

A close-up photograph of industrial machinery, showing a yellow metal frame and a blue metal track with a roller assembly, likely part of a linear motion guide system.

DESIGN AND ALIGNMENT OF LINEAR MOTION GUIDES

Introduction

The primary function of a linear guide system is to enable an application payload to be easily moved in one linear direction (the linear guide system's travel axis) while constraining motion in all other directions. Motion constraint is achieved through multiple points, lines, or planes of contact between a linear guide system's mobile carriage guide elements and stationary track.

While some guide elements are truly static (such as plain bearings) and others rotate during travel (such as guide wheels), the guide elements in all linear guide systems essentially have a fixed contact profile with their running surfaces, in the plane normal to the travel axis. Track in linear guide systems must therefore maintain consistent contact profiles in order for carriages to properly travel on them. Variations in contact profile dimensions, such as varying distances or angles between running surfaces, can cause the carriage to have acceptable running characteristics over some portions of the track while binding and clearance develops in other portions of the track.

A constant track running surface profile (commonly referred to as "parallel" running surfaces) can be achieved through a few general track system designs. Several general track system design philosophies exist, each of which is optimized for specific application situations. Each design is capable of provide the prismatic running surface profile requirement, but differ in the level of difficulty required to achieve it. This article explains some of the designs and techniques for ensuring track running surface profiles are parallel in a linear guide system.

LINEAR GUIDE TRACK DESIGNS

Track can be divided into two general design types - single piece and assemblies.

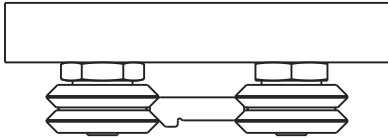


Figure 1. Example of a Vee Guide Wheel Carriage on a Single Piece Track

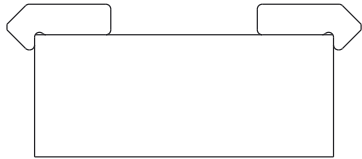


Figure 2. Track Pair Mounted on Common Single Piece Substrate

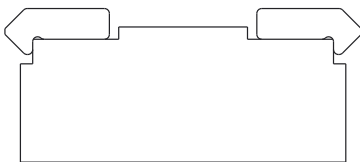


Figure 3. Track Mounting Datum Surfaces and Mounting Substrate with Machined Register Surfaces

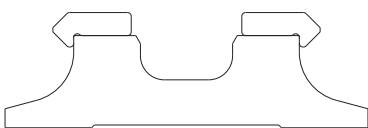


Figure 4. Example of Track Assembly with Custom Substrate to Accommodate Drive Elements

Single Piece Track Design

The simplest track design is a single piece track. The track has all requisite running surfaces, fabricated in a manner that ensures they are parallel along the entire length.

Single piece track are the simplest solution for assembly since they come from the manufacturer with all running surfaces fabricated to be parallel. Assemblers can install them into their applications without any additional concern for assembly adjustment or special assembly substrate preparation (aside from ensuring that the substrate surface is flat. Many manufacturers offer single piece track as standard products. As a result, they are produced and stocked on a regular basis, enabling them to be acquired quickly and at low cost.

Track Assembly System Design

A linear guide system utilizing one single piece track is not practical for every application. Single piece track typically are only available in a limited range of standard product profile sizes that are considered popular and cost-effective to produce. Many applications require wide track systems to provide higher roll moment load capacity and stiffness, or to support larger carriage payloads.

For these applications, track systems comprised of two separate pieces of track are the solution. The track pair can be mounted on a common single piece substrate, or they may be mounted on independent substrates that are connected with intermediate components. The complete track and substrate structure is typically called a track assembly.

The parallelism between the surfaces of the track pair depend on how they are assembled onto their substrate. Parallel sets of track register surfaces on the substrate can ease the alignment process; track pairs become parallel to each other when constrained against parallel register surfaces. The register surfaces can be machined onto a substrate, or raw stock material with precise profiles can be used.

Some manufacturers offer fully track fully assembled onto custom designed substrates to eliminate the need for end users to design and fabricate their own substrates.

When track pairs are used, each track only needs to have half of the running surfaces present on a single piece track. Single piece track with the full set of running surfaces required for individual usage are typically called "double edge" track while track with fewer running surfaces and intended for use in pairs are typically called "single edge" track. Double edge track is more costly to produce and the presence of running surfaces on both sides is unnecessary if they are used in pairs in a track assembly.

LINEAR GUIDE TRACK DESIGNS



Figure 5. Double Edge Track

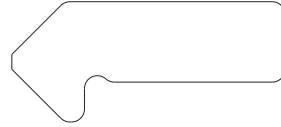


Figure 6. Single Edge Track

In applications where a linear guide system with a very wide track span is required, it can be easier to design and build the guide system from a pair of smaller, standalone double edge track linear guide systems, with the individual carriages connected by a carriage spanning plate, instead of a pair of single edge track and a one-piece carriage. When a pair of linear guide systems is used, each side can be assembled and adjusted one at a time. Splitting up the carriage system from one piece into multiple smaller ones makes the carriage system components easier to fabricate, handle during assembly, and adjust.

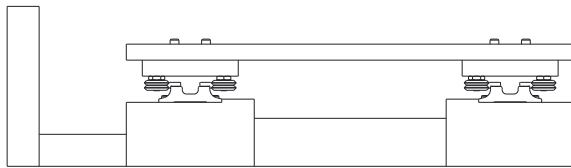


Figure 7. Example of a Wide Linear Guide System Composed of A Pair of Double Edge Track Assemblies and A Carriage Spanning Plate

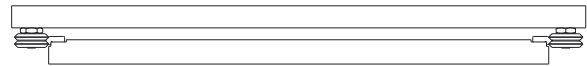


Figure 8. Example of a Wide Linear Guide System Composed of A Pair of Single Edge Track and A One Piece Carriage

ALIGNMENT OF LINEAR GUIDES TO APPLICATION COMPONENTS

Most applications require that their linear guides transport payload along a very specific path for processing or manipulation. Applications include CNC machines where cutting, grinding, or joining tools are mounting to the guides. The guides must be parallel to the working surfaces or else the tools may cause inaccurate processing of the product. Other applications where the linear guides need to be aligned to application components or product include pick and place machines and packaging lines.

There are two primary methods for aligning linear guides in an application – integrated alignment features or manual alignment. Integrated alignment features include machined-in features or assembly components that act as parallel register features that are machined or assembled to be parallel to the application components. This is the same idea as the register features for the track on the track assembly substrate, but carried over to the next level of assembly in the application. In applications where integrated alignment features are not possible, manual alignment can be performed. Manual alignment requires setup fixturing and fine adjustment to ensure parallelism between features.

Common alignment techniques are described and illustrated on the following pages. The example systems have a linear guide system comprised of one double edge track assembly and one carriage. The linear guide will be mounted to a substrate beam in the example system and need to be parallel to an adjacent vertical work surface. The track assembly substrate in the linear guide has clearance holes for the screws to pass through, while the corresponding mounting holes on the substrate beam are threaded. The outside faces of the track assembly substrate in the examples are assumed to be parallel to the track running surfaces.

LINEAR GUIDE TO WORK SURFACE ALIGNMENT METHOD 1

Integrated Alignment Features

In this example system, the substrate beam has a vertical register surface that is parallel to the work surface. When the track assembly is fastened to the beam with one edge of the track substrate contacting the register surface along its full length, the track assembly automatically becomes parallel to the work surface.

The parallelism between the work and substrate beam register surfaces can be achieved by fabricating the register surface into the beam after the two parts are assembled together, or the register surface can be pre-fabricated and aligned to the work surface through the usage of precisely dimensioned connecting components.

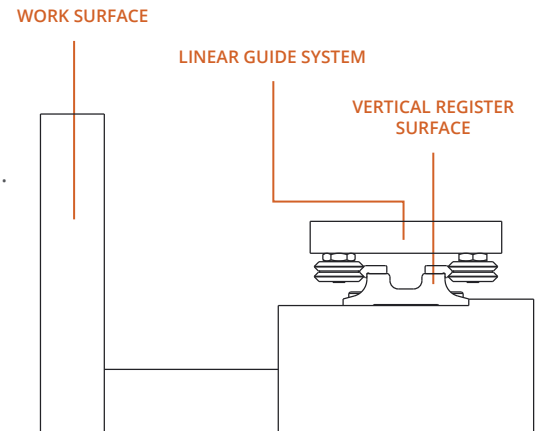


Figure 9. Substrate Register Surface for Alignment of Linear Guide System

LINEAR GUIDE TO WORK SURFACE ALIGNMENT METHOD 2

Manual Alignment with Setup Blocks

In this method, setup blocks are temporarily sandwiched between the linear guide and the work surface during linear guide assembly to control their alignment.

The work surface is completely flat in this example, so the setup blocks should have identical dimensions. The length of the blocks should also be such that they force the track assembly's mounting holes line up with the substrate beam mounting holes. At least two setup blocks are recommended for this process. More may be necessary for very long linear guides.

In this example, the setup blocks were pressed into contact against the track, but any track assembly feature can be used as long as it is parallel to the track running surfaces.

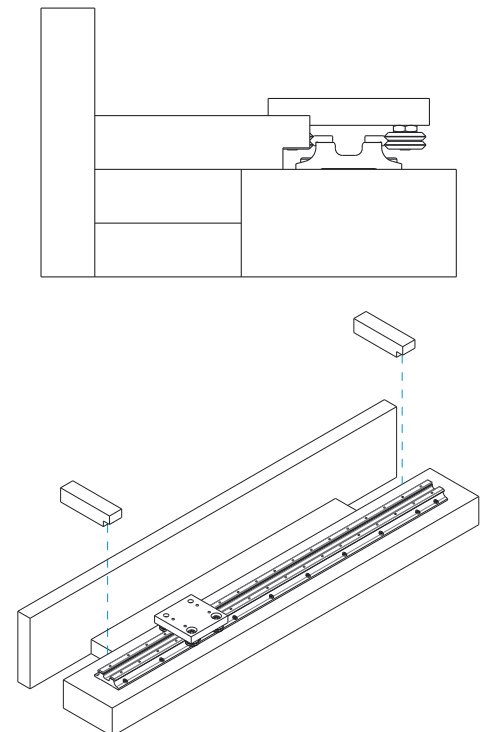
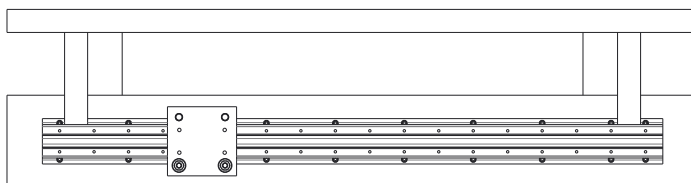


Figure 10-12. Setup Block Method for Aligning Linear Guide to Work Surface

ALIGNMENT OF TRACK OR TRACK ASSEMBLY PAIRS

In wider systems utilizing pairs of linear guides, the linear guides must be parallel to each other, as well as to any critical features in the application. Some of the techniques described above for aligning a single linear guide to the application components can be used here as well.

In the example systems shown below, the linear guide system is comprised of a pair of track assemblies and the carriage system is comprised of a wide, spanning plate that is firmly attached to a carriage on each linear guide. The track assemblies are attached to the substrate with screws. The track assemblies have clearance holes for the screws to pass through, while the substrate has threaded holes. For simplicity, it is assumed that the substrate beam mounting hole sets each linear guide are parallel to each other and to the work surface. It is also assumed that the track assemblies mounting surfaces on the two substrate beams are parallel and at equal heights, and the track assembly pair only need to be adjusted for parallelism in the horizontal direction.

LINEAR GUIDE PAIR ALIGNMENT METHOD 1

Integrated Alignment Features

This method is an extension of the first method described for aligning a single linear guide system to a work surface. In this case two register surfaces are needed, one for each linear guide. The two register surfaces need to be parallel to each other and, if necessary, to the work surface.

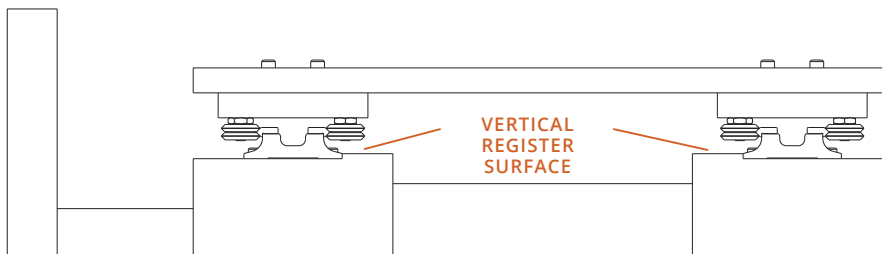


Figure 13. Linear Guide Pair System with Integrated Alignment Features on Mounting Substrate

Step 1

The individual linear guides are assembled and fully fastened onto the substrate beams.

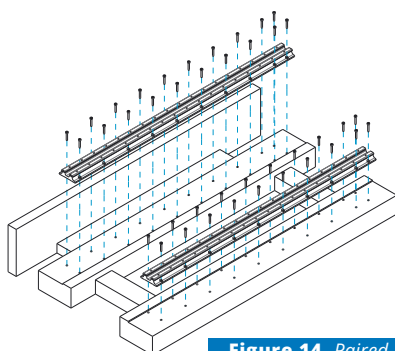


Figure 14. Paired Linear Guide System Assembly on Substrate with Register Surfaces (Carriages Hidden for Clarity)

Step 2

The carriage spanning plate is installed and firmly fastened over the carriages.

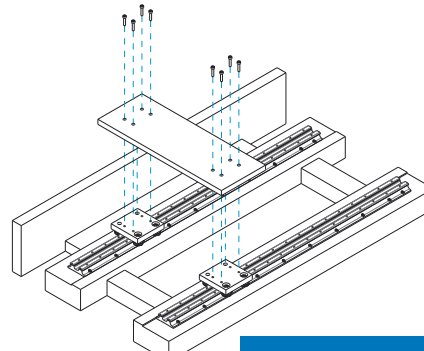


Figure 15. Carriage Spanning Plate Assembly on Carriages after Linear Guide Pair

LINEAR GUIDE PAIR ALIGNMENT METHOD 2

Manual Alignment with Setup Blocks

This alignment technique is an extended version of the one described earlier for aligning a single linear guide to a work surface. Spacer blocks are used between the two track assemblies to ensure they are parallel to each other.

Step 1

Both linear guides are assembled on the substrate beams. At this time, both linear are likely to be skewed relative to each other.

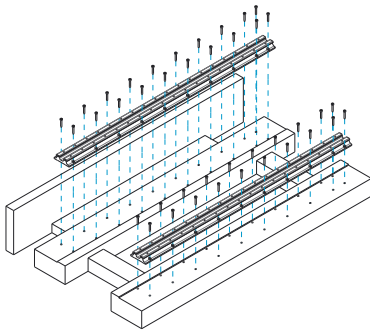


Figure 16. Paired Linear Guide System Assembly on Substrate with Register Surfaces (Carriages Hidden for Clarity)

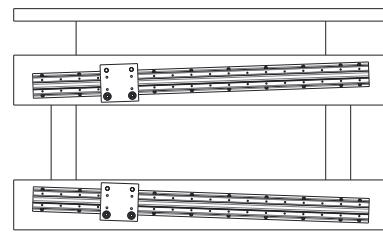


Figure 17. Linear Guides in Typical Initially Assembled State (Misalignment Exaggerated for Viewing)

Step 2

One linear guide is designated the reference side, and the other is designated the adjustable side. The reference side linear guide should be fully fastened while the adjustable side linear guide should be kept loosely fastened. If the entire linear guide system must be parallel to an application feature, such as work surface, the reference side linear guide must be aligned to this feature prior to being fully fastened. The single linear guide alignment method 2 described can be used for this procedure.

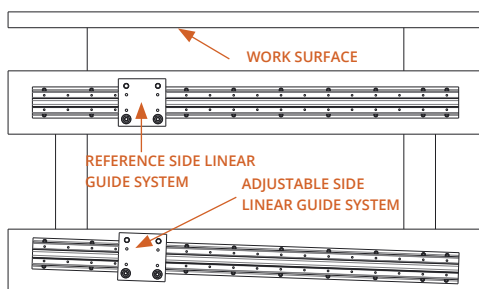


Figure 18. Linear Guide Pair, after Reference Side Linear Guide Has Been Aligned to the Work Surface

Step 3

One linear guide is designated the reference side, and the other is designated the adjustable side. The reference side linear guide should be fully fastened while the adjustable side linear guide should be kept loosely fastened. If the entire linear guide system must be parallel to an application feature, such as work surface, the reference side linear guide must be aligned to this feature prior to being fully fastened. The single linear guide alignment method 2 described can be used for this procedure.

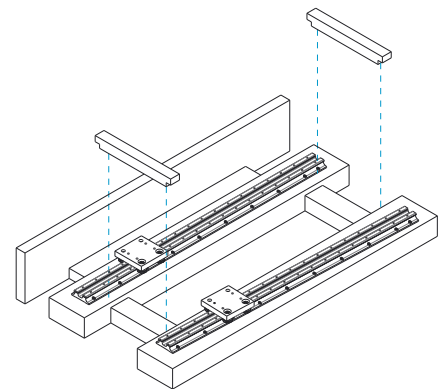


Figure 19. Linear Guide Pair Setup Block Insertion

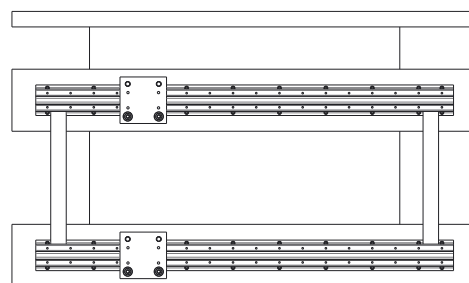


Figure 20. Linear Guide Pair after Alignment

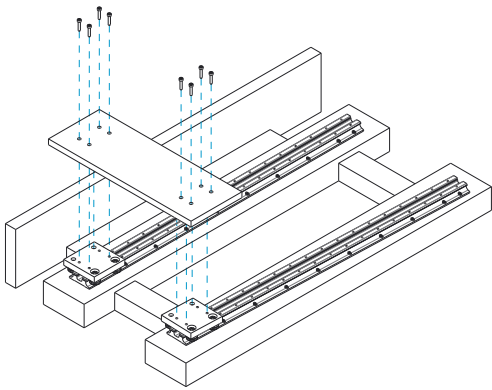
LINEAR GUIDE PAIR ALIGNMENT METHOD 3

Manual Alignment with Setup Blocks

An alternative manual alignment method to using spacer blocks is to use the self-aligning properties of carriages on linear guide pairs when they are connected in a specific manner. This method can be used when fabrication of dedicated spacer blocks is not practical or alignment requires are not as critical.

Step 1

Assemble the track assemblies the substrate beams, using steps 1-2 of linear guide pair alignment method 2.



Step 3

Push the carriage system back and forth along the full length track assemblies. Carefully pay attention to the drag characteristics of the carriages. The fully fastened carriage and track assembly on the reference side will start pulling the adjustable side components into closer alignment; this can be detected in the form of the carriage drag characteristics becoming more uniform over time.

Step 4

After a few back and forth carriage passes, or after the drag characteristics feel sufficiently uniform, fully fasten the adjustable side components.

Step 5

Perform at least one more back and forth carriage pass to verify that the drag characteristics are acceptable and did not change during the full fastening. If they did change, loosen the adjustable side components slightly and repeat steps 3-4. If this is still inadequate, it may be necessary to manually shift the adjustable components at sections where excessive tightness or clearance was detected.

This method is an extension of the first method described for aligning a single linear guide system to a work surface. In this case two register surfaces are needed, one for each linear guide. The two register surfaces need to be parallel to each other and, if necessary, to the work surface.

Step 2

Move the carriages towards one end of the track assemblies and assemble the carriage spanning plate over them.

The plate should be fully fastened to the carriage on the reference side track assembly and loosely fastened to the carriage on the adjustable sidetrack assembly.

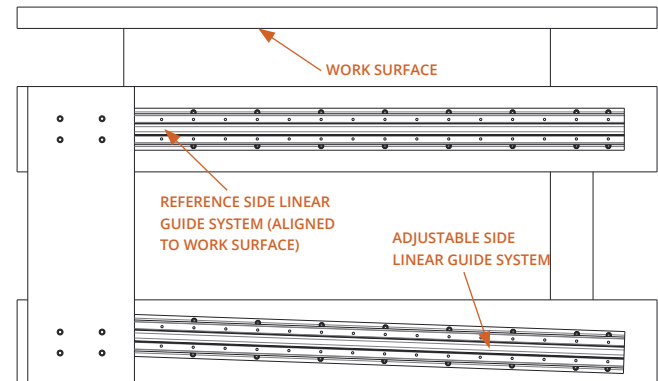
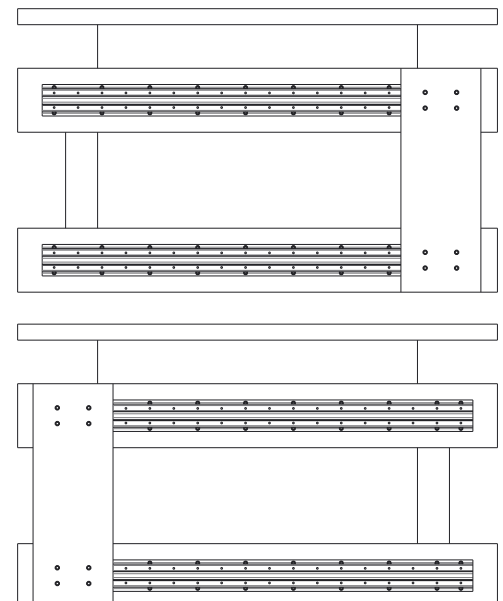


Figure 21. Linear Guide System, after Alignment of Reference Side Linear Guide Work Surface and Carriage Spanning Plate Assembly (Adjustable Side Linear Guide Misalignment Exaggerated for Viewing)



CONCLUSION

Alignment of Linear Guides to Application Components

Each of these alignment methods one has its own advantages and disadvantages that affect its suitability for a given application.

Integrated alignment features can reduce manual alignment time and effort, but requires fabricated register features which may be expensive to produce or may be difficult to assemble into the system while remaining parallel to the desired features.

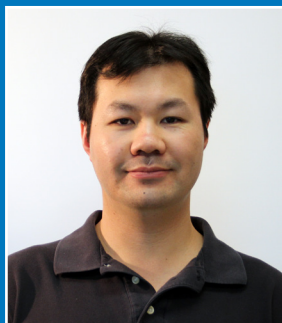
The setup block method requires fabrication or sourcing of suitable size blocks, which may be acceptable for systems that are assembled with regularity but may not be desirable for one-off systems. Depending on their shape and the surfaces that they can rest on, it may also be difficult to keep multiple blocks from becoming skewed when linear guides are pressed against them.

The carriage self-alignment method is not suitable for very precise applications. It is also not suitable for larger systems where the weight of the linear guides may prevent the carriages from effectively moving them. Finally it is not suitable for applications where the linear guide pair is mounted vertically since gravity may cause the adjustable side components from staying aligned after the carriage has passed over them.

For some applications, a combination of two or more methods may be the best solution.

ABOUT

Bishop-Wisecarver develops innovative motion solutions that are expertly designed and delivered to perform from a company you can trust. Leveraging nearly 70 years of experience, we've earned the reputation of providing unmatched quality, reliable service and engineering support for every stage of a customer's design cycle. No matter your application, volume shipment requirements or extreme environmental conditions, Bishop-Wisecarver listens to your specific needs and delivers innovative solutions.



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