US Patent & Trademark Office
Patent Public Search | Text View

United States Patent	12384058
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Forget; Jean-François et al.

Signal transmission device for articulated mechanism

Abstract

A robotic arm having at least pair of structural members rotatably coupled to one another, with a first one of the structural members defining a central passage. A communications link is at least partially within the robotic arm for signal transmission between within the robotic arm. The communications link includes a signal transmission device having a coiled portion, with ends of the coiled portion adapted to be connected to parts of the communications link, whereby the coiled portion is a segment of the communications link. The coiled portion has one of its ends connected to the second one of the structural members to rotate with the second one of the structural members, the other of the ends of the coiled portion connected to a component associated with the first one of the structural members through the central passage to rotate with the first one of the structural members, at least a portion of the coiled portion expanding or contracting radially during relative rotation between the pair of structural members.

Inventors:	**Forget; Jean-François (Montreal, CA), Frigon; Nicolas (Laval, CA)**
Applicant:	**KINOVA INC.** (Boisbriand, CA)
Family ID:	**1000008751681**
Assignee:	**KINOVA INC. (Boisbriand, CA)**
Appl. No.:	**18/260544**
Filed (or PCT Filed):	**January 07, 2022**
PCT No.:	**PCT/CA2022/050013**
PCT Pub. No.:	**WO2022/147619**
PCT Pub. Date:	July 14, 2022

Prior Publication Data

Document Identifier	Publication Date
US 20240051157 A1	Feb. 15, 2024

Related U.S. Application Data

us-provisional-application US 63135122 20210108

Publication Classification

Int. Cl.: **B25J19/00** (20060101)

U.S. Cl.:

CPC **B25J19/0033** (20130101); **B25J19/0041** (20130101);

Field of Classification Search

CPC: B25J (19/0029); B25J (19/0041)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
7559590	12/2008	Jones	901/29	B25J 19/0041
9713247	12/2016	Lida	N/A	H05K 1/025
10913165	12/2020	Jonas	N/A	B25J 19/0041
11147731	12/2020	Varghese	N/A	B25J 9/0006
11305438	12/2021	Yamazaki	N/A	B25J 9/1674
11331816	12/2021	Muneto	N/A	B25J 19/0029
12103180	12/2023	Sansfaçon et al.	N/A	H02K 21/24
12109694	12/2023	Kastler	N/A	G02B 6/3874
2013/0270399	12/2012	Berkowitz	248/65	B25J 19/0029
2015/0114162	12/2014	Kirihara et al.	N/A	N/A
2015/0128748	12/2014	Rueb	N/A	N/A
2019/0118316	12/2018	Takahara	N/A	B23Q 17/2241
2020/0361081	12/2019	Caron L'Ecuyer et al.	N/A	N/A
2022/0118634	12/2021	Pfister	N/A	B25J 9/102
2023/0249367	12/2022	Radin-Macukat	74/490.02	B25J 19/0029

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
3100992	12/2017	CA	N/A
102019120116	12/2020	DE	B25J 19/0029
20120008743	12/2011	KR	N/A

Primary Examiner: Cook; Jake

Attorney, Agent or Firm: NORTON ROSE FULBRIGHT CANADA LLP

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) The present application claims the priority of U.S. Patent Application No. 63/135,122, filed on Jan. 8, 2021 and incorporated herein by reference.

TECHNICAL FIELD

(1) The present application relates to the field of robotics involving mechanisms such as articulated mechanisms and robot arms and to signal transmission through such articulated mechanisms.

BACKGROUND OF THE ART

(2) Robotic arms are increasingly used in a number of different applications, from manufacturing, to servicing, and assistive robotics, among numerous possibilities. In robotic arms, body members (also known as links) may be interconnected by motorized joints, the body members respectively connected to opposite rotating parts of a motorized joint.

(3) Due to the relative rotation between links of a robotic arm, various systems have been devised for signal transmission along the robotic arm, for instance to control the motorized joints. For example, slip rings are used as an interface between the adjacent links. It is however known that slip rings may be exposed to degradation due to inherent friction. Moreover, the limited signal transmission capacity through slip rings is such that some industrial robots communicate internally with low-speed buses only meant for robot control. Consequently, there is a limit on the types of tooling and sensors that may be connected at the end effector of robot arms. In some instances, it may be required that externally-run wires be used. These wires may be difficult to rigidly fix, difficult to keep clean, may be prone to damage, and may reduce the range of motion of the robot by introducing an artificial constraint.

SUMMARY

(4) It is an aim of the present disclosure to provide a mechanism such as a robot arm that addresses issues related to the prior art.

(5) Therefore, in accordance with a first aspect of the present disclosure, there is provided a robotic arm comprising: at least pair of structural members rotatably coupled to one another, with a first one of the structural members defining a central passage; a communications link at least partially within the robotic arm for signal transmission between within the robotic arm, the communications link including a signal transmission device having a coiled portion, with ends of the coiled portion adapted to be connected to parts of the communications link, whereby the coiled portion is a segment of the communications link, wherein the coiled portion has one of its ends connected to the second one of the structural members to rotate with the second one of the structural members, the other of the ends of the coiled portion connected to a component associated with the first one of the structural members through the central passage to rotate with the first one of the structural members, at least a portion of the coiled portion expanding or contracting radially during relative rotation between the pair of structural members.

(6) Further in accordance with the aspect, for example, the second one of the structural members defines a receptacle, the coiled portion being received in the receptacle.

(7) Still further in accordance with the aspect, for example, at least one tab projects from a wall of the receptacle to hold the coiled portion captive in the receptacle.

(8) Still further in accordance with the aspect, for example, one of the ends of the coiled portion is fixed to a wall of the receptacle.

(9) Still further in accordance with the aspect, for example, the signal transmission device has a ribbon cable construction.

(10) Still further in accordance with the aspect, for example, the communications link has one or more data communication buses enabling data communication at rates from 10 mbit/sec to 20

gbit/sec inclusively.

(11) Still further in accordance with the aspect, for example, the communications link includes Ethernet signal transmission.

(12) Still further in accordance with the aspect, for example, the communications link includes USB signal transmission.

(13) Still further in accordance with the aspect, for example, the communications link includes Ethercat signal transmission.

(14) Still further in accordance with the aspect, for example, the coiled portion is impedance controlled actively or passively.

(15) Still further in accordance with the aspect, for example, the signal transmission device includes an elongated portion extending from one of the ends of the coiled portion into the central passage, the elongated portion having an end fixed in rotation to the first one of the structural members.

(16) Still further in accordance with the aspect, for example, the elongated portion and the coiled portion have a continuous integral ribbon cable construction.

(17) Still further in accordance with the aspect, for example, the coiled portion lies in a plane, and the elongated portion extends from the coiled portion in a direction normal to the plane.

(18) Still further in accordance with the aspect, for example, the coiled portion lies in a plane, and wherein an axis of rotation between the pair of structural members is normal to the plane.

(19) Still further in accordance with the aspect, for example, a PCB is fixed to the second one of the structural members and is communicatively connected to the coiled portion.

(20) Still further in accordance with the aspect, for example, the communications link includes a sequence of PCB-signal transmission device-PCB-cable-PCB-signal transmission device-PCB-cable- . . . .

(21) Still further in accordance with the aspect, for example, a window is defined in a cover plate on one of the structural members to monitor the coiled portion.

(22) Still further in accordance with the aspect, for example, the communications link includes at least one of a repeater, an amplifier, a switch.

(23) Still further in accordance with the aspect, for example, a curve radius of the coiled portion is between 12 mm and 30 mm.

(24) Still further in accordance with the aspect, for example, the communications link has a high speed communication port or connector at an end effector interface.

(25) Still further in accordance with the aspect, for example, the high speed communication port or connector is wired internally.

(26) Still further in accordance with the aspect, for example, the high speed communication port or connector is a RJ45 connector.

(27) Still further in accordance with the aspect, for example, the high speed communication port or connector uses centrally-oriented and reversible spring-loaded connectors adapted for communication with an end effector.

(28) Still further in accordance with the aspect, for example, the high speed communication port or connector is a M8 connector.

(29) Still further in accordance with the aspect, for example, the high speed communication port or connector is a M12 connector.

(30) Still further in accordance with the aspect, for example, the coiled portion allows for rotational movement between the pairs of structural members of at least one complete revolution.

(31) In accordance with another aspect of the present disclosure, there is provided a robotic arm comprising: at least pair of shells rotatably coupled to one another, with a first one of the shells defining a central passage, and a second one of the shells defining a receptacle; a signal transmission device having an elongated portion and a coiled portion, with connectors at the end of the elongated portion and at the end of the coiled portion, wherein the elongated portion extends

through the central passage, and the connector at the end of the elongated portion rotating with the first one of the shells, wherein the coiled portion is received in the receptacle, the connector at the end of the coiled portion rotating with the second one of the shells, the coiled portion expanding or contracting diametrically during relative rotation between the pair of shells.
(32) In accordance with another aspect of the present disclosure, there is provided a robotic arm comprising: at least pair of shells rotatably coupled to one another, with a first one of the shells defining a central passage, and a second one of the shells defining a receptacle; a signal transmission device having a coiled portion, with connectors at the ends of the coiled portion, wherein the coiled portion is received in the receptacle, the connector at one end of the coiled portion rotating with the second one of the shells, the connected at the other end of the coiled portion connected to a component associated with the first one of the shells, the coiled portion expanding or contracting diametrically during relative rotation between the pair of shells.

Description

DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a perspective view of an articulated robot arm in accordance with an embodiment of the present disclosure;
(2) FIG. **2** is a perspective view of an exemplary effector end of the articulated robot arm of FIG. **1**;
(3) FIG. **3** is a perspective view of a signal transmission device for the articulated robot arm of FIG. **1**;
(4) FIG. **4** is a perspective view of the signal transmission device as installed in a joint of the articulated robot arm of FIG. **1**;
(5) FIG. **5** is a face view of the signal transmission device and link of FIG. **4**;
(6) FIG. **6** are a series or schematic views showing a window for monitoring the signal transmission device; and
(7) FIG. **7** is a schematic view of an exemplary motorized joint unit using the signal transmission device.
DETAILED DESCRIPTION
(8) Referring to the drawings and more particularly to FIG. **1**, a mechanism such as a robot arm in accordance with the present disclosure is generally shown at **10**, and is also referred to as an articulated robotic arm or robotic arm, etc. The robot arm **10** shown is of the type displacing an end effector is 6 degrees of freedom, though fewer or more degrees of freedom may be present. Although the signal transmission system described herein is shown on the robot arm **10**, it may be used with other mechanisms, such as articulated mechanisms or arms, serial mechanisms or arms, parallel mechanisms or arms, or like mechanisms or arms. However, for simplicity, the expression “robot arm” is used throughout, but in a non-limiting manner. The robot arm **10** is a serial articulated robot arm, having an end effector end **10**A, i.e., the end at which an end effector is connected, and a base end **10**B. The effector end **10**A is configured to receive any appropriate tool, such as gripping mechanism or gripper, anthropomorphic hand, tooling heads such as screwdrivers, drills, saws, an instrument drive mechanism, camera, etc. As shown in FIG. **2**, a port **10**A′ is at the effector end **10**A, and may be any appropriate port, including a RJ45 connector, a M8 connector, a M12 connector, a pogo pin connector, etc. The port **10**A′ may use centrally-oriented and reversible (180 degree orientation change supported) spring-loaded connectors. The port **10**A′ enables high speed data transmission, enabled by the use of multiple of the signal transmission device of the present disclosure along the robot arm **10**. For example, the signal transmission device described herein may enable the transmission of Ethernet signals, USB signals, Ethercat signals, via one or multiple high speed data buses. Transmissions speeds may be of 10 mbit/sec or more as a possibility. The high speed communication may be done wirelessly and converted to a wired

interface at the end effector. The end effector secured to the effector end **10**A is as a function of the contemplated use, and more than one end effector may be used (e.g., a camera may be used with a gripper, as one combination among many others). An interface **10**A″ may also be present, and may include buttons, an additional port, etc.
(9) The base end **10**B is configured to be connected to any appropriate structure or mechanism. The base end **10**B may be rotatably mounted or not to the structure or mechanism. By way of a non-exhaustive example, the base end **10**B may be mounted to a wheelchair, to a vehicle, to a frame, to a cart, to a robot docking station. Although a serial robot arm is shown, the joint arrangement of the robot arm **10** may be found in other types of robots, including parallel manipulators.
(10) The robot arm **10** has a series of links **20**, interconnected by motorized joint units **30** (for simplicity, only two shown in FIG. **1**, but with numerous other motorized joint units **30** being present, e.g., at a junction between each link **20**), at the junction between adjacent links **20**. A bottom one of the links **20** is shown and referred to herein as a robot arm base link **20′**, or simply base link **20′**, and may or may not be releasably connected to a docking cradle. The links **20** define the majority of the outer surface of the robot arm **10**. The links **20** also have a structural function in that they form the skeleton of the robot arm **10** (i.e., an outer shell skeleton), by supporting the motorized joint units **30** and tools at the effector end **10**A, with loads supported by the tools, in addition to supporting the weight of the robot arm **10** itself. Electronic components may be concealed into the links **20**. The motorized joint units **30** interconnect adjacent links **20**, in such a way that a rotational degree of actuation is provided between adjacent links **20**. According to an embodiment, the motorized joint units **30** may also connect a link to a tool at the effector end **10**A, although other mechanisms may be used at the effector end **10**A and at the base end **10**B. For example, the link **20** at the effector end **10**A may be described as a wrist, rotatable about its central axis, shown as X in FIG. **2**. The motorized joint units **30** may also form part of structure of the robot arm **10**, as they interconnect adjacent links **20**. The signal transmission device **40** is provided in one or more of the links **20**, for establishing a communications linkthrough the link **20**. In an embodiment, each link **20** includes one of the signal transmission device **40**, with the signal transmission devices **40** being serially connected from the base end **10**B to the effector end **10**A, such that an end effector and a base controller may be communicatively coupled, for example.
(11) Referring to FIG. **3**, the signal transmission device **40** is shown in greater detail. In an embodiment, the signal transmission device has a tape-like body supporting circuitry, such as with multiple channels. For example, the tape-like body may be ribbon cable, flat multicore cable and/or geometrically as a clockspring or clock spring. The tape-like body may be flexible (i.e., elastically deformable). In an embodiment, there is no springing effect, in that the clock spring does not exert a substantial pulling action on its ends. The signal transmission device **40** has a pair of connectors **41** at its opposed ends. In an embodiment, the connectors **41** are flat connectors that may for example be a bend in the tape-like body of the signal transmission device **40**, and that have circuit contacts. Other possible connectors **41** may include ZIP connectors, IDC connectors or other ribbon cable connectors. The flat connectors **41** shown in FIG. **3** are merely examples of connectors that may be used. The signal transmission device **40** may also have an elongated portion **42**. The elongated portion **42** has any appropriate length, based on the length of the respective link **20**, for example. The elongated portion **42** is shown as being straight, but may be bent or feature a fold towards a defined direction. For example, if the signal transmission device **40** is in an elbow link **20** (as present in the robot arm **10** of FIG. **1**), the elongated portion **42** may be bent, curved or precisely folded to conform to the shape of its link.
(12) The signal transmission device **40** may further include a coiled portion **43** at the end of the elongated portion **42**. The coiled portion **43** may be known as a spiral-wound portion, with at least two loops (more than three loops shown in FIG. **3**). In an embodiment, a bend in the tape-like body causes the elongated portion **42** to transition to the coiled portion **43**. The elongated portion **42** and the coiled portion **43** may be said to have a continuous integral ribbon cable construction, in that

they may be constituted of a single ribbon cable or equivalent, shaped in the manner shown in FIG. **3**. A referential system X-Y-Z is provided to explain a geometry of the signal transmission device **40**, and is provided merely to assist the geometry. The elongated portion **42** extends along direction X. The coiled portion **43** lies between a pair of Y-Z planes, i.e., planes parallel to the Y-Z axes. In an embodiment, direction X (or a vector of direction X) is normal to the Y-Z planes in which the coiled portion **43** lies for the elongated portion **42** to extend generally normally to the coiled portion **43**, but the elongated portion **42** may also extend in a direction that is not normal to the Y-Z planes. In an embodiment, the elongated portion **42** may be rotated about an axis parallel to direction X, as shown as e, for example as the elongated portion **42** rotates with its respective link **20**. If the connector **41** at the end of the coiled portion **43** is fixed during a rotation of the elongated portion **42**, a radial dimension of part of the coiled portion **43** varies to allow the rotation. Stated differently, during use, the connectors **41** rotate relative to one another, about direction X, and the coiled portion **43** allows such rotation by changing its radial dimensions in its coil.

(13) Referring to FIGS. **4** and **5**, an installation of the signal transmission device **40** in structural components of links **20** is shown, with the XYZ referential system being the same as in FIG. **3**. In FIGS. **4** and **5**, a pair of adjacent ones of the links **20** are illustrated by shells **50** and **60**, the shells **50** and **60** being rotatably connected to one another, for instance by one of the motorized joint units **30** (FIG. **1**), concealed from view in FIG. **4** by the shells **50** and **60**. In an embodiment, it may be said that the shells **50** and **60** are part of a motorized joint unit **30**, as they form the relatively rotatable structural members of a motorized joint unit **30**. In an embodiment, structural link members (such as visible in FIG. **1**) are secured to shells **50** and **60**. The shell **50** is part of or may be integrally connected to one of the links **20**, and the shell **60** is part of or may be integrally connected to the adjacent link **20**, with the rotational degree of freedom between the shells **50** and **60**. The rotational degree of freedom between the shells **50** and **60** may have its axis parallel or quasi parallel to direction X. The shells **50** and **60** are structural link members, in that they are structural parts of the links **20**. The expression shell is used to express the notion that shells **50** and **60** form a hard outer case for some of the components of the robotic arm **10**, including parts of the signal transmission devices **40**.

(14) The shell **50** may have a tubular construction. The tubular construction may be embodied by an annular body portion **51**. A cavity **52** is open at an end of the annular body portion **51**, and may be delimited by a support surface **52**A, for receiving the coiled portion **43** of the signal transmission device **40**. The support surface **52**A may define a plane that would correspond to one of the Y-Z planes in FIG. **3**. A central hole **52**B may be defined in the support surface **52**A, through which the central hole **52**B may communicate with a passage that would correspond to direction X in FIG. **3**.

(15) The tubular configuration of the annular body portion **51** may be used so as to conceal numerous components of one of the motorized joint unit **30** (FIG. **1**), hidden from FIGS. **4** and **5** by the support surface **52**A. The annular body portion **51** may have a monoblock construction, or may be an assembly of parts. According to an embodiment, the annular body portion **51** defines a peripheral wall **53** that may have a generally cylindrical shape, as shown. The peripheral wall **53** may have other shapes, such as frusto-conical. The peripheral wall **53** may be smooth and/or may have surface features, e.g., connector holes, flange **53**A, etc. A rim **54** is at an axial end of the peripheral wall **53**. The peripheral wall **53** extends beyond the support surface **52**A to define the cavity **52**, in which the coiled portion **43** of the signal transmission device **40** is received. Blocks **55** may optionally extend inwardly from the peripheral wall **53**. The blocks **55** may have tapped holes for receiving fasteners. The blocks **55** and fasteners may be used to secure a motorized joint unit **30**, or other structural component, to the shell **50**.

(16) Still referring to FIGS. **4** and **5**, a ring structure **56** may project from the support surface **52**A. The ring structure **56** may be integrally connected to the support surface **52**A, or may be attached to it. During assembly of the robot arm **10**, the support surface **52**A and the ring structure **56** are fixed

to one another, so as to rotate with one another. The ring structure **56** defines a receptacle with the support surface **52**A, for lodging the coiled portion **43** of the signal transmission device **40**. The receptacle communicates with the central hole **52**B. The ring structure **56** may be generally circular in shape, so as to surround the receptacle, and the coiled portion **43** therein. The ring structure **56** is an arrangement among others to hold the coiled portion **43** captive in the shell **50**, with other arrangements defined by posts, abutments, etc. In another embodiment, the coiled portion **43** abuts against the peripheral wall **53**.

(17) In an embodiment, the ring structure **56** may have various components, that may be integral with the ring structure **56**, or that may be standalone as well. In a variant, fastener blocks **57** are integral with and project from the ring structure **56**. The fastener blocks **57** are on an exterior of the ring structure **56**. The fastener blocks **57** and fasteners **57**A (e.g., set screws, bolts) are provided to connect components to the ring structure **56**. For example, the fastener blocks **57** are used for securing a PCB to the shell **50**, in such a way that the printed-circuit board is conductively connected to the signal transmission device **40**. An alternative to fastener blocks **57** would be posts projecting upwardly from the support surface **52**A. As yet another possibility, the PCB is connected to the shell **50** by way of tapped holes **57**B. The PCB may generally lie in the Y-Z plane.

(18) Tab block(s) **58** may also be present. The tab block **58** may be an integral part of the ring structure **56**, as a possibility. The tab block **58** may receive a tab **58**A, or like clip. The tab **58**A may be a L-shaped tab, for example, that would define an abutment extending in another Y-Z plane (FIG. **3**). Accordingly, when the coiled portion **43** of the signal transmission device **40** is in the receptacle, the coiled portion **43** is held captive between the support surface **52**A and the tab **58**A. The tab block **58** and tab **58**A are one contemplated solution among others to hold the coiled portion **43** captive in the shell **50**, with other possibilities including using the printed-circuit board, a plate, a disc, etc. The tab **58**A allows the radial dimension variations of the coiled portion **43**.

(19) A slot **59** may also be defined in the ring structure **56**, for attachment of the coiled portion **43** of the signal transmission device **40** at its connector **41**. The slot **59** may open to the interior of the receptacle. The slot **59** may be viewed as a clocking feature as it holds the connector **41** at a fixed clock position. Other holding features may be present, such as a clip located at or near the junction between the elongated portion **42** and the coiled portion **43**. The connector **41** of the signal transmission device **40** is fixed when fitted in the slot **59**. Moreover, the slot **59** holds the connector **41** in such a way that it is above the coiled portion **43**, and above or level with a Y-Z plane of the coiled portion **43**. Therefore, if a printed-circuit board is fixed to the fastener blocks **57** or held in similar manner to hover over the cavity **52**, it may be in conductive contact with the connector **41**, for a communications link to be formed. The slot **59** in the ring structure **56** is one solution among others to attach the connector **41** at the end of the coiled portion **43** to the shell **50**. Other configurations may include strap(s), an arc, a bridge, etc.

(20) Referring to FIG. **4**, an annular body portion **61** of the shell **60** is shown. The annular body portion **61** is continuous with the annular body portion **51** of the shell **50**, with the capacity for rotation relative to one another. The shell **60** may also have a hollow shaft **62** or like central tubular structure, that is aligned with the central hole **52**B. Therefore, when the signal transmission device **40** is installed in the shells **50** and **60**, the elongated portion **42** of the signal transmission device **40** extends along the hollow shaft in such a way that the connector **41** at the end of the elongated portion **42** is exposed at the end of the shaft **62**, for serial communication with a printed-circuit board, or with another signal transmission device **40**, etc.

(21) In a variant, the connector **41** at the elongated end **42** of the signal transmission device **40** is fixed so as to rotate with the shell **60**. Therefore, both connectors **41** of the signal transmission device **40** are secured to a respective one of shells **50** and **60**. When the motorized joint unit **30** imparts a relative rotation between the shells **50** and **60**, the coiled portion **43** of the signal transmission device **40** varies in diameter to allow the rotation of the shells **50** and **60**. For example, the coiled portion **43** may have a curve radius from 12 mm to 30 mm, inclusively. The

variation in diameter may be for any coil segment of the coiled portion **43**. More particularly, the coiled portion **43** may be described as being a spiral, as observed from FIG. **4**, with numerous loops. The variation in diameter may be for a single one of a loop, a portion of a loop, a more than one loop. The coiled portion **43** has a shape to preserve its spiral configuration and to prevent the creation or presence of kinks.

(22) The use of the signal transmission devices **40** to establish a serial communications link from the base end **10**B to effector end **10**A in the robot arm **10** allows high bandwidth to be run internally in the robot arm **10**. For example, the signal transmission devices **40** may be selected to enable at least a Gigabit bandwidth. The signal transmission device **40** is an impedance-controlled multiline rotary connection that features a flex cable construction. The impedance control may be passive or active. In an embodiment, the signal transmission device **40** is designed to handle multiple ethernet or other communication busses (e.g., one or more) at speeds of 100 mBit, 1 Gbit or faster, in a compact, highly integrated form directly in the links **20** (e.g., Ethercat, USB Superspeed, etc.). The coiled portion **43** of the signal transmission device **40** may have a sufficient length so as not to constraint rotation to one revolution, so as not limit robot motion, i.e., at least one revolution is possible. In an embodiment, from a reference orientation between the shells **50** and **60**, the coiled portion **43** of the signal transmission device **40** may have a sufficient length to allow ±360 degrees, i.e., one revolution to either direction of the reference orientation, and thus a total of at the least two revolutions.

(23) In an embodiment, with reference to FIG. **7**, the assembly of FIGS. **4** and **5** is one of the motorized joint units **30**, and includes the signal transmission device **40**, passing through the central passage as explained above. On the side of the shell **50**, the illustrated PCB, to which the connector **41** of the coiled portion **43** is in electric contact, may include a CPU or like controller, a telecommunications chip (e.g., Ethernet switch). The signal transmission device **40** extends from the shown PCB, to another PCB connected to the shell **60**. Hence, the elongated portion **42** is straight. The PCBs at opposed ends of the motorized joint unit **30**, i.e., on the shell **50** and the shell **60**, are then interconnected by wire, from one motorized joint unit **30** to another. The motorized joint unit **30** may be said to have structural members rotatably coupled to one another, with a first one of the structural members defining a central passage. A communications link is in the motorized joint unit **30** arm for signal transmission along the robotic arm, the communications link including a signal transmission device having a coiled portion, with ends of the coiled portion adapted to be connected to parts of the communications link, whereby the coiled portion is a segment of the communications link. The coiled portion has one of its ends connected to the second one of the structural members to rotate with the second one of the structural members, the other of the ends of the coiled portion connected to a component associated with the first one of the structural members through the central passage to rotate with the first one of the structural members, at least a portion of the coiled portion expanding or contracting radially during relative rotation between the pair of structural members.

(24) Referring to FIG. **6**, the arrangement of the signal transmission device **40** in the robot arm **10** may also include means for indexing/aligning the motorized joint unit **30** and signal transmission device **40** together for maintenance purposes. A cover plate **70** may be installed onto the shell **60** so as to conceal the coiled portion **43** in the receptacle defined above. A window **71** may be present in the cover plate **70** (or in the wall featuring the support surface **52**A), for the coiled portion **43** to be visible. The position of the coiled portion **43** as seen through the window **71** allows a visual determination of the clocking of the shell **50** relative to the shell **60**. For example, the left-hand side figure shows a maximum possible expansion of the coiled portion **43**. The right hand side figure shows a maximum possible contraction of the coiled portion **43**. The central image shows a neutral position from which rotation is possible in either direction. The window **71** may be used for visual alignment at assembly. As another option, an optical sensor **72** (FIG. **7**) may be present to monitor the signal transmission device **40** through the window **71**, and assist in managing the clocking of

the shells **50** and **60** relative to one another.

(25) By allowing for higher speed internal data communication through a serial connection of signal transmission devices **40**, more advanced and intelligent end of arm sensors, such as high speed and high resolution cameras, depth sensors, etc, and application-specific tooling (ex: complex and force/controlled assembly, inspection, finishing tooling) are possible without external wiring. The signal transmission device **40** may further include or may operate in conjunction with repeaters, amplifiers and/or switches for different protocols and speeds.

(26) In an embodiment, the signal transmission device **40** has the coiled portion **43**, but does not include the elongated portion **42** integral with the coiled portion **43**. For example, the coiled portion **43** may be electrically connected at its central end (within the coil) to a circuit component that extends along the joint. For example, the coiled portion **43** may have a connector **41** at its center, such a connector **41** being operatingly connected to a cable, printed circuit, etc. In another embodiment, a communications link of the robot arm **10** has a sequence of PCB-signal transmission device **40**-PCB-cable (e.g., Ethernet)-PCB-signal transmission device **40**-PCB-cable . . . . The expression "communications link" is used as the signal transmission device(s) **40** is(are) part of a wired system by which signals and power are sent between components of the robot arm **10**, such as between a base controller and an end effector, or any other component pair (e.g., a receiver/transmitted in the robot arm **10** and the end effector, or plug or port at the effector end **10**A). In a variant, each link **20** has at least one PCB and signal transmission device **40**. An exception could be for the base link **20**′ and wrist, that may have only a PCB, only a signal transmission device **40**, or two PCBs for a single signal transmission device **40**, for example. The communications link may be said to be without slip rings from base to effector end.

Claims

1. A robotic arm comprising: at least pair of structural members rotatably coupled to one another for rotation about an axis of rotation, with a first one of the structural members defining a central passage generally extending along the axis of rotation; a communications link at least partially within the robotic arm for signal transmission within the robotic arm, the communications link including a signal transmission device having a coiled portion, with ends of the coiled portion adapted to be connected to parts of the communications link, whereby the coiled portion is a segment of the communications link, and an elongated portion extending from one of the ends of the coiled portion into the central passage, wherein the coiled portion has one of its ends connected to a second one of the structural members to rotate with the second one of the structural members, the elongated portion connected to a component associated with the first one of the structural members through the central passage to rotate with the first one of the structural members, at least a portion of the coiled portion expanding or contracting radially during relative rotation between the pair of structural members.
2. The robotic arm according to claim 1, wherein the second one of the structural members defines a receptacle, the coiled portion being received in the receptacle.
3. The robotic arm according to claim 2, wherein at least one tab projects from a wall of the receptacle to hold the coiled portion captive in the receptacle.
4. The robotic arm according to claim 2, wherein one of the ends of the coiled portion is fixed to a wall of the receptacle.
5. The robotic arm according to claim 1, wherein the signal transmission device has a ribbon cable construction.
6. The robotic arm according to claim 5, wherein the communications link has one or more data communication buses enabling data communication at rates from 10 mbit/see to 20 gbit/see inclusively.
7. The robotic arm according to claim 1, wherein the coiled portion is impedance controlled

actively or passively.
8. The robotic arm according to claim 1, wherein the elongated portion has an end fixed in rotation to the first one of the structural members.
9. The robotic arm according to claim 1, wherein the elongated portion and the coiled portion have a continuous integral ribbon cable construction.
10. The robotic arm according to claim 8, wherein the coiled portion lies in a plane, and the elongated portion extends from the coiled portion in a direction normal to the plane.
11. The robotic arm according to claim 1, wherein the coiled portion lies in a plane, and wherein an axis of rotation between the pair of structural members is normal to the plane.
12. The robotic arm according to claim 1, wherein a window is defined in a cover plate on one of the structural members to monitor the coiled portion.
13. The robotic arm according to claim 1, wherein the communications link includes at least one of a repeater, an amplifier, a switch.
14. The robotic arm according to claim 1, wherein a curve radius of the coiled portion is between 12 mm and 30 mm.
15. The robotic arm according to claim 1, wherein the communications link has a high speed communication port or connector at an end effector interface.
16. The robotic arm according to claim 1, wherein the coiled portion allows for rotational movement between the pairs of structural members of at least one complete revolution.
17. The robotic arm according to claim 1, wherein the central passage is defined by a hollow shaft of the first one of the structural members.
18. The robotic arm according to claim 17, wherein a motorized joint unit surrounds the hollow shaft.
19. A robotic arm comprising: at least pair of structural members rotatably coupled to one another for rotation about an axis of rotation, with a first one of the structural members having a hollow shaft defining a central passage generally extending along the axis of rotation a motorized joint unit surrounding the hollow shaft and configured to drive a rotation between the structural members about the axis of rotation; a communications link at least partially within the robotic arm for signal transmission within the robotic arm, the communications link including a signal transmission device having a coiled portion, with ends of the coiled portion adapted to be connected to parts of the communications link, whereby the coiled portion is a segment of the communications link, and an elongated portion extending from one of the ends of the coiled portion into the hollow shaft, wherein the coiled portion has one of its ends connected to a second one of the structural members to rotate with the second one of the structural members, the elongated portion connected to a component associated with the first one of the structural members through the hollow shaft to rotate with the first one of the structural members, at least a portion of the coiled portion expanding or contracting radially during relative rotation between the pair of structural members.