(54) Title: INTEGRATED CONVEYOR BED

(57) Abstract: A conveyor system, and method of controlling the conveyor system, includes providing a conveying surface (58), at least one motor (52a) propelling the conveying surface and a plurality of lower-level controllers (106). At least one of the lower-level controllers adapted to control the at least one motor. An upper-level controller (108) is provided in communication with the plurality of lower-level controllers (106). The upper-level controller is adapted to send communications to the lower-level controllers for controlling the at least one motor (52a). A communication bus is provided that carries the communications between the upper-level controller and the lower-level controllers. The upper-level controller is adapted to automatically assign each lower-level controller a unique communication address. The unique communication address enables the upper-level controller to send messages over the communication bus (146) to individual ones of the lower-level controllers.
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INTEGRATED CONVEYOR BED

BACKGROUND OF THE INVENTION

The present invention relates generally to conveyors, and more particularly to the control, installation, and operation of conveying systems.

Conveyor systems are used in a wide variety of material handling applications. These includes such things as conveying luggage throughout airports conveying parcels through transportation terminals, conveying manufactured parts or components throughout factories, conveying inventory, sorting and conveying items to be transported, and various other applications. Such conveying systems may use conveyors having endless belts that are rotated around end rollers to cause the top surface of the belt to move in the direction of conveyance. Such conveying systems alternatively may use conveyors having a series of rollers, selected ones of which are driven to cause articles positioned on the rollers to move in the direction of conveyance. An example of one such roller conveyor is disclosed in U.S. Patent No. 6,253,909 issued to Kalm et al., entitled MODULAR POWER ROLLER CONVEYOR, the disclosure of which is hereby incorporated herein by reference. Still other types of conveyors may use movable slats to transport articles, as well as other structures.

The installation and commissioning of prior conveying systems has typically been a labor-intensive process. The design and installation of prior conveying systems has often involved a great deal of custom engineering of the system in order to make the system match the physical layout of the customer's site, as well as match the conveying needs of the customer. Such custom engineering not only includes the physical aspects of the individual conveyors making up the system, but also the programming and control logic that is used to control the overall system. In addition to significant amounts of labor, such custom engineering and design requires extra time for the custom-designed parts and system components to be manufactured. The installation of conveying systems has therefore consumed a significant amount of both labor and time, all of which translate into increased costs for the customer of the conveying system. These costs, of course, are desirably reduced.

In the past, the software that controls the conveying system so that it performs functions has usually been a custom-designed program specifically tailored to a particular conveyor installation. The software is designed according to the
specific number of conveyor lines entering the system, the number and location of
merges, the number and location of the destinations that articles may be routed to,
and a number of different factors that are specific to a given installation. Further,
the location of the controls for each portion or segment of the conveying system
must be determined, often manually. This may involve having a technician walk
around to each control in the system and physically assign it a software address
during the installation of the conveying system. These software addresses are
incorporated into the software so that communications between the various control
components can be properly implemented. Reducing the amount of time and labor
involved in these tasks is highly desirable.

SUMMARY OF THE INVENTION

A conveyor system, and method of controlling the conveyor system,
according to an aspect of the invention, includes providing a conveying surface, at
least one motor propelling the conveying surface and a plurality of lower-level
controllers. At least one of the lower-level controllers adapted to control the at least
one motor. An upper-level controller is provided in communication with the
plurality of lower-level controllers. The upper-level controller is adapted to send
communications to the lower-level controllers for controlling the at least one motor.
A communication bus is provided that carries the communications between the
upper-level controller and the lower-level controllers. The upper-level controller is
adapted to automatically assign each lower-level controller a unique communication
address. The unique communication address enables the upper-level controller to
send messages over the communication bus to individual ones of the lower-level
controllers.

The various aspects of the present invention provide an improved conveying
system that simplifies the installation, operation, and maintenance of the system.
The modularity of the physical conveyor beds, as well as the modularity of the
control functions, permits easier installation of conveying systems. The use of
automatic self-addressing features further reduces the amount of labor necessary to
install a conveying system.

These and other advantages of the present invention will be apparent to one
skilled in the art in view the following written description and the accompanying
drawings.
BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a perspective view of a conveyor bed according to one aspect of the present invention;

FIG. 2 is a front, elevational view of the conveyor bed of FIG. 1;

FIG. 3 is a side, elevational view of the conveyor of FIG. 1 illustrated with a side panel removed to show the underlying components;

FIG. 4 is a side, perspective view of various electrical and electronic components of the conveyor bed of FIG. 1;

FIG. 5 is a schematic diagram of a bed controller according to one aspect of the present invention;

FIG. 6 is a schematic diagram of a bed controller and two brushless motor controllers according to one aspect of the present invention;

FIG. 7 is a diagram of various control components of a conveyor bed and an adjacent conveyor bed according to one aspect of the present invention;

FIG. 8 is a schematic diagram of a material handling control system which may utilize various components of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will now be described with reference to the accompanying drawings wherein the reference numerals in the following written description correspond to like-numbered elements in the several drawings. A conveyor bed 50 according to one aspect of the present invention is depicted in FIG. 1. Conveyor bed 50 may be a modular unit that may be used as part of a conveying system made up of additional modular conveying units, or a conveying system made up solely of a single conveyor bed. Conveyor bed 50 includes a conveying surface which may be driven by a plurality of rollers 52 that are supported on each of their ends by a frame 54 and driven either through O-rings from a drive, such as a motorized roller, or through an endless member, such as disclosed in commonly assigned Application Serial No. 10/411,924, filed April 11, 2003, entitled TAPE DRIVE CONVEYOR which is incorporated herein by reference. Frame 54 includes first and second side members 56a and 56b. Side members 56a and 56b generally extend the length of conveyor bed 50 in a parallel orientation. The top surfaces of rollers 52 in the illustrated embodiment define a conveying surface 58 on which articles, such as packages, boxes, cartons, or other types, may be placed. The conveying surface may also be defined by belts or the like as disclosed in commonly assigned
Application Serial No. 10/358,690, filed February 5, 2003, entitled BELT
CONVEYOR the disclosure of which is hereby incorporated by reference. One of
more of rollers 52 is powered. In operation, the rotation of the powered rollers
causes articles placed on conveying surface 58 to move longitudinally along the
length of conveyor bed generally in a direction of conveyance 60.

As will be described in more detail herein, conveyor bed 50 may be
constructed in a generally modular fashion. The modular nature of conveyor bed 50
includes both the physical construction of conveyor bed 50, as well as the control
components and functions that may be used with conveyor bed 50. In addition to
the modular nature of conveyor bed 50, may include high voltage electrical power
lines such as insulated cables, bus ducts, or the like that simplify the installation of
conveyor systems, as well as the use of high powered conveyor components, such as
motors and the like. Conveyor bed 50 may further include a number of control
components that are specially designed to be easily installed, removed, serviced, and
otherwise used in conjunction with conveyor bed 50, as well as different variations
of conveyor beds.

A more detailed construction of side member 56a and b is depicted in FIG. 2.
As illustrated, each side member 56 includes a lower member 62, an upper member
64, a cover 66, and a C-clamp 68. Upper and lower members 64 and 62 generally
extend for the length of conveyor bed 50. Upper and lower members 64 and 62 may
be made of any suitable material. For example, members 64 and 62 may be
extruded aluminum with an anodized finish. Other constructions and materials of
course can also be used. Right and left lower member 62a and b are connected to
each other by a cross member 70 that extends underneath rollers 52 in a direction
generally transverse to the direction of conveyance 60. Lower members 62a and b
are rigidly secured to cross member 70 by way of bolts, or any other suitable
fastener. Upper member 64a and b are releasably secured to lower member 62a and
b, respectively, by way of C-clamps 68. C-clamps 68 are made of a flexible material
that snap fittingly fits over a shoulder defined in upper member 64. By suitably
flexing C-clamp 68, it can be removed from upper and lower members 64 and 62.
Once so removed, upper member 64 can be freely removed off of the top of lower
member 62. The removal of upper member 64 allows for differently dimensioned
upper member 64 to be easily used on conveyor bed 50.
Cover 66 is selectively positionable along the outer side of upper and lower members 64 and 62. Cover 66 includes an upper flexible tab 72 and a lower flexible tab 74. Flexible tabs 72 and 74 are positioned on a side of cover 66 that is not visible to outside personnel when cover 66 is attached to side members 56a and b. Upper and lower flexible tabs 72 and 74 selectively secure cover 66 to upper and lower member 64 and 62. Upper flexible tab 72 flexibly fits over a vertical outer flange 76 of upper member 64. Lower flexible tab 74 flexibly fits over a vertical, outer flange 78 defined on lower member 62. Cover 66 can be removed from upper and lower members 64 and 62 by either sliding cover 66 along members 64 and 62 in a direction generally parallel to the direction of conveyance 60, or by pulling cover 66 outwardly until cover 66 sufficiently flexes to allow flexible tabs 72 and 74 to disengage from flanges 76 and 78.

When cover 66 is attached to upper and lower member 64 and 62, two separate cavities are generally defined. An upper cavity 80 is generally defined by cover 66, a top wall 82 of upper member 64, a sidewall 84 of upper member 64, and a bottom wall 86 of upper member 64. A lower cavity 88 is generally defined by cover 66, a top wall 90 of lower member 62, a sidewall 92 of lower member 62, and a bottom wall 94 of lower member 62. Upper and lower cavities 80 and 88 extend generally along the entire length of conveyor bed 50 in a direction parallel to the direction of conveyance 60. Upper cavity 80 provides a housing for one or more photo-sensors 96 and photo reflectors 98 that may be included in conveyor bed 50. Lower cavity 88 proves a housing for a number of control components as well as various cabling, as will be described in more detail herein.

As illustrated in FIG. 2, sensors 96 emit a beam of light 100, or other electromagnetic energy across conveyor bed 50 at a height slightly above conveying surface 58. This height may be about 5 millimeters, although other heights may be used. Light beam 100 is emitted from sensor 96 such that it impinges reflector 98, and is thereby reflected back to sensor 96. Sensor 96 includes photoreceptors that detect the reflected light beam 100. When an article is traveling on conveying surface 58 adjacent photosensor 96, the article will interrupt light beam 100, thereby allowing photosensor 96 to detect the presence of an article. Photosensors 96 and reflectors 98 may be any conventional, commercially available sensors and reflectors. The number of sensors 96 and reflectors 98 in a given conveyor bed 50 can be varied, depending on the particular design and/or application to which a
conveyor bed 50 will be used. A spring 97 may be positioned above photosensor 96 to help maintain photosensor 96 in its proper position. Alternatively, separate photo emitters and photoreceptors can be used on opposite sides of the conveyor bed. As illustrated in FIG. 3, conveyor bed 50 includes 3 photosensors 96 and three reflectors 98. FIGS. 8-37 depict various other types of conveyor beds that may use different numbers of sensors and reflectors.

As mentioned previously, several of the rollers 52 are motorized rollers. These motorized rollers are designated by the reference number 52a. Motorized rollers 52a are preferably, although not necessarily, constructed to contain all of the motor components within the roller itself. Examples of these types of motorized rollers are disclosed in U.S. Patents 5,088,596 issued to Agnoff and 4,121,127 issued to Adelski et al., the disclosures of which are both hereby incorporated herein by reference. Regardless of which type of motorized roller is used in the present invention, the motorized roller may advantageously be a 48-volt motorized roller.

48-volt motorized rollers provide more power than conventional 24-volt motorized rollers that have been often used in the past. The motorized roller may include a gear-type reducer or may be a direct-drive type of motor. In the illustrative embodiment, motorized rollers 52a are 48-volt, direct drive motorized rollers of the type disclosed in commonly assigned German patent application Serial No. 10324664.9 filed May 30, 2003, entitled ROLLERS AND ROLLER MOTORS, the disclosure of which is hereby incorporated herein by reference.

Each conveyor bed 50 includes a control system or circuit made up of a plurality of control elements and electrical power components. Some of these elements are illustrated in FIG. 3. Each motorized roller 52a is controlled by a motor controller 106. Each bed 50, or set of conveyor beds 50, includes at least one bed or functional controller 108. Functional controller 108 sends commands to each of the motor controllers 106 that dictate how motor controllers 106 will control the operation of motorized rollers 52a. Motor controllers 106 may be variable frequency drives, or other types of motor drivers.

FIG. 4 depicts a plurality of different control elements that may be present in a conveyor bed 50. These include bed controller 108, motor controller 106, photosensors 96 and reflectors 98, and low voltage power supply 110. Bed controller 108, low voltage power supply 110, and motor controller 106 are all housed within plastic casings 138 (FIG. 3) that fit in lower cavity 88 of side
members 56. These casings 138 may be made of any suitable materials, such as thermoplastic injection molded plastics like ABS, or other materials. Each of the casings preferably includes an upper tab 122 and a lower tab 124 (FIG. 2). Lower tab 124 fits into a lower hook 126 defined along sidewall 92 of lower member 62. Upper tab 122 fits into an upper hook 128 that is also defined along sidewall 92 of lower member 62. At least one of tabs 122 and 124 is preferably flexible enough to allow the casing to be snap fit into upper and lower hooks 128 and 126. One or both of upper and lower tabs 122 and 124 are also preferably flexible enough to allow the casing to be easily manipulated out of hooks 126 and 128. Hooks 126 and 128 thus allow the casings to be easily inserted into conveyor bed 50, as well as to be easily removed for servicing, replacement, or other purposes. The casings may be slid longitudinally while positioned in hooks 126 and 128 in a direction that is generally parallel to the direction of conveyance. Power is supplied to motors 52a, as well as bed controllers 108, motor controllers 106, and the control elements making up the control circuit as described in more detail in the commonly assigned co-pending application entitled CONVEYOR BED EMERGENCY STOP filed concurrently herewith (Attorney Docket No. SIE04-P-106B), the disclosure of which is hereby incorporated herein by reference.

Bed controllers 108 are interconnected with a cable 151 defining a communication bus 146. Communications bus 146 may be any communications bus, but preferably is a low cost, open communications bus, such as Profibus. Bed controller 108 includes a first communications bus input 148 and a second communications bus input 150 (FIG. 5). First communications bus input 148 is positioned on bed controller 108 to be operably coupled, such as via a female port 132, to an adjacent electrical component, such as a motor power infeed 152, or a motor controller 106. Second communications bus input 150 is provided to receive communications from an external source. For example, when bed controller 108 is to be programmed, the software that is used by bed controller 108 can be transferred to bed controller 108 by a computer temporarily connected to second communications bus input 150.

Bed controller 108 further includes a pair of network connections 154 that allow bed controller 108 to be connected to a network 194 (FIG. 39). The network 194 may be an Ethernet-based network. The network connections 154 connect multiple bed controllers 108 from different conveyor beds 50 together. The network
connections further connect bed controllers 108 to a host, such as a material flow host 192, also referred to as an area controller, as will be described in more detail herein. Each bed controller 108 is treated as a node on the network, and includes a unique communications address which the particular bed controller 108 is responsive to. Bed controller 108 uses the network connections 154 to send communications to other bed controllers 108, as well as to a material flow host 192. The network management system may also send communications to the various bed controllers 108. Bed controller 108 may further include a network proxy for the Profinet, or other network 194 that allows network 194 to transmit information to communications bus 146. This information may include updates to the framework for the motor controllers, polling of diagnostic data, monitoring of the speed of motors 52a, and monitoring faults, as well as other information.

A schematic diagram of some of the internal components of bed controller 108 is depicted in FIG. 5. Bed controller 108 includes a microprocessor 156. Microprocessor 156 can be any suitable microprocessor, and may be a 16 bit, 32 bit, or other type of microprocessor. Microprocessor 156 is in communication with various types of memory, including synchronous D-RAM (SDRAM). Microprocessor 156 is also in communication with a plurality of flash E-PROMs (FEPROM). One of these flash E-PROMs contains the program memory and another one contains non-volatile memory. The data contained in the non-volatile memory is stored and maintained, even in the event that power is lost to bed controller 108. Microprocessor 156 is in communication with communications bus 146, which may be a Profibus, as noted above. First communications bus input 148 and second communications bus input 150 of bed controller 108 pass through a transceiver 158, before passing on to microprocessor 156. Bed controller 108 also includes a self-addressing chain port 160, which is connected to a line 190a used for the automatic addressing of motor controllers 106, as will be described in more detail herein. Programmable bed controller 108 can monitor various parameters of the conveyor bed and carry out advanced diagnostics using such monitoring capabilities. The parameters that can be monitored are numerous and may include motor current, motor temperature, sensor health, and the like. This reduces downtime of the conveyor system.

Network connections 154 are designed to be Ethernet connections. The Ethernet may be a standard Ethernet, or a fast Ethernet. It will, of course, be
understood that other types of networks beside Ethernets may be used within the scope of the present invention. Each network connection 154 includes a standard RJ45 shield which is operably coupled to a pair of transformers 170. Each transformer 170 is coupled to a physical layer (PHY) 172. Physical layers 172 are each coupled to a media access controller (MAC) 174. Media access controllers 174 are both coupled to a switch 176, which is operably coupled to microprocessor 156 over a media independent interface (MII) 178. As will be described in more detail herein, microprocessor 156 uses network connections 154 to communicate with other bed controllers 108, as well as with material flow host 192. Bed controller 108 may further include a plurality of light-emitting diodes (LEDs) 179 that provide diagnostic information regarding the operation of controller 108, such as whether the Ethernet link is active or not, whether the power is on, or the like.

Motor controller 106 includes a cable 147 for communicating with photosensor 96, as well as cables 149 for controlling the motorized roller 52a (FIG. 4). Motor controllers 106 may further include additional I/O ports (not shown) for controlling and/or monitoring such things as limit switches, pilot lights, solenoids, and conveyor brakes. Motor controllers 106 receive messages sent over a communications bus 146 that are either addressed to a specific motor controller 106, or that are globally broadcast to all motor controllers 106 that are in communication with each other on bus 146. The set up and installation of a conveyor system using conveyor beds 50 is simplified by the fact that bed controllers 108 and motor controllers 106 are configured to automatically assign communications addresses to each of the motor controllers 106 that are in communication with bed controller 108 via communications bus 146. This automatic self-addressing occurs regardless of the number of motor controllers 106 that may be in communication with bed controller 108 via bus 146. This automatic self-addressing eliminates the step of a technician or other personnel having to manually assign communications addresses to each of the motor controllers 106 and communicate this information to bed controller 108.

This automatic self-addressing takes place by using a self-addressing wire 190 illustrated in FIG. 12. Self-addressing wire 190 is divided into separate segments. Segment 190a connects a bed controller 108 to a chain in port of a first motor controller 106a. A second segment 190b of the self-addressing wire connects a chain out port of the first motor controller 106a to the chain in port of next
downstream and adjacent motor controller 106b. If more than two motor controllers 106 are to be controlled by a given bed controller 108, an additional segment 190c of the self-addressing wire connects the chain out port of motor controller 106b to the next downstream motor controller 106c (not shown). Additional motor controllers 106 are similarly connected by additional segments of self-addressing wire 190. The self-addressing wire segments 190 therefore connect each motor controller 106 to each other in a daisy-chain fashion.

When the control system for a conveyor bed is initialized, all motor controllers 106, except for the first motor controller 106a, remain in a reset mode. Before any communications take place across communications bus 146, bed controller 108 uses self-addressing wire 198 to activate the first motor controller 106a. This signal does not pass any farther than motor controller 106a. In other words, it is not communicated to any of the downstream segments 190b, c, etc.

Motor controller 106a sends to the bed controller 108 over communication bus 146 a default address stored in that motor controller 106a. The bed control, in turn, sends to the motor controller at its default address a new communication address that is a unique address. The bed controller then communicates with that motor controller, at its newly assigned communication address, an instruction to activate the chain out port of that motor controller. The activation of the chain out port of motor controller 106a activates the chain in port of motor controller 106b. This activates motor controller 106b, which communicates its default address to bed controller 108 over communication bus 146. Bed controller 108 then responds by sending a new unique address to motor controller 106b and instructs motor controller 106b to activate its chain out port which activates motor controller 106c.

This sequence of activating a motor controller assigning a new communication address to that motor controller and, in turn, activating the next motor controller, continues until the end of the chain of motor controllers receives a communication address assigned by the motor controller. This method of assigning communication addresses is especially useful with master/slave networks, as exists between the bed controllers and the motor controllers, but may also find application with a network where the controllers are at the same level.

While FIG. 6 illustrates only brushless motor controllers 106 as being connected to the daisy-chain configuration of wire 190, it would also be possible to connect self-addressing wire 190 to one or more non-brushless motor controllers 107.
or other slave controllers. Controllers 107 would be self-addressed in the same manner as described above with respect to controller 106. It will be understood that, other than in FIG. 6, motor controller 106 may control either brush or brushless motors 52a. Also, I/O devices and other devices may be self-addressed in this manner.

In order to facilitate the programming of bed controller 108, it is preferable to physically locate bed controller 108 in a standard position on conveyor bed 50. It is also helpful to daisy-chain motor controllers 106 together in the same sequence that they physically are located on conveyor bed 50. For example, bed controller 108 may always be positioned at an upstream end of conveyor bed 50, with all of the associated motor controllers 106 sequentially in communication from the upstream end of the bed 50 to the downstream end. By making this arrangement standard, any bed controller 108 will know that the motor controller 106 with a particular communications address will be the upstream-most motor controller. Bed controller 108 will further know that the communications address that was handed out immediately after the first motor controller 106 belongs to the next most downstream motor controller 106, and so on. The sequence of the addresses of the motor controllers 106 will therefore correspond to their physical location along conveyor bed 50 from the upstream end to the downstream end. Other types of standard arrangements of the motor controllers 106 with respect to their physical location and their communications addresses can be used within the scope of the invention.

FIG. 7 depicts a schematic overview of the electrical components and interconnections for a first conveyor bed 50a, as well as a portion of an adjacent conveyor bed 50b. Material flow host 192 is depicted in FIG. 7 and communicates with bed controllers 108 via network 194, which, as noted above, may be an Ethernet. Network 194 is coupled to the network connections 154 on each of the bed controllers 108. Material flow host 192 may be a programmable logic controller (PLC), a conventional personal computer (PC), or any other type of programmable control element. It may be programmed using ladder diagrams, statement lists, graphical flowcharts, or other means. Material flow host 192 controls a section or area of conveyor beds 50 in a given conveying system. Material flow host 192 oversees the operation of the conveying system by controlling relatively broad areas of the conveying system so that they properly interact with each other. For example,
one material flow host 192 may oversee a number of different conveyor beds involved in the induction process in a warehouse or factory. Another material flow host 192 may oversee the sortation area of the conveying system where articles are sorted onto different branch conveyors. In addition to collecting status information from bed controllers 108, material flow host 192 send high-level speed commands to the various bed controllers 108 to control the speed at which articles are processed in a given area. Material flow host 192 may further transmit routing information for individual articles to the appropriate bed controllers for article sorting purposes. Material flow host 192 can dynamically alter the speed of the conveyors in their area according to the dynamically changing conditions of articles in the conveying system. Bed controller 108 is illustrated in FIG. 7 as being in communications with, and controlling, six different motor controllers 106.

A conveying system 288 according to one aspect of the present invention is depicted in a plan, schematic view in FIG. 8. Conveying system 288 is but one illustrative example of a conveying system that can be constructed using the modular conveyor beds and modular functions of the present invention. Conveying system 288 includes a plurality of different types of beds. For example, conveying system 288 includes strip belt conveyor beds 212a-d, straight belt driven conveyor beds 216a-p, curved conveyor beds 228a-e, a junction strip belt conveyor bed 232, nose-over conveyor beds 240a-b, inclined conveyor beds 248a-b, a right angle transfer conveyor bed 256, a merge conveyor bed 280, and a positive sortation conveyor 266. Bed controllers 108a-q are illustrated adjacent to the sections of the conveyor system which they control. For example, bed controller 108a includes a communications bus 146a that extends for the length of conveyor beds 212a and 212b. Bed controller 108a therefore controls the operation of both of beds 212a and 212b. Bed controller 108a controls these two conveyor beds by sending the appropriate signals over communications bus 146a to the motor controllers 106 that are in communication therewith. For purposes of clarity, motor controllers 106 are not illustrated in FIG. 8. Likewise, low voltage power supplies 110, high voltage power supplies 112, and motor power infeeds 152 are not illustrated.

Each of the bed controllers 108 may be in communication with each other over network 194 (not illustrated). While other configurations may be used, bed controllers 108a and 108b may be programmed to carry out the modular function of dynamic accumulation described previously. Bed controllers 108b, d, f, and j may
all be programmed to carry out the modular function of metering. Bed controllers 108c, g, k, and l may all be programmed to carry out the modular function of merging. Bed controllers 108h and m may both be programmed to carry out the modular function of transportation. Bed controller 108i may be programmed to carry out the modular function of zero gap accumulation. Conveyor beds 108n and o may be programmed to carry out the modular function of diverting. Finally, conveyor bed controllers 108p and q may be programmed to carry out the modular function of zero pressure accumulation. All of these bed controllers 108a-q may be in communication with one or more material flow host 192 (not shown). These area controllers may be used to oversee various sections of conveying system 288. For example, one area controller may control the portion of conveying system 288 involved in the diverting and separating of articles. Another area controller may oversee the merging of the various conveyor lines.

The installation and set up of conveying system 288 is relatively straightforward. The appropriate types of conveyor beds 50 are chosen according to the needs of the customers material handling requirements. Once these modular conveyor beds are selected and laid out, the appropriate modular functions can be selected and downloaded onto each of the bed controllers 108. As has been discussed previously, each bed controller 108 includes the means to automatically assign and determine the addresses of each of the motor controllers 106 under its control. A person therefore does not need to manually integrate this information into the overall system. Further, network 194 may be configured to allow each of the bed controllers 108 to automatically assign and determine communications addresses for themselves. This further reduces the amount of time and labor necessary to install a conveying system, such as conveying system 288. Further, while not shown in FIG. 38, the power supply wires that supply power to each of the conveyor beds 50 are generally integrated within the body of the conveyor beds, as has been described previously. Wire management issues in the installation of the conveying system are therefore greatly reduced.

A material handling computer system 300 that may incorporate various aspects of the present invention is depicted in block diagram form in FIG. 39. Material handling computer system 300 includes a plurality of computer subsystems depicted in hierarchical form. An enterprise system 302 refers to an overall computer system whose tasks include order processing, keeping track of product
inventory, and other functions related to the facility in which the system is installed. The product inventory may be entirely contained within a single warehouse or manufacturing facility, or it may refer to geographically separate locations in which inventory is present. The enterprise system 302 may include a company's ordering function. Thus, when a company receives orders for certain products, these are communicated to enterprise system 302. Enterprise system 302 monitors the available inventory of the company and determines how best to process the order. Enterprise system 302 communicates the purchase order to a warehouse management system 304. The warehouse management computer system 304 will typically be specific to a given geographic location. Thus, if inventory is stored at multiple geographic locations, enterprise system 302 will select which geographic location will be utilized to process the order. Once chosen, it will communicate the order to the selected warehouse management system, computer 304. The warehouse management system 304 keeps track of the inventory in the specific warehouse that it oversees. When it receives the customer's purchase order, it communicates this information to a material flow host computer 306. Material flow host computer 306 knows the specific location of all of the items within the warehouse, as well as what automated material handling devices must be utilized to retrieve the products that have been ordered. Computer 306 monitors and controls the flow of products within a warehouse from one location to another. It sends commands to whatever material handling structures are present in the warehouse that will be utilized to process the order.

Material flow host computer 306 may oversee a variety of different material handling components in a given warehouse or environment. These include bed controllers 108 that have been discussed previously. Material flow host computer 306 may also oversee an automatic guided vehicle system (AGV) 290, which uses automatic guided vehicles to transport items from selected locations within an environment. Material flow host computer 192 may further oversee an automatic storage and retrieval system 292 (AS/RS). Further, material flow host computer 306 may also oversee one or more article sorters 294, such as linear sorters, carousel sorters, or the like. Material flow host computer 192 may communicate with a network management system 306, AGV system 290, automatic storage and retrieval system 292, sorters 294, and other devices 291, such as bar code scanners, RFID readers, and the like, over network 194. If material flow host computer 306
determines that a particular order will have to be retrieved within the warehouse by use of both AGVs and a conveying system, it sends appropriate commands to AGV system 290 and material flow host 192. By way of example, AGV system 290 may pick up the item being ordered and deliver it to a given conveyor bed, such as conveyor bed 212a in FIG. 8. The material flow host 192 that oversee conveying system 288 will send the appropriate commands to the bed controllers 108 to ensure that the item is properly directed to either conveyor bed 216p or 216o. Material flow host 192 communicates over network 194 to bed controllers 108 and any necessary inputs/outputs 298. As illustrated in FIG. 39, material flow host 192 may also be configured to communicate directly over network 194 with motor controllers 106. Communications with motor controllers 106 may also be carried out through bed controllers 108, as has been described previously. Further, as has described previously, bed controllers 108 oversee the operation of motor controllers 106 and various inputs/outputs 299 via communications bus 146.

Warehouse management system 304, material flow host computer 306, network 296, and network 194 may all be operably coupled to a user interface with visualization 308. The connections of material flow computer 306, network 296, and network 194 to visualizations display 308 may be carried out by using Microsoft object linking and embedding for process control (OPC), although other types of protocols may be used. User interface with visualization display 308 allows the various components of each network 194 and 296, as well as the status of material flow computer 306 in warehouse management system 304 to be graphically displayed. User interface with visualization display 308, therefore, for example, may display all of the bed controllers 108 and motor controllers 106 in a given conveying system. In addition to displaying this information, diagnostic information and the monitoring of these components may also be carried out through control system 300 and user interface with visualization display 308. User interface with visualization display 308 provides one interface for the operator to access information and input data from warehouse management system 304, material flow host 192, and network management system 306 at one interface.

Material handling computer system 300 allows for dynamic flow based on decisions from an upper level host, such as material flow host computer 306. This dynamic flow is accomplished by evaluating the current operating status of the conveyor system and using business rules to determine the best flow for the
conveyor load to be transported. These flow changes may be accomplished by dynamically changing speeds of conveyor units, changing routing directions at routing devices, or directional changes of a section or lane of conveyors.

The speed of a conveyor section can be changed dynamically by material flow host computer 306 transmitting desired speed over network 194 to programmable bed controller 108. Then the programmable bed controller sends the correct speed command over the controls network 146 to the motor controllers 106 to enable the conveyor-powered rollers 52 to run at the speed command that was sent from computer 306.

Material handling system 300 includes the ability to track load information. The direction to a destination that a conveyor routing component uses can be dynamically changed by material flow host computer 306 transmitting desired direction over network 146 to the programmable bed controller 108 that is located at the routing component. Material flow host computer 306 sends a routing table that contains the direction a load will be routed based on its destination information. There can be several directions a load can travel to reach an end destination. This enables loads to reach a destination using the most effective routing path based on the loads priority and available routing directions.

The direction of a conveyor lane or section can be dynamically changed by material flow host computer 306 transmitting desired direction over network 146 to the programmable bed controller 108 located on the conveyor component. Computer 306 sends a direction command that will change the direction of the conveyor section or lane. This allows loads that can no longer reach their destination by means of the conveyor section they are on to be able to reach their destination using a different routing path.

In addition, material handling computer system 300 has the ability to change modes of various conveying components “on the fly.” This allows, by way of example, the function performed by various conveying components to be changed through the work shift as flow needs demand. These functions may include transportation slug accumulation, singulation accumulation, and reverse slug accumulation, to name a few. This may be accomplished by material flow host computer 306 transmitting function commands over network 146 to the programmable bed controller 108 located on the conveying device. As previously set forth, the software modules necessary to carry out these transportation or
accumulation functions may be downloaded to the programmable bed controller 108 either before or concurrently with the changeover to the new function.

While the present invention has been described in terms of embodiments depicted in the drawings and discussed in the above specification, it will be understood by one skilled in the art that the present invention is not limited to these particular embodiments, but includes any and all such modifications that are within the spirit and scope of the present invention as defined in the appended claims.
What is claimed is:

1. A conveyor system, comprising:
   a conveying surface and at least one motor propelling said conveying surface;
   a plurality of lower-level controllers, at least one of said plurality of lower-level
   controllers adapted to control said at least one motor;
   an upper-level controller in communication with said plurality of lower-level
   controllers, said upper-level controller adapted to send communications to said lower-level
   controllers for controlling said at least one motor; and
   a communications bus that carries the communications between said upper-level
   controller and said lower-level controllers, said upper-level controller adapted to
   automatically assign each lower-level controller a unique communications address, said
   unique communications address enabling said upper-level controller to send messages over
   said communications bus to individual ones of said lower-level controllers.

2. The conveying system of claim 1, wherein said plurality of lower-level controllers
   being dormant until being individually sequentially activated, wherein an activated lower-
   level controller communicates with said upper-level controller and receives a communication
   address from said upper-level controller.

3. The conveying system of claim 2 wherein said upper-level controller activates a first
   one of said lower-level controllers and wherein said one of said lower-level controllers
   activates another of said lower-level controllers.

4. The conveyor system of claim 1 further including an enablement connection between
   said upper-level controller and said plurality of lower-level controllers in a daisy chain
   fashion, said enablement connection being separate from said communications bus, wherein
   said enablement connection activates individual ones of said lower-level controllers
   sequentially to enable said lower-level controllers to communicate with said upper-level
   controller one at a time to receive unique communication addresses from said upper-level
   controller.

5. The conveyor system of claim 1 wherein at least one of said lower-level controllers
   providing input/output functions.
6. The conveyor system of claim 1 wherein the conveyor includes a plurality of upper-level controllers and a second communications bus, each of said upper-level controllers being in communication with each other over said second communications bus.

7. The conveyor system of claim 1 wherein said upper-level controller is programmed to operate in multiple different modes of operation and wherein said upper-level controller can be controlled to switch between different ones of said multiple modes.

8. The conveyor system of claim 1 wherein said upper-level controller sends commands to said at least one of said plurality of lower-level controllers adapted to control the speed of said at least one motor.

9. The conveyor system of claim 1 wherein said plurality of lower-level controllers monitors parameters of devices controlled by said lower-level controllers and wherein said upper-level controller diagnoses malfunctioning of said devices in response to values of said parameters.

10. The conveyor system of claim 7 wherein said plurality of upper-level controllers track articles moving through said conveyor system wherein said upper-level controllers dynamically route articles moving through said conveyor system.

11. A method of controlling a conveyor system having at least one motor and a plurality of lower-level controllers, at least one of said plurality of lower-level controllers adapted to control said at least one motor, said method comprising:

   providing an upper-level controller in communication with said plurality of lower-level controllers and sending communications with said upper-level controller to said lower-level controllers for controlling said at least one motor;

   providing a communications bus that carries the communications between said upper-level controller and said lower-level controllers; and

   automatically assigning each lower-level controller a unique communications address with said upper-level controller, said unique communications address enabling said upper-level controller to send messages over said communications bus to individual ones of said lower-level controllers.
12. The method of claim 11 including said plurality of lower-level controllers being dormant until being individually sequentially activated and an activated lower-level controller communicating with said upper-level controller and receiving a communication address from said upper-level controller.

13. The method of claim 12 including said upper-level controller activating a first one of said lower-level controllers and said one of said lower-level controllers activating another of said lower-level controllers.

14. The method of claim 11 including providing an enablement connection between said upper-level controller and said plurality of lower-level controllers in a daisy chain fashion, said enablement connection being separate from said communications bus, and further including activating individual ones of said lower-level controllers sequentially with said enablement connection to enable said lower-level controllers to communicate with said upper-level controller one at a time to receive unique communication addresses from said upper-level controller.

15. The method of claim 11 wherein at least one of said lower-level controllers providing input/output functions.

16. The method of claim 11 wherein the conveyor includes a plurality of upper-level controllers and a second communications bus, each of said upper-level controllers being in communication with each other over said second communications bus.

17. The method of claim 11 wherein said upper-level controller operates in multiple different modes of operation wherein said upper-level controller can be controlled to switch between different ones of said multiple modes.

18. The method of claim 11 wherein said upper-level controller sends commands to said at least one of said plurality of lower-level controllers adapted to control the speed of said at least one motor.
19. The method of claim 11 wherein said plurality of lower-level controllers monitors parameters of devices controlled by said lower-level controllers and wherein said upper-level controller diagnoses malfunctioning of said devices in response to values of said parameters.

20. The method of claim 28 wherein said plurality of upper-level controllers track articles moving through said conveyor system wherein said upper-level controllers dynamically route articles moving through said conveyor system.
Fig. 5
Fig. 6
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B65643/08 B65637/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B656

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Relevant to claim No.</th>
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<tr>
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<td>page 2, paragraph 12 page 2, paragraph 19 - page 3, paragraph 22 page 4, paragraph 30 - paragraph 31 page 5, paragraph 65 - paragraph 98 page 13, paragraph 123 - paragraph 128 figures 1-29</td>
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<td>US 6 460 683 B1 (PFEEFFFER MICHAEL W) 8 October 2002 (2002-10-08) column 1, line 50 - line 57 column 2, line 2 - column 3, line 38 figures 1-9</td>
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Date of the actual completion of the international search
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Date of mailing of the international search report
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