditions play a large part in selecting a cable carrier. If the application is in a dirty or contaminated area, an enclosed carrier is the best choice. An open carrier is lightweight and makes inspecting and replacing cables easier.

Another important consideration is the bend radius of the cable carrier. Bend radius is measured from the center of the curve loop to the center of the pivot pin on the side link. A larger bend radius means less stress on the cable and a longer service life.

CABLE TRAYS VERSUS CABLE CARRIERS IN **MOTION APPLICATIONS**

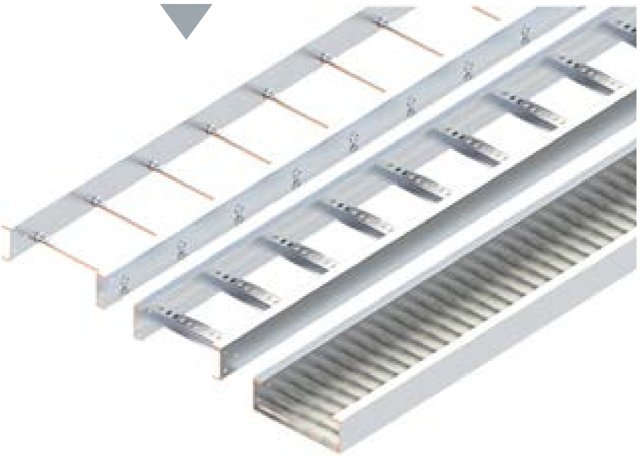
Shown here is a cable tray.

Cabling in a motion control system can run the gamut from a single wire running to a single-axis direct drive, to a complicated system of expensive cables and wiring on multi-axis robots. As a result, it is necessary to consider cable management in your system design. A simple design may only require twist-tie type bundlers but as systems become more complex, with longer, heavier cables, you may need to upgrade to cable trays or cable carriers to prevent sagging and undue strain on cables.



Shown here is a cable carrier.

Cable trays are often made of metal, like this aluminum design from Cope, which can be manufactured in ladder, trough and hat styles.



CABLE TRAYS FOR STATIC CABLE RUNS

Cable trays are best suited to stationary applications. These devices route cables in a system, providing protection from contaminants and necessary ventilation while keeping different cable types separated.

Featuring a U-shaped open design, the cables are simply placed into the tray, which can be closed or open to the air.

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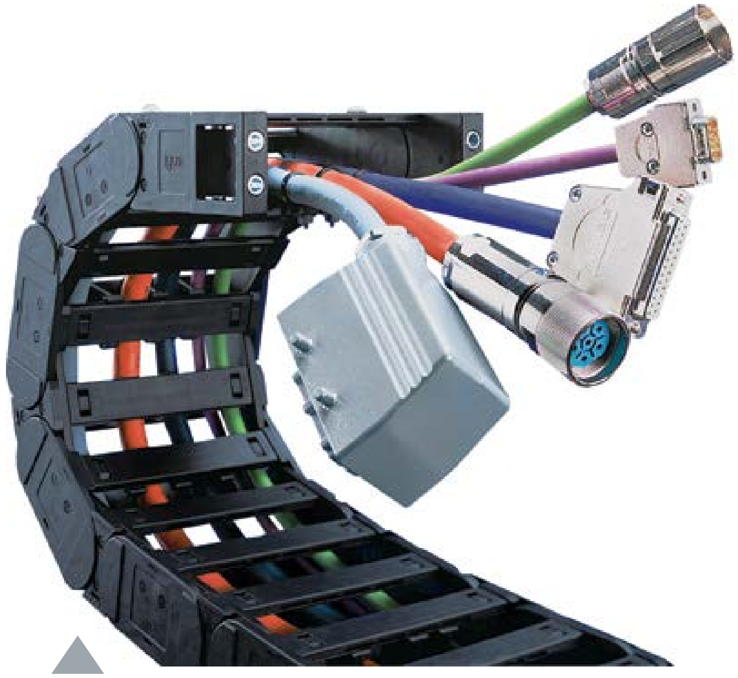
CABLE TRAYS VERSUS CABLE CARRIERS IN MOTION APPLICATIONS

Typically manufactured from stainless steel, aluminum, plastic, or fiberglass, they may be designed ladder style or in solid, ventilated or perforated designs with knockouts for cable exits.

It is important to consider the cables that are being routed when choosing a cable tray, including its weight and diameter. On a related note, be aware of the span between supports and the cable run distance, as cable weight can have an impact here. Finally, understand the application where the cables are used; for instance, if they need to be protected from contaminants with a closed design or if they will require ventilation.



Plastic cable carriers, such as this model from igus, feature a modular, easy to maintain and lightweight design. They can be provided to users empty or pre-filled with complete cable assemblies.

The twisterband HD cable management system guides cables rotationally in applications with limited installation space. Image courtesy of igus.

CABLE CARRIERS PREVENT CABLE DAMAGE IN DYNAMIC MOTIONS

Plastic cable carriers, such as this model from igus, feature a modular, easy to maintain and lightweight design. They can be provided to users empty or pre-filled with complete cable assemblies.

Cable carriers are advanced components that house cables and hose in motion systems. Available in metal or plastic designs, they help prevent sagging, tangling and crushing of cables in robotics, machine tool, and large off-road and industrial machinery.

Unlike cable trays or ladders, these devices are best suited to systems that require movement, such as robotics, machine tool and large off-road and industrial machinery. They can support the heavy weight of numerous cables and hoses, without sagging or putting stress on the cabling. They also prevent cable from tangling and getting caught in moving parts of a machine.

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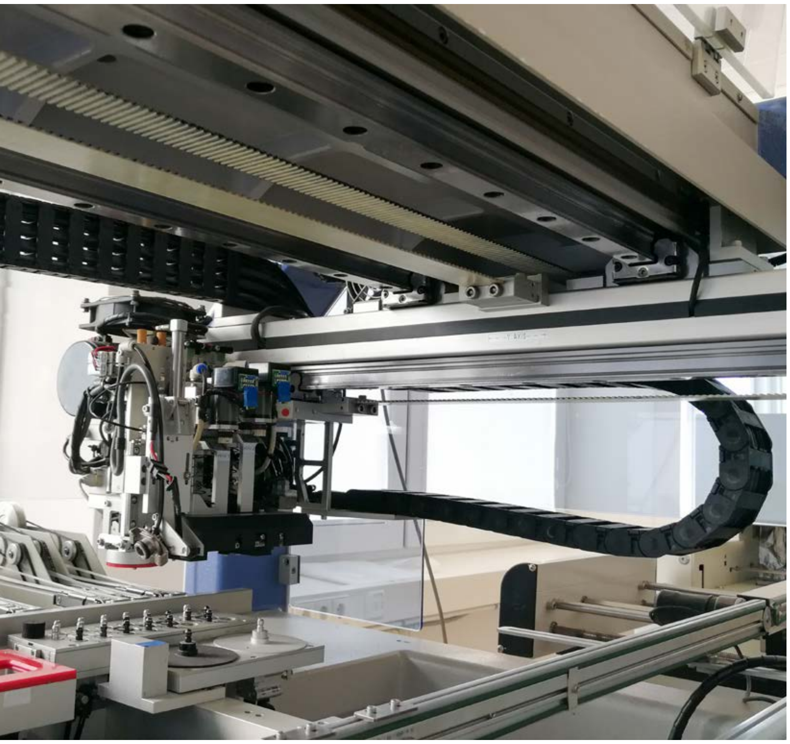
CABLE TRAYS VERSUS CABLE CARRIERS IN MOTION APPLICATIONS

Two styles are available: closed or open. Closed carriers protect cables from environmental damage posed by contaminants like metal shavings, while open carriers offer visual and quick and easy access.

Plastic cable carriers, made from high-performance polymer or nylon, offer reduced weights while being corrosion resistant in hostile environments. Some polymer designs resist seawater and mineral oils, for use in harsh applications.

Plastic cable carriers can be easily opened and disassembled. They feature a modular design, for easy configuration to most applications. The easy-to-maintain designs mean damaged or



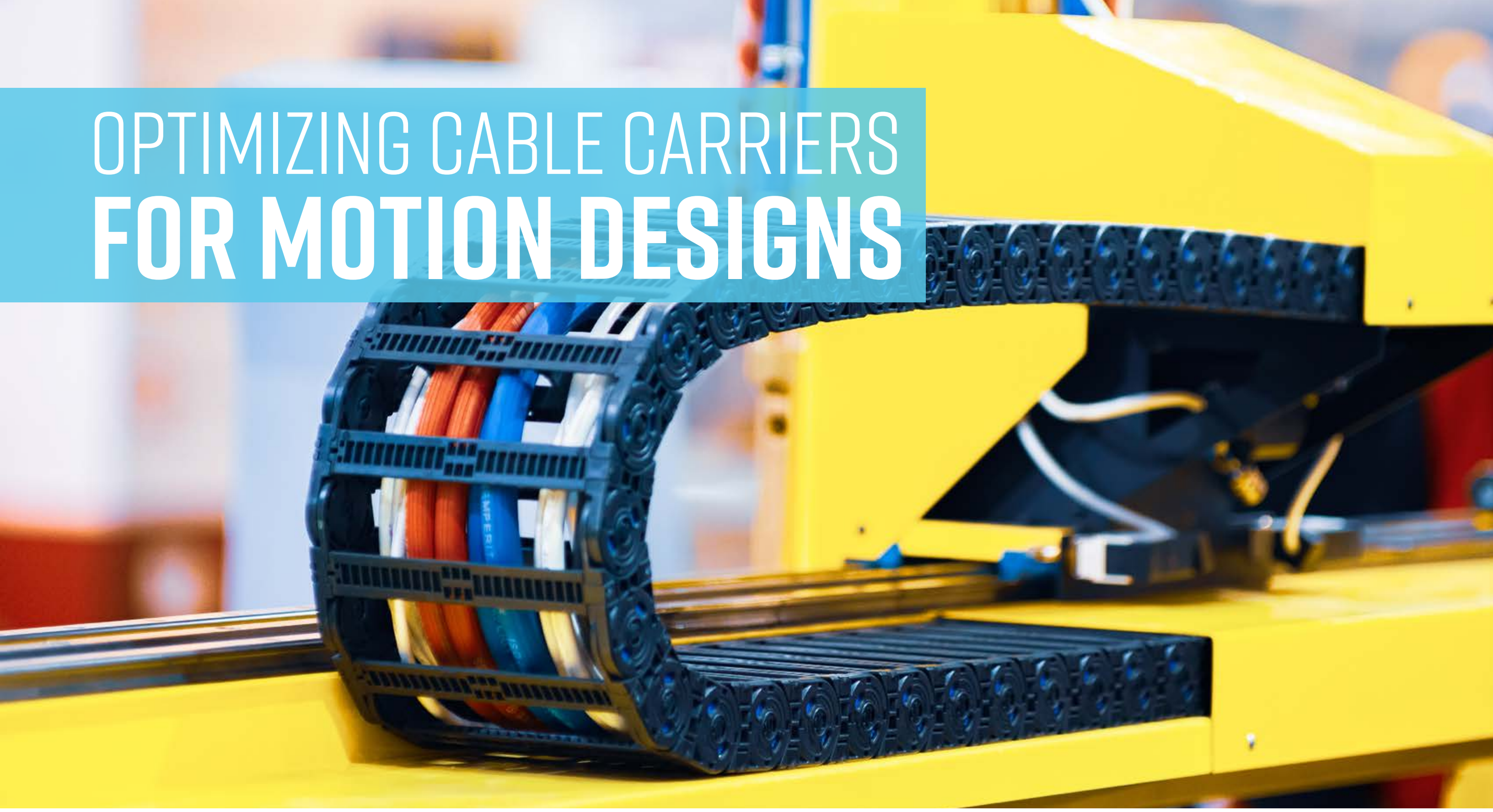
e-chain® cable carriers are virtually maintenance-free and guaranteed to last up to 36 months. Image courtesy of igus.

broken links can simply be removed and substituted with a new link. Some plastic carriers can be opened by hand.

Steel and other metal alloy carriers are best suited for heavy mechanical loads that run long distances carrying large cables and hose. Steel cable carriers are designed to handle harsh environments—even long-term temperatures above 600° without negative impact.

They also offer high resistance to many harsh and corrosive chemicals, so are usually found where maintenance is difficult. These extreme applications include everything from mining to marine and oil and gas to foundries.

OPTIMIZING CABLE CARRIERS **FOR MOTION DESIGNS**



Cable carrier styles can be either open or closed. Open varieties allow for easy access to the cables and visible access as well, whereas closed carriers seal off the cables from the environment to protect from environmental contaminants such as metal filings.

Environmental conditions play a large part in selecting a cable carrier. If the application is in a dirty or contaminated area, an enclosed carrier is the best choice. An open carrier is lightweight and makes inspecting and replacing cables easier.

One of the most crucial factors is choosing the right bend radius for the cable carrier. Bend radius is measured from the center of the curve loop to the center of the pivot pin on the side link. A larger bend radius means less stress on the cable and a longer service life. It's important for the bend radius, with the exception of applications with space restrictions, to be larger than the recommended minimum bend radius of the cables and media that make up the fill package.

All cable carriers have a predetermined radius stopping point on each link. When a number of links are assembled, these stopping points restrict the carrier from fully pivoting and form a curve loop, or minimum bend radius.

All cable carriers have multiple bending radii to choose from and every manufacturer suggests a minimum bend radius. The bending radius chosen for the cable carrier will depend on the cable or hose with the largest diameter. Selecting a considerably larger bend radius than required for the fill package will extend the lifespan of the cables and hoses.

GENERAL RULES FOR SELECTING THE BEND RADIUS

Don't exceed the manufacturer's suggested minimum bend radius; however, using the largest bend radius possible is optimal.

If you don't know the recommended minimum bend radius of the cables in the fill package, follow these guidelines from NFPA 79 2007: "Cables with flexible properties subject to movement shall be supported in such a way that there is neither mechanical strain on the connection points nor any sharp flexing. When this is achieved by the use of a loop, it shall provide the cable with a bending radius of at least 10 times the diameter of the cable."

The larger the bend radius, the less stress is put on the cables and hoses, which will ensure longer service life.

Keep in mind that the minimum bending radius is partly based on a temperature range for flexing. Special consideration is needed when the environment reaches or exceeds the temperature rating for the cable. This is especially true for low-temperature applications using thermoplastic cables, which tend to stiffen when exposed to the cold. Stiff cables can raise the radius of the cable carrier and lead to mechanical failures. Best practice is to use a cable with a low-temperature rated PUR or TPE jacket and/or consult the manufacturer for bend radius recommendations.

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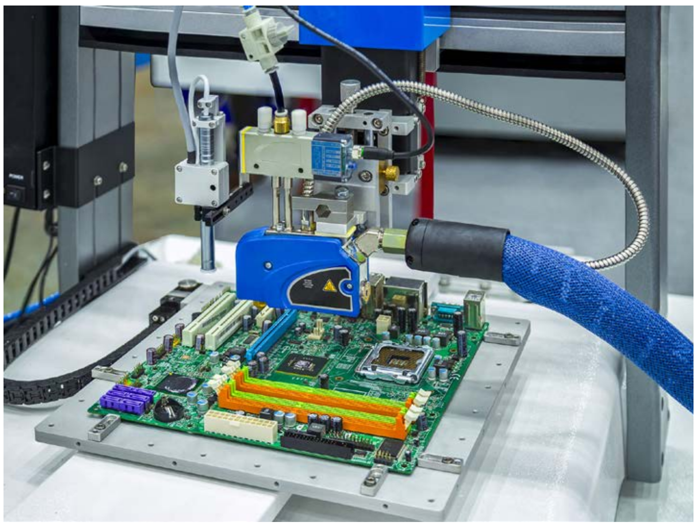
OPTIMIZING CABLE CARRIERS FOR MOTION DESIGNS

In applications with severe space restrictions, the bend radius of the cable carrier may need to be smaller than the recommended minimum bend radius for the fill package. This is not ideal, but if it cannot be avoided, use cables specially designed for low bend radius installations or consult your cable carrier manufacturer for the best solution.



BASIC CARRIER DESIGN AND SELECTION

At the outset of a cable carrier design, it's best to begin with determining the size. The first step, essentially, is drawing a box. This is going to be the cavity of the cable carrier itself. The next step is to add the cable to the hoses that you'd be using. From there, you determine the "B" dimension. This nomenclature is mostly industry-standard — everybody uses "B." Here, we are specifically talking about the cavity height, which is not manufacturer-dependent. Let's say the cavity height of the track itself is determined by the OD of the largest cable or hose. Now, we generally use a safety factor. Again, this is industry-standard as well. You want to add 10% up to the nominal size for cables, and for hoses, you want to add 20%. You add more for hoses because, with especially high-pressure hoses, you may get expansions and you want to give the cables and hoses room to move inside the carrier. It is important to note that when laying the cables, you put the cables to the outsides and work your way inward with the lighter cables. This helps with the balance and stability of the system.

The next step is determining the "A" dimension. This is the cavity width. This is determined by adding the ODs of all the cables and hoses, plus safety factor, and then the width of any separation that you're going to use. Although there are exceptions, typically, separators are a good idea. A heavy separator keeps like cables with like cables. Ideally, you do not want to have a cavity that has more than two times the height of the OD. You want to ensure that each cavity has no more than twice the height of the largest cable or hose inside it.

The next step would be to consult your manufacturer's catalog for the appropriate series, and then check the "C" and "D" dimensions, space restrictions, and again "C" being the outer width and "D" being the outer height. Also, make sure that whatever contains your cables and hoses also fits within whatever envelope you have as well.

This will give you the general measurements on the series of the carrier that you're working with. From there, you must establish the minimum bend radius. One of the advantages of cable carriers is that they will allow you to select a minimum bend radius that the cable will not bend tighter than. Doing this can be challenging. The rule of thumb is typically eight to ten times OD because there are many different cables available. You may have big, five hundred MCM cables or SO cords, and these are typically not designed to be high flux. On the other hand, there are some high flux cables, where they'll go as low as three and a half to five times diameter.

The next step is to consult the catalog to select the closest standard bending radius available, and then you're going to check the "K" and "H" dimensions against the space restrictions. The "H" is the curve height; you must make sure that whatever radius you have will fit inside the envelope you're working with. The "K" dimensions, or the depot, is when the carrier is fully retracted — from the center line pivot point of the first length, to the end of the carrier. This can be a tricky dimension, and not everybody designs for it.

The next step is determining the length. What is the required machine travel? How far are you moving? Then you determine whether the carrier can be center-mounted. This means that if you mount the stationary end of the track, in the middle of the travel, you will only need half the travel's worth of cable carrier. What you'll get is an extension, half travel extension, or half travel attraction at the center point.

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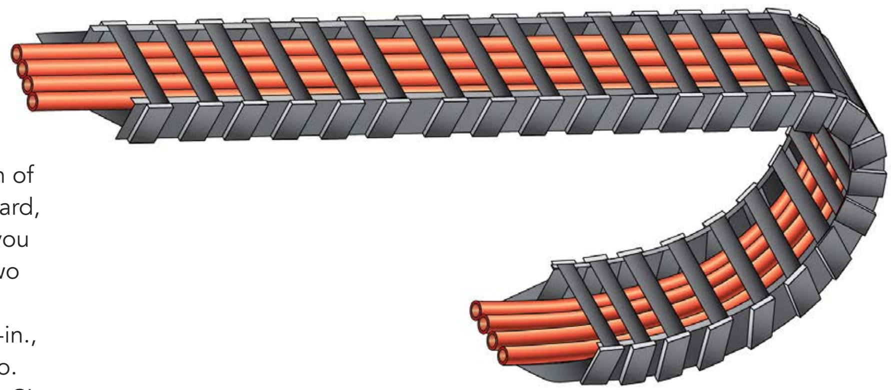
OPTIMIZING CABLE CARRIERS FOR MOTION DESIGNS



You're going to then consult the catalog for the curve length of the selected radius. CL is, again, pretty much industry-standard, and the way it is calculated is pi times radius. This is where you get your curve. Again, another industry-standard is to use two safety lengths. Virtually everybody in the industry uses two safety lengths. What that means is, if you have a length of 5-in., and you are 10-in. off-center, you can just use travel over two. Be cautious, though. Again, travel over two, plus offset, plus CL is how you determine the length of cable carrier.

SELECTING CONSTRUCTION

When looking at the construction, people often ask, "Does the environment require an enclosed carrier?" "What is the required unsupported span?" "What's the budget?" "Are there high velocities or accelerations?" But the most basic, most fundamental question is, "Plastic or steel?" Ideally, you want to work with the right medium for your application, and the application you used last week might not necessarily be the same application you use next week, so you may need to move back and forth.

As a general rule, people consider plastic tracks lighter, less expensive, and easier to access. As a general rule, steel carriers are often heavier, more robust, more expensive, and more challenging to access. These are just general guidelines, and individual applications will require more in-depth analysis.

Another thing to consider is open versus closed. This question is relatively straightforward. Are there chips or debris present? Are these chips red hot? If the answer to either of those questions is no, you do not need the enclosed carrier. Typically, they are more expensive, although some people like the aesthetics and do not mind the increased cost. But as a general rule, if you neither have the debris or particulate, you do not need an enclosed carrier.

DESIGN CONSIDERATIONS

Environment plays a critical role in cable carrier design considerations. For example, depending on the working environment, the application might require standard yellow, dichromate plating which has a specific salt-sprayed rating. Or, it may require a zinc-nickel plating which provides two and a half times what a standard yellow dichromate. This is just one example for metal carries.

In certain applications, like an explosive environment, a conductive plastic with a specific surface resistivity might be necessary. Polypropylene is another plastic that potentially can be used in high humidity, underwater applications, because it doesn't absorb moisture. Those are typically good choices for high-moisture environments.

Crossbar selection lends itself to cable performance and cable wear performance, so certain bar selections can be used. The best approach is an aluminum flat bar, as it provides a wide wear surface, and it also gives you the more robust track or chain. Price can be a concern, but it's a robust solution. It's certainly more cost-effective to have than to replace your cables, down streams. It should be noted that these bars are typically available from most manufacturers in either plastic or steel carriers, so whether you're using plastic or steel, you can have a variety of different bar options.

For track selection, especially with complicated applications, it's equally as important to make sure you're working with a manufacturer who does have good quality systems, good RMV systems, and who can support you along the way.

Also, more and more companies have been adapting to lean manufacturing criteria. The idea is, planning upfront. What are the attributes you're looking for? Making the cable carrier or selection process work, you want both the product and the process to integrate this with your systems. As for some of the capabilities to look for, FEA, rapid prototyping, FMEA, APQP, these are just some of the things many manufacturers now offer and that you should take advantage of.

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OPTIMIZING CABLE CARRIERS FOR MOTION DESIGNS

INSTALLATION

Finally, installation. Every track and every installation on paper looks great. It's worth talking to your manufacturer ahead of time about how you're going to be using this. If the last step that the manufacturer does is put crossbars on, and the first step is to pull those crossbars off, to install cables and hoses, it would make more sense to consult ahead of time and have the track sent with the cables and hoses, with the crossbars shipped loosely. Budgeting some time for upfront consulting and discussing with a manufacturer what will happen, especially on a large project or on a new application, could save significant time and money down the line.

Seemingly smaller considerations like, "Is it going up in the air? How do you want the tracks shipped to you? Do you want it in one piece? Do you want it in ten-ft assemblies?" Conducting online meetings with your manufacturer or even approvals online, can speed the process up significantly. A sound installation comes from planning. Again, measure twice, cut once.

VALUE ADDED

Everybody wants to work with plug-and-play systems. The trick with value-added is to make sure that the value-added works for you. For example, one of the value-added services that many manufacturers provide includes pre-installing cables and hoses. This can be a real benefit for some companies, but other customers, because of unique application specifics or non-standard systems, it would never work.

HOW TO SPECIFY METAL CABLE CARRIERS

Cable carriers are essentially hollow chains that enclose electrical cables, as well as hydraulic or pneumatic hoses. They guide and protect the enclosed cables during motion, preventing wear and damage. An important function of cable carriers is to constrain bending to a single plane and to limit the minimum bend radius. This both prevents entanglement and avoids high stresses due to overly tight bends. Cable carriers also prevent cables from getting caught in moving parts of a machine.

Steel and other metal alloy cable carriers are required when the cable carrier may be subjected to heavy mechanical loads, physical damage, or high temperatures. They are often used for the largest cables and hoses, operating in harsh environments.

Important questions to ask when selecting a cable carrier include:

- External dimensions: How much movement is required and how much space is available to accommodate the length of the track, as well as the height of the bend?
- What type of motion must the cable carrier allow? Most cable guides are designed to accommodate linear motion along a single axis but multi-axis linear motion or rotation can also be accommodated.
- Internal dimensions and minimum bend radius: How much space is required to accommodate the cables and/or hoses? What are their minimum bend radii?
- Ingress protection: Will there be debris present in the working area, such as wood chips, swarf, or dirt? Do the cables or hoses need to be protected from this debris? What about water or chemicals? Open cable carriers make it easier to access cables but closed cable carriers are required for good ingress protection.
- Corrosion resistance: Will the machine operate in a humid or corrosive environment? Are there any other considerations of chemical resistance? This is particularly important for metal cable carriers were corrosion resistant alloys or coatings may be required.
- Is physical damage a consideration? If there is a risk of significant impacts or wear then an armored cable carrier may be required to resist this.
- What is the required operating temperature range?
- What vibrations will the machine be subjected to? Some designs of cable carrier will damp vibrations better than others.
- Will the machine be operating in a clean room environment? This would mean that a low-wear cable carrier is required which does not produce particulate matter as bearing surfaces wear.

The first cable carriers were constructed in metal. Metal cable carriers have now been replaced by plastic for most applications. Plastic is less costly, self-lubricating, corrosion resistant, and provides adequate protection for most applications. Plastic can also form a flexible continuous boot, for a completely sealed closed cable carrier. Metal cable carriers remain able to carry the highest loads and operate in the highest temperatures. They therefore still have a role for large machinery and harsh environments.

LUBRICATION OF STEEL CABLE CARRIERS

Often used in highly corrosive environments, steel cable carriers provide a high strength-to-weight ratio and maximum unsupported spans. They usually feature a special coating to resist corrosion from chemicals and other abrasive materials.

Generally, lubrication isn't required. Should it be required, certain applications have more abrasive environments where a dry lubrication is required, but in the majority of applications, lubrication of the steel chain is not required.

For applications that require real lubricity where you need very low friction on a steel track, you can use self-cleaning links.

In addition, the manufacturer can install wear discs — often made of nylon — ahead of time, in between the steel, to reduce friction. This offers some added lubrication, if this is required.

The obvious downside of lubrication is it's going to pick up dirt and contaminants. If you lubricate with a W-40 or something like that, it's going to pick up particulate or debris near it, which is not a good thing for the cable carrier or the cables housed inside of it.

HOW TO SPECIFY **PLASTIC CABLE CARRIERS**

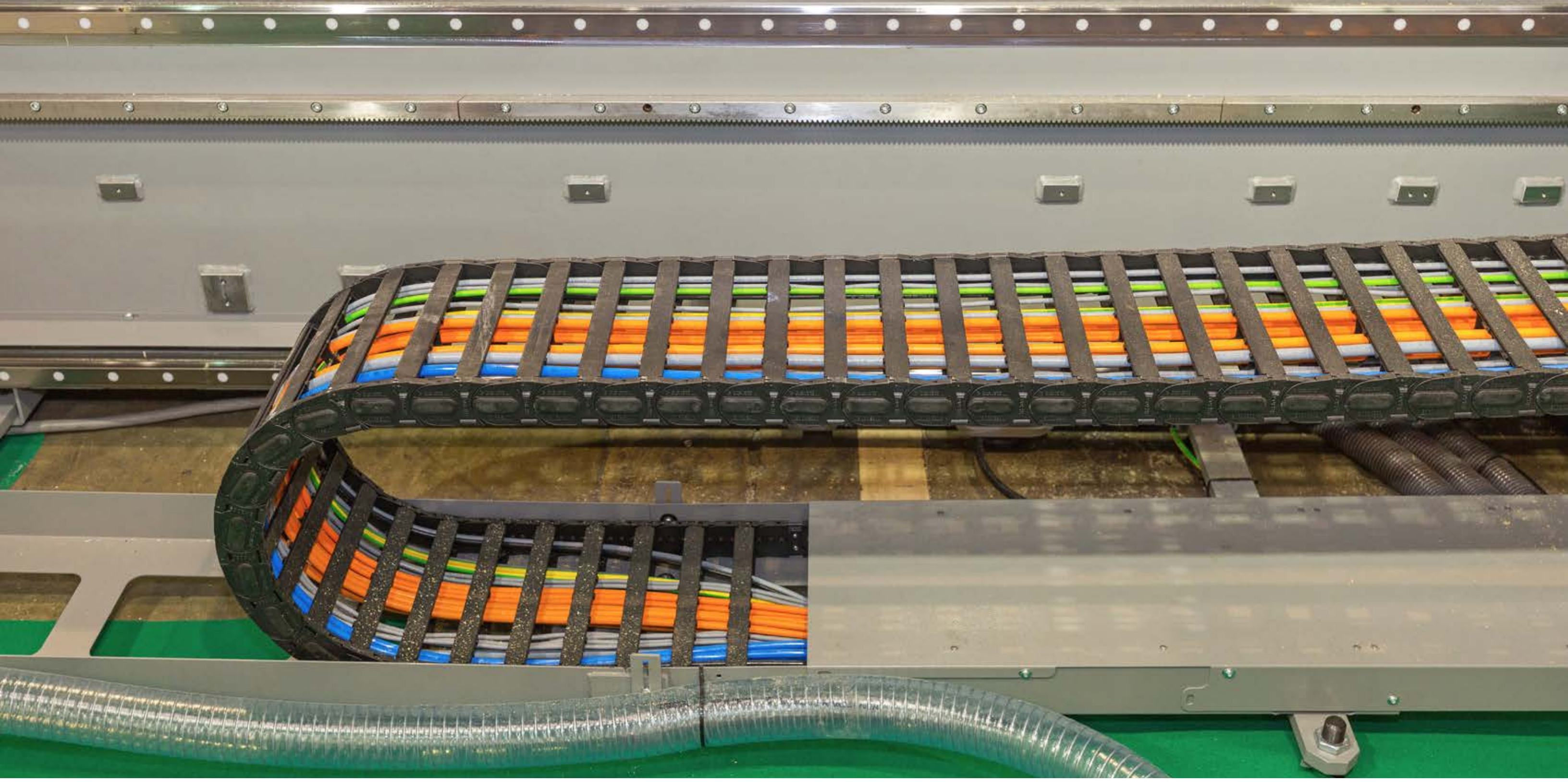
Plastic cable carriers are fitted to machines to protect and guide cables and hoses. Cable carriers are constructed as a chain of rigid plastic sections. These form an articulated rectangular box section through which cables and hoses are inserted. Enclosing the cables and hoses prevents some formsof damage. The articulated nature of cable carriers allow machine motion while constraining the cables to a defined path and limiting the bend radius. This prevents the high stresses that can occur if a cable is forced into a very tight bend radius, while also preventing entanglement or entrapment in moving machinery.

Although the first cable carriers were made from steel, plastic cable carriers are now more common. They are better suited to most applications, except where very high loads or temperatures will be encountered. Advantages of plastic include corrosion resistance, ability or easily form into complex shapes, self-lubrication, and lower cost.

When specifying a cable carrier, the cables and/or hoses that it must carry should first be considered. Important considerations include the diameters of the cables, their minimum bend radius, and their weight per unit length. Weights for hoses must include fluids they carry. The machines total travel distance is also vital. Most applications will require a single linear motion, but cable carriers can also be specified for multi-axis motion and rotation. Given these parameters, the cable carrier can be sized to suit the application.

It is also important to consider the operating environment. This will include any debris or fluids present, humidity and the presence of corrosive chemicals, temperature, vibration, and any clean room requirements. If ingress protection is required than a closed cable carrier will be required. Humidity and corrosion are generally not a problem for plastic cable carriers but some chemicals may be. Temperatures of over 600 degrees will normally require a metal cable carrier and even significantly lower temperatures will cause issues for some plastic cable carriers. If there is any concern over chemical resistance or temperature, check the cable carrier specification. If operating in a clean room environment it is important that any particulate matter produced by wear will be within the allowance for the clean room specification.

e-chain® cable carriers can travel more than 2,600ft, even in extreme weather conditions. Image courtesy of igus.



TEMPERATURE LIMITATIONS **OF PLASTIC CABLE CARRIERS**

Many types of plastic are used in cable management systems, but the most common standard plastic that most people use is glass-filled nylon or nylon six.

This material is best suited to applications that range in temperatures from –40° to 240°F on the high end. However, this operating temperature range can be increased by using special plastics or additives to increase longevity, durability and strength.

Although using these special additives or materials, operating outside of this realm can reduce mechanical values and service life.

Additionally, you must consider the cables or hoses that will be installed in the cable track. If you're using standard cables or hose, you can use standard cable tracks. However, if your hose or cables are rated for extreme temperatures, you must find a matching cable management system.

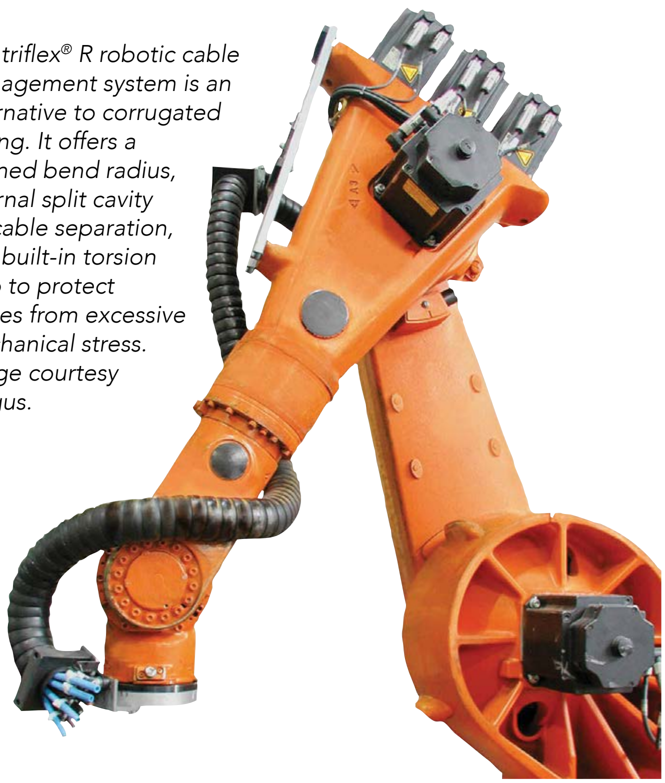
Finally, consider whether the application is indoors or outdoors, as different materials may have UV resistance that should also be included in outdoor, high-temperature applications.

ALL ABOUT MULTI-FLEX CABLE CARRIERS USED ON ROBOTIC ARMS

Good cable management is vital to the accurate and reliable operation of an industrial robot. Cables that catch and snag will affect the accuracy of a robot. Over time they will result in unplanned maintenance and excessive downtime. Robotic cell integrators have identified cable issues as the most significant cause of downtime.

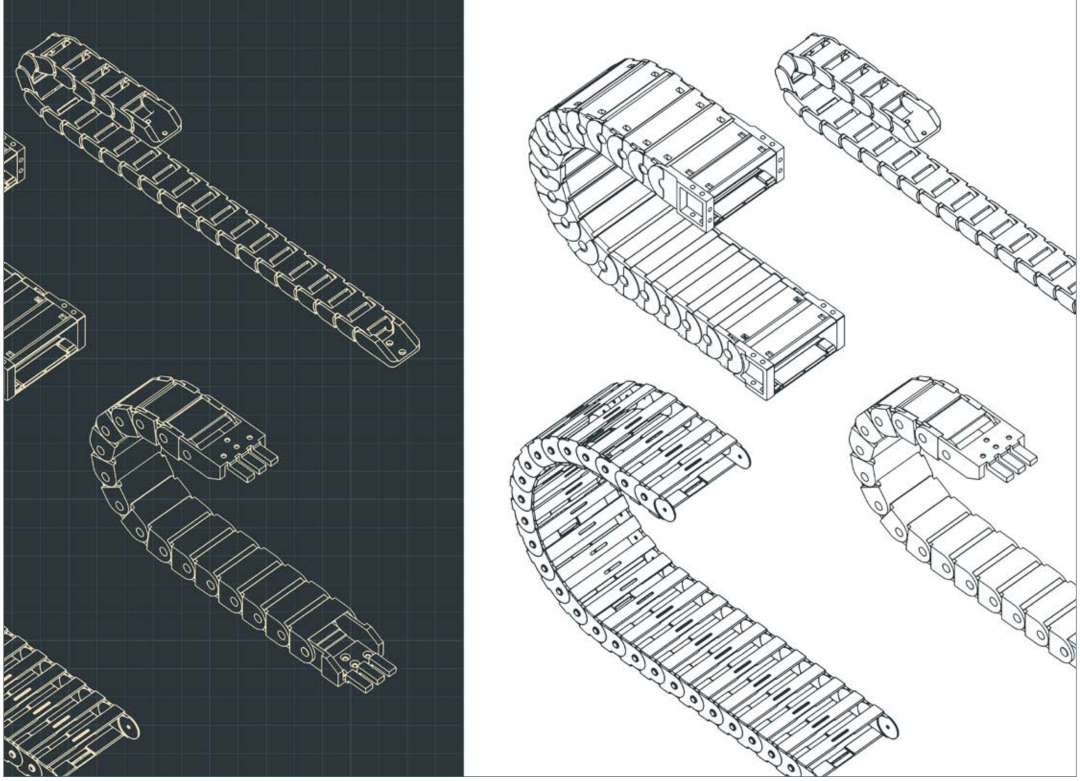
While standard chain-link style cable carriers can only bend in a single plane, multi-flex cable carriers can be bent in any direction. The simplest construction for a multi-flex cable carrier is a corrugated tube. Available as flexible conduit, these tubes provide a low cost way to protect cables and hoses while flexibly routing them in any direction. However, for the smooth drag-free motion and robust cable protection required on industrial robots, a more sophisticated approach is required. Typically, ridged circular segments are joined into an articulated round chain that can flex in any direction. This approach provides a smooth predictable motion with little resistance to bending until a hard limit is reached at which point there is a very robust protection against bending beyond the minimum bend radius.

The triflex® R robotic cable management system is an alternative to corrugated tubing. It offers a defined bend radius, internal split cavity for cable separation, and built-in torsion stop to protect cables from excessive mechanical stress. Image courtesy of igus.



Several methods are used to construct articulated multi-flex cable carriers. Some designs use a flexible central spine which supports rings held on spokes. This creates an open cable carrier, with the gaps between the rings providing easy access to cables. The bend is limited by contact being made between the rings. Another approach is to use segments with partial spherical surfaces which are articulated with each joint forming a spherical joint.

When installing cable carriers on a six-axis robot, it's best to consider the robot in three segments. This allows the cables to move with the robot, preventing tangling, snagging and corkscrewing. The first segment wraps around the base of the robot, allowing the first axis to rotate. This segment should use a multi-axis reverse-bend cable carrier, terminated in a junction box on the second axis. A modular multi-axis cable carrier should then be used between the second and third axis, with a junction box on the third axis. The final cable carrier then runs through to another junction box at the end effector. Strain-relief cables should be used throughout.



IS AN OPEN OR CLOSED CABLE CARRIER **BETTER FOR MY APPLICATION?**

Open cable carriers have an open chain-link structure with cross bars that contain cables and hoses. Enclosed cable carriers form a complete tube, this can be achieved using a chain-link structure with sliding covers, or as a homogeneous fully sealed corrugated tube, such as a flexible conduit. All cable carriers prevent wear, damage and snagging, by guiding and protecting cables and hoses. Closed cable carriers also provide protection against contaminants. If there is a risk that foreign bodies such as metal chips, or corrosive chemicals, could damage cables, then a closed carrier is the best choice. Where contaminants are not expected to cause any issues, open carriers are often a better choice. Open carriers provide easy access for cable replacement, are lighter and also enable visual inspection of cables. Open carriers are also often less costly

When selecting a closed carrier, the type of contaminant and level or protection will be key considerations. Contaminants can include debris such as metal chips or fluids. Large debris moving at speed may require an enhanced level of mechanical protection, while fluids may be corrosive. Both open and closed cable carriers are available in metal or plastic. While humidity will accelerate corrosion in metal carriers, some chemicals may be more problematic for plastic cable carriers. If there is a requirement to shield cables from very high temperatures then a metal cable carrier may be required.

Chain-link style enclosed conduits provide the greatest mechanical protection. They have clearly defined limits on bend radius and smooth motion. However, they involve sliding contacts which are difficult to seal completely against small particles and fluids. Corrugated tubes provide a completely sealed cable carrier, but with lower levels of mechanical protection and, especially against heavy forces resulting in a tight bend radius. Another approach to fully enclose cables is to use an open cable carrier with a secondary sliding channel which provides a seal around it. This can be a cost-effective solution, especially for long travels.

Other critical considerations when selecting any cable carrier include the bend radius, sizes and weight of cables, travel distance and axes of motion.

PRE-HARNESSED (PRE-ENGINEERED) CABLE-CARRIER ASSEMBLIES PRELOADED WITH CABLES AND HOSES

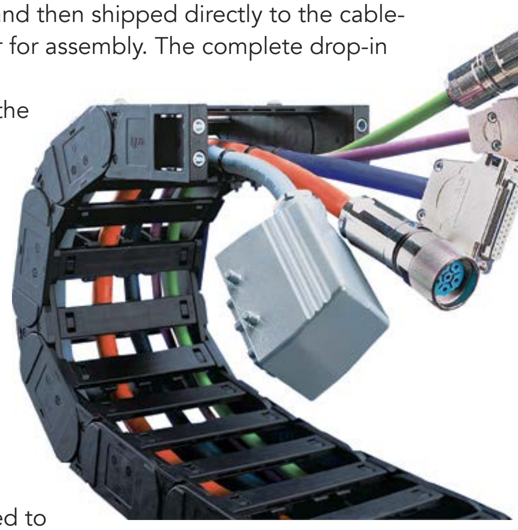
Cable carriers are hollow chains which guide and protect cables and hoses during motion. They are typically installed on-site with the cables and hoes fitted through manifolds and junction boxes, and fixing plates, brackets and guide or support structures installed. Although it can make sense to carry out this work in-situ, it is also possible to buy-in a pre-engineered assembly. This can greatly simplify and accelerate a new installation. Purchasing a turn-key solution is especially useful in harsh environments or where there are access constraints, such as off-shore or on bridges.

A pre-harnessed cable-carrier may simply consist of the required set of cables and/or hoses, fitted into a cable carrier. This will normally include end connectors, but it might also include custom brackets to allow drop-in replacement, junction boxes and manifolds, guidance and support structures, enclosures, or safety mechanisms.

Supports and guide trays are often fabricated to suit a specific installation and it therefore makes sense to have these supplied with a pre-harnessed cable-carrier assembly. Some applications may require self-aligning brackets to allow for misalignment or movement in the structure or machinery to which the cable-carrier is attached. For very long travel applications, support structures can be fitted with carriages running on rollers which guide and support the carrier with minimal friction. Other special support and guide structures might include sliding covers or roll-up doors.

Special bars may be used when it is vital for cables and hoses to maintain accurate separation and alignment with the neutral axis of the cable-carrier. These special bars can be machined with holes sized and positioned to suit the particular configuration of cables and hoses for the installation.

Pre-engineered cable-carriers can be fully specified by the end user, with the cable-carrier manufacturer supplying the complete assembly to this specification. Alternatively, cables, houses, brackets and other components may be ordered from separate suppliers and then shipped directly to the cable-carrier manufacturer for assembly. The complete drop-in system can then be directly shipped to the installation site.



Some applications need a rapid and dependable installation, meaning that a pre-engineered cable-carrier assembly really makes sense. These include situations where there is a need to minimize downtime, as well as where there are access constraints or harsh environments. Drop-in pre-harnessed carrier assemblies are, therefore, often used in military and off-shore applications. In these cases, the carrier assembly may be supplied on a storage reel further simplifying handling, storage and installation.

DIFFERENT WAYS TO SECURE CABLE TRACKS **(CABLE CARRIERS) TO MACHINERY**

Cable carriers guide and protect electrical cables, as well as hydraulic or pneumatic hoses. They limit the minimum bend radius and therefore bending stresses, while often also constraining bending to a single plane. They shield and protect cables from wear, prevent entrapment in moving machinery and avoid entanglement. To do this effectively, it is essential that the cable carrier is properly secured to machinery. The method of securing will depend on the type of cable carrier being used. As a minimum, all cable carriers should be securely fastened at each end, using an end connector, mounting surface or junction box. Depending on the type, some additional guiding or securing may also be necessary.

The drag chain style of cable carriers are the most common type. They limit bending to a single plane and are typically used for linear motion applications. This type of carrier usually has a special link at each end with a flat mounting surface containing holes for fasteners. This may be bolted directly to a flat surface, or often to an angled bracket allowing it to be secured to a surface which is perpendicular to the cable run. These cable carriers may be supplied in standard lengths, with end connectors fitted at each end, or be modular in construction. Modular cable carriers are made up of individual chain links which typically snap together using a push-fit connection. When constructing these modular cable carriers, end connectors must be specified and installed.

Longer drag chains, typically over 5 m in length, will operate more reliably if they run in a guide trough. This channel section provides a low friction surface on which the cable guide can run without snagging. Guide troughs must also be securely fastened to the machine or floor. Typically, they have feet installed at regular intervals for this purpose.

Multi-flex cable carriers permit bending in any direction and are often used on multi-axis robots. This type of cable carrier still needs to be secured at each end but also often requires securing at a number of points in-between. Multi-flex cable carriers are normally terminated at each end at a junction box. The links are secured at the junction boxes and intermediate points along the length using clamps. These clamp around the circumference of the cable carrier and provide feet to secure the clamp to a surface with bolts.