Designing with Flexible Flat Cable

A unique silicone flat cable delivers high performance in tough applications.

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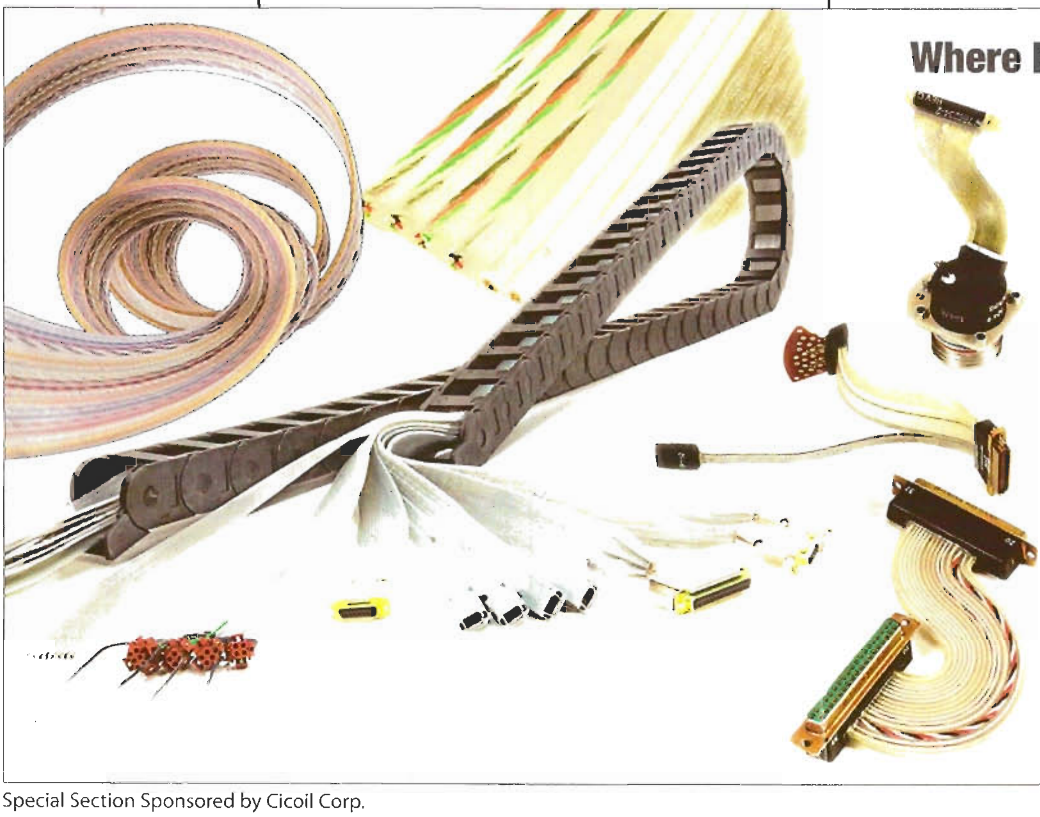
Most engineers think of flat cable as inexpensive wiring that runs between computer peripherals. But not all flat cable is created the same. There is a special category of flat cable that excels in uses where space efficiency isn't the only consideration. What's called Extruded Silicone cable is designed specifically for motion control and automation where flexibility, strength, and space economy carries a premium.

An Extruded Silicone cable is a collection of wire conductors that has been encased in a silicone jacket by means of a special extrusion process. The most typical form factor for these cables is that of a flat cross section with conductors lined up in parallel. But cables can be extruded in other shapes to handle specific needs, such as to snug-fit into a wiring channel.

Extruded cable technology is unique to Cicoil Corporation, based in Valencia, California. The basic technology of encasing conductors in silicone jackets has been in use for over 50 years and can be found in diverse applications ranging from jet fighters to industrial motion control equipment. A recent development is the ability to manufacture silicone-jacketed cable in continuous lengths through use of a proprietary extrusion process (Fig. 1 on next page). This reduced costs, improved precision, and made it possible to manufacture long cable lengths that were impractical with older methods. These older methods involved molding wires in silicone, and curing the resulting cable for up to two days.

FLAT VERSUS ROUND CABLES

It is also useful to contrast the make-up of Extruded Silicone flat cable with the construction of typical round "flex" cable. Round cables generally are characterized by insulated wires in a bundle which is surrounded by several layers of other material. The bundle is usually wrapped in either a textile material or a polymer chosen to minimize frictional heating as the cable moves. A PVC jacket surrounds these layers. In shielded cables, there is an



Where Flat Cable Excels

Extruded flat cable is available in a wide variety of configurations, enabling engineers to optimize the cable package for the application. The silicone rubber jacket, and the use of high-flex conductors, make it twice as flexible as other widely used types of flat cables, and ideal for flexing, repetitive motion applications. The silicone jacket provides a waterproof case resistant to extreme heat and cold.

Cicoil Extrusion Process

The exclusive Cicoil extrusion process produces silicone cables in continuous lengths.

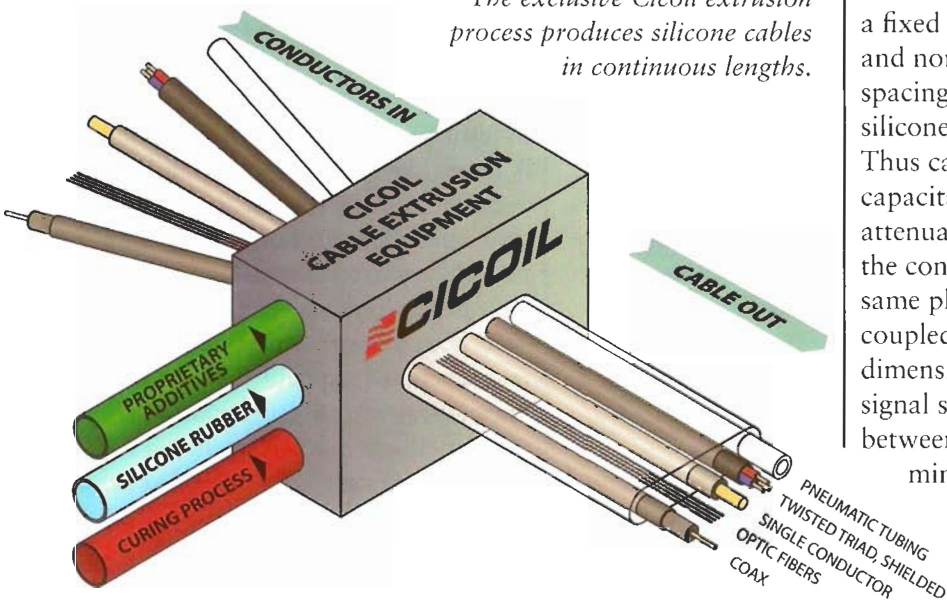


Fig. 1

additional set of layers consisting of another low-friction wrap, braided copper, and an overall jacket of PVC or other material selected for abrasion resistance. A point to note about this construction is its use of multiple layers of insulation and special low-friction materials necessary to reduce the friction that arises as cables go through numerous cycles of repetitive motion (Fig. 2).

Round "Flex" Cable

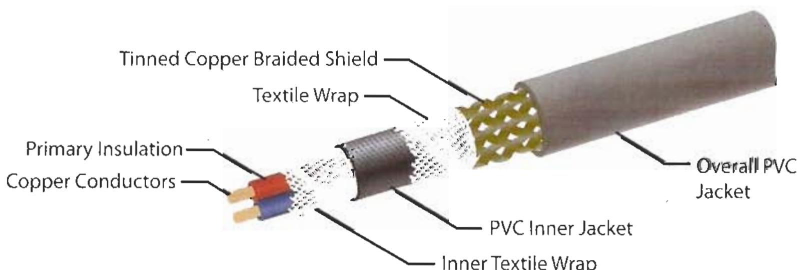


Fig. 2

For comparison, an Extruded Silicone cable also makes more efficient use of insulating material. It needs no low-friction tapes and fillers because conductors don't move within the silicone material that forms the outer jacket. And when bent in the plane of its thin cross section, Extruded Silicone has inherently more flexibility than round cable. The flat form factor of Extruded Silicone also provides better heat dissipation than round cables because there is more surface area for a given volume. The larger surface area lets flat cables carry a higher current level for a given temperature rise and for conductors of a given cross section. Conductors in flat cable also have a fixed geometry that makes for consistent and non-varying electrical qualities. The spacing of conductors in the extruded silicone never changes as the cable moves. Thus cable impedance, inductance, capacitance, time delay, crosstalk, and attenuation all remain constant. Similarly, the conductors in the cable all have the same physical and electrical length. This, coupled with the fact that the dielectric dimensions stay constant, means that signal skewing and differential time delays between signals in the cable stay at a minimum.

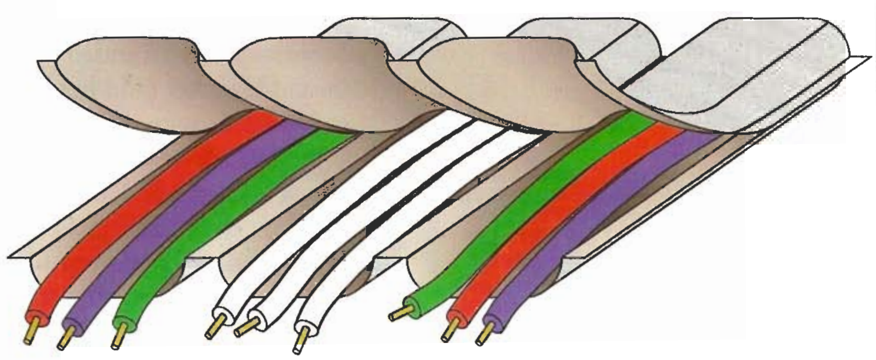
Finally, flat cables can form an inherently high-density interconnect system. Packing density of flat cable is higher than is possible with round cables. The fact that conductors can be visible in the silicone extrusion simplifies coding, inspection, and tracing circuits for trouble shooting.

EXTRUDED SILICONE VS. OTHER FLAT CABLES

In addition, it is illustrative to compare Extruded Silicone cable with other types of flat cable. The type of flat cable used in computer peripherals is often called ribbon cable. It is inexpensive and easy to terminate because its geometry is standard. Its conductors are laid out in a standard pitch so insulation displacement connectors (IDCs) for ribbon cable are a standard item. The jacketing material is usually PVC, though some special-purpose ribbon cables may use other materials to handle high or low temperatures or applications that demand plenum-rated cabling.

The problem with ribbon cable is that it is not designed for repetitive flexing. Its PVC jacketing is relatively brittle. There are special-purpose jacketing materials exhibiting more flexibility, but they tend to lack mechanical toughness and resistance to harsh chemicals. In addition, ribbon cables are only available in a single wire gauge for all conductors (28 AWG) which limits their use.

2-Piece PTFE Cable Construction



Two PTFE shell halves are sintered together to produce wire jackets.

Fig. 3

There is another type of flat cable that uses PTFE (also known as Teflon®) as a jacketing material. This material has a reputation for low friction, and flat cables made with PTFE jackets target applications that demand a long life despite repeated flex cycles. One problem with PTFE flat cables is that their manufacturing process induces potential weaknesses in the cable. PTFE cabling is created by sintering together two half shells of PTFE material that sandwich conductors in between (Fig. 3). The seam formed by the two half shells is a point of weakness that can eventually rupture after repeated flexing. Once ruptured, PTFE cable cannot be repaired; it must be replaced.

Moreover, wires in the PTFE jacket are not held in place within the jacketing material. They can creep from their initial position or be pulled out of place by forces from the connections at the ends of the wires. To head off such difficulties, PTFE flat cable employs clamps at regular intervals along the cable, which adds cost and weight to the overall design. In linear motion applications, for example, these drawbacks of PTFE cable result in higher inertias for the motor to overcome, increased system vibration, and longer settling times, all of which reduce the performance of the system.

In contrast to this behavior, Extruded Silicone cable needs no clamping system because the conductors can't creep out of the silicone encasing them. The encapsulating silicone also acts as a shock absorber, damping and reducing vibration. This further lengthens the life of the cable in applications characterized by severe shaking and oscillations.

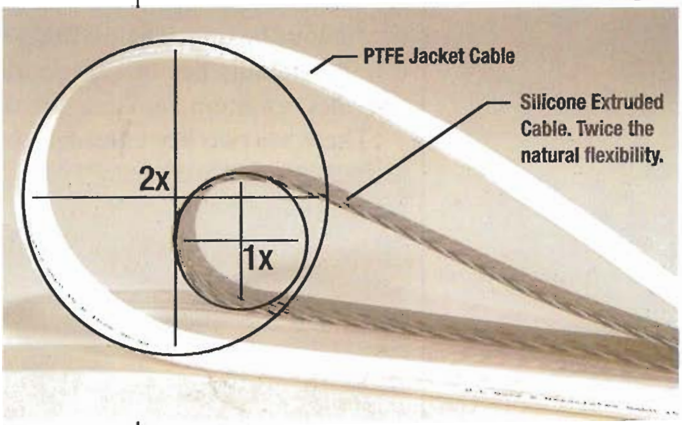
When Extruded Silicone cables get a nick or puncture, they are self healing. The flexible silicone rubber closes around small discontinuities. Larger holes or cuts can be repaired in the field with RTV.

DESIGN CONSIDERATIONS

Specifying cable in applications characterized by repeated motion should allow for four key qualities: allowable bend radius, life cycles under constant flexing, package constraints, and environmental factors.

The bend radius of Extruded Silicone cable, like that of any cable, depends on the gauge of the wire and type of conductors used in the cable. In general, the finer the gauge of the conductors, the smaller the allowable bend radius. It should be noted, however, that competing cables using PTFE jackets have a bend radius more than twice as large as Extruded Silicone cables, given that each cable contains the same conductors (Fig. 4). Thus Extruded Silicone cables can serve in uses that may not be suitable for PTFE cables, as they will fit in a more compact space.

Fig. 4



Most industrial automation equipment today operates 24/7, often with robotic elements that execute rigorous motions repeatedly, sometimes thousands of

Cicoil's unique flat cables hold a variety of conductors and can be shaped into profiles that are optimized for specific applications.

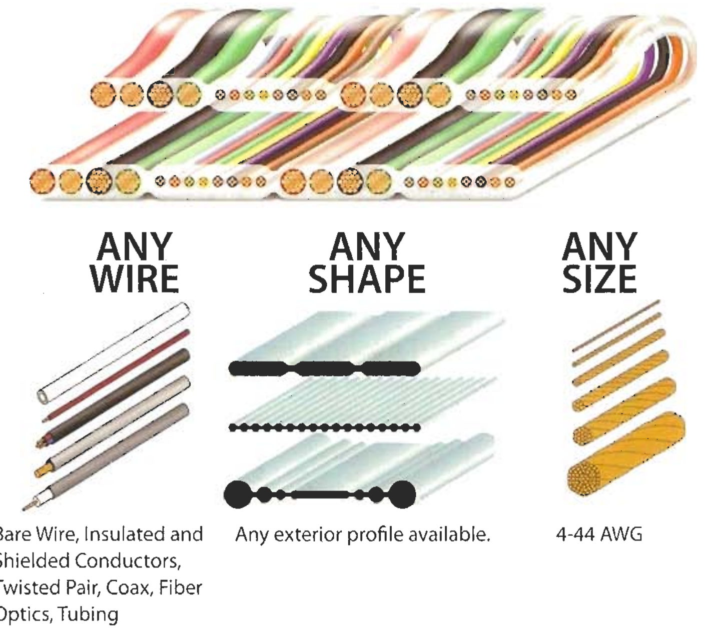


Fig. 5

times a day. These applications stress not only the moving parts of the machine, but also the electrical cabling. Engineers spend considerable time sizing electromechanical movers, but often give little thought to whether the cabling is sized properly. The frequent result is that the cabling won't handle the rigors of the application, resulting in costly premature failures.

In fact, industry research has shown that wiring and cabling causes over 50% of the quality and reliability issues in automation equipment. For these reasons, designers should plug in a safety factor to ensure cabling will meet flex-cycle needs.

Standard cabling will not last in these applications, as the cables are not designed to flex continuously. Flat cables are best for continuous flexing. Their wire conductors can individually flex in a single plane, which provides optimum flex life.

There are two key considerations for cable that must last a long time in flexing applications: the wire conductors and the cable jacket.

Under continuous flexing, conductors containing multiple strands of fine-gauge wire will last the longest. For example, standard 28 AWG is typically composed of 7 strands of 36 AWG wire, while 28 AWG high-flex wire is composed of 19 strands of 40 AWG wire (or even finer gauge). The finer-gauge base wire exhibits less cold-working under constant flexing. The minimal cold-working lets these wires last through tens of millions of flexing cycles.

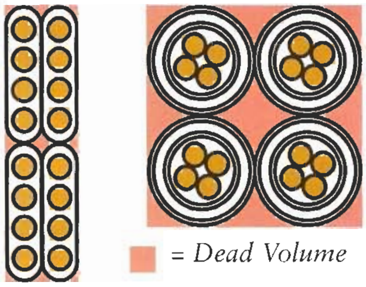
Given cabling that contains finely stranded wire, the cable jacket (and how the jacket holds wire conductors) is the next determinant of a long flexing life. PVC or other thermoplastic jackets are too brittle to withstand continuous flexing, so most high-flex cables use PTFE or silicone rubber as the primary cable jacket. PTFE and silicone rubber can both withstand tens of millions of flexing cycles. However, silicone rubber is a better choice for uses involving extremely tight bend radii, as it is inherently more flexible than PTFE.

Another benefit of Silicone Extruded cables is that the wire conductors are completely encased in the silicone rubber, versus being loose inside a typical PTFE cable. Loose wires will rub against each other, increasing friction, cold working, and reducing wire life. PTFE cables often need additional clamping throughout their length to minimize such effects, which raises the system's cost and weight/inertia. In contrast, Extruded Silicone cable's encapsulation of individual conductors optimizes wire life in continuous-flexing applications.

Space is increasingly a factor as companies continue to add features and capabilities to automated machines and processes. The premium paid for industrial floor space has forced machine footprints to shrink. The result is often a mandate to do more in less space. In this environment, the design of cabling is often an afterthought. Cable runs are frequently 'stuffed in' to leftover space. But the usual result is less-than optimum, and it can lead to unforeseen maintenance or troubleshooting issues.

Engineers should consider cabling early in the design process; not only assessing space considerations, but also assembly and accessibility criteria. Generally, round cabling will take up more space than flat cable, as the geometry of flat cabling inherently saves space (Fig. 6). Within flat cable, however, not all cable types are equally space-efficient. PTFE flat cable, for example, is limited to pre-formed shapes, as the wires are inserted into 'pods' formed by the PTFE jacket.

Fig. 6



Flat cables are more space-efficient than round cables.

The result can be less than optimum, as the designer is limited to pre-existing cable profiles.

Silicone Extruded cable, however, can be produced with exactly the size and shape needed for the conductors it contains. Conductor spacing can be precisely controlled, as can the thickness of the silicone rubber jacketing, to give exactly the dimensions the application demands. In addition, Silicone Extruded cable can be produced with any outside profile (Fig. 5, opposite). This lets the cable shape be optimized for the specific space at hand.

Another unique feature of Silicone cabling is its ability to be 'formed' into S curves and other non-linear shapes (Fig. 7). This lets the designer bend the cable around obstructions to promote extremely compact packaging. This type of 'curved flat cable' has been used for many years in supersonic missiles and military aircraft to save space and weight. It also is becoming more frequently used in industrial applications.

Silicone extruded cable can be shaped in the lateral plane to further optimize space utilization.

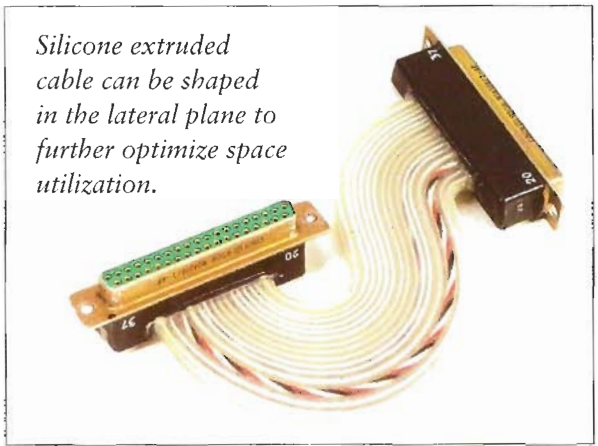


Fig. 7

Temperature index is the temperature at which a material will sustain burning when the oxygen concentration in the air mixture is 20.9%. A typical silicone rubber base has a temperature index of around 250°C. Extruded Silicone cables are rated for operation in temperatures of -65°C to +260°C (Fig. 8).

Silicone retains room-temperature flexibility and other qualities throughout its -65°C to +260°C operating range. In addition, the linear coefficient of thermal expansion for Cicoil silicone rubber is extremely low (about 0.00018 in/in/°F) while the linear coefficient of thermal expansion for PTFE is approximately 4.7 times as much (0.00085 in/in/°F). This means that extruded silicone cable will retain its package size much better than will PTFE cables throughout wide temperature ranges, which may be important in applications involving extremely tight spaces.

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Fig. 8
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