

Vernier Motion Encoder System

(Order Code: VDS-EC)



The Vernier Motion Encoder System* is a Vernier Dynamics System outfitted for the precise study of dynamics cart motion without the use of ultrasonic motion detectors. The encoder system consists of several parts:

- A track with an encoder strip along the length of the track
- A dynamics cart with an optical encoder and infrared (IR) transmitter
- A receiver, attached to the end of a track

The encoder strip consists of alternating black and white bars with a 4 mm period, allowing the optical sensor to detect the passage of the bars as the cart moves. With two sensors appropriately placed, a change in position with 1 mm resolution can be determined, as well as the direction of travel. A narrow infrared beam transmits motion data to a receiver.

No alignments or adjustments are necessary, as the receiver attaches firmly to the track, and the cart rides in slots on the track. The IR beam is not disturbed by reflections from nearby objects.

The system is designed for use in physics and physical science courses for motion and energy experiments. An optional Optics Expansion Kit (order code: OEK) converts the track to an optics bench.

Some typical experiments done with the system include

- Motion under zero acceleration
- Motion under constant acceleration with the ramp inclined
- Inelastic collisions using the included hook-and-pile tabs
- Elastic collisions using the included magnetic bumpers

Parts Included with the Vernier Motion Encoder System

- Motion Encoder Cart with magnetic and hook-and-pile end caps
- Motion Encoder Receiver
- Plunger Cart with magnetic and hook-and-pile end caps
- Mass – 500 g
- Combination 1.2 m dynamics track/optics bench with encoder strip
- Adjustable leveling feet
- Mounting hardware for Dual-Range Force Sensor and accelerometers
- Adjustable End Stop
- Motion Detector Bracket

* Patent Pending

- 2 Photogate Brackets
- Rod Clamp
- Allen wrench 3/32 inch

Collect Data with the Vernier Motion Encoder System

This sensor can be used with the following interfaces to collect data:

- Vernier LabQuest® as a standalone device or with a computer
- Vernier LabQuest® Mini with a computer
- Vernier LabPro® with a computer

WARNING: The Motion Encoder Receiver is not compatible with the Texas Instruments TI-Nspire Lab Cradle. Connecting the Receiver to the Lab Cradle will render the Cradle inoperative, requiring repair by Texas Instruments.

Essential steps for using the Vernier Motion Encoder System:

1. Attach the receiver to the end of the track, matching the encoder strip on the track to the markings on the receiver.
2. Place the track on a level surface.
3. Insert two AAA batteries (not included) into the encoder cart.
4. Connect the receiver to an interface such as a LabQuest 2. If using a computer, connect the interface to your computer, and launch *Logger Pro*.
5. Turn on the cart by pressing the power button. It will glow blue when the cart is on.
6. Place the cart on the track, wheels in grooves, with the blue light facing the receiver.
7. Begin data collection, and let the cart roll.

Data-Collection Software

This sensor can be used with an interface and the following data-collection software.

- **Logger Pro 3** This computer program is used with LabQuest or LabPro. Version 3.8.6.2 or newer is required.
- **LabQuest App** This program is used when LabQuest is used as a standalone device. Versions 1.7.1 for the original LabQuest and 2.2.1 for the LabQuest 2, or newer, are required.

NOTE: Vernier products are designed for educational use. Our products are not designed nor are they recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

Specifications

Measurement Range	1.2 m track
	2.2 m track
Accuracy and Resolution	1 mm
Optimum data-collection rate	15–30 Hz

Calibration of the Vernier Motion Encoder System

This sensor is equipped with circuitry that supports auto-ID. When used with LabQuest, LabQuest 2, or LabQuest Mini, the data-collection software identifies the sensor and configures an experiment appropriately.

No calibration of the Vernier Motion Encoder System is necessary. The printed bars on the track determine the scale, and the cart encoder counts the passage of the bars. Available units are meters and feet, selectable in software.

In contrast, it is possible and desirable to zero the encoder. Unlike an ultrasonic motion detector, there is no way for the system to have an unchanging reference position; it can only count bars from the point at which the cart is placed on the track. As a result, you may want to move the cart to the receiver end of the track and zero the reading in software.

The positive direction can be reversed so that readings increase as the cart moves toward the receiver. A reversed coordinate system is helpful when using two Vernier Motion Encoder Systems to monitor the motion of two encoder carts, so that the positive direction is the same in both cases.

Because the track strip must be continuous, the Vernier Motion Encoder System cannot be used with the Track-to-Track Coupler.

Power

The Motion Encoder Cart requires two AAA batteries. Either NiMH rechargeable batteries or alkaline disposable batteries can be used. Turn on the cart by pressing the clear power button on the cart endcap. It will glow blue when power is on. Press again to turn off. The cart will turn itself off after 20 minutes of inactivity. Any motion on the track will cause the timer to be reset. The receiver is powered by the interface.

Battery life depends on use and the range setting. Low battery level may cause erratic detection of the cart motion, including incorrect velocity signs. Replace the batteries if this is seen.

Range Setting of the Motion Encoder Cart

The IR transmitter on the cart has two power levels available. The default 1 m setting conserves battery power. If the cart is used on a 2.2 m track, set the cart to the higher 2 m power level. If this setting is not used, the receiver will not reliably sense the position of the cart at the far end of the track. The switch is located inside the battery compartment.

Use of Two Vernier Motion Encoder Systems on the Same Track

Some experiments require measuring the motion of two carts. This can be done by purchasing the Motion Encoder Cart and Receiver (order code: MEC-VDS) to add a second encoder cart, receiver, and strip to your Vernier Motion Encoder System. A Motion Encoder Receiver is placed at either end of the track, and two Motion Encoder Carts are used on the track, each with its transmitter facing the unobstructed

receiver. A second encoder strip must be applied to the track, one on either side of the center slot.

Consider reversing the direction of one receiver so that the same direction is positive for each system. Put the carts together, and zero both systems. This will put the carts on the same coordinate system; if they move together in contact, their position readings will be the same.

Use of Multiple Vernier Motion Encoder Systems in the Same Room

Because of the narrow IR beam used for signaling between the cart and receiver, interference should be rare. However, if one apparatus is apparently interfering with another, the problem can be resolved by repositioning one of the tracks.

All Motion Encoder Carts are interchangeable; that is, there is no matching of cart to receiver.

Data-Collection Notes for the Motion Encoder System

- The optical motion encoder can only make relative position measurements, so that the zero point is initially determined by where on the track the cart is first placed when the power is on. If you want zero to be near the receiver, initially place the cart next to the receiver. This behavior is very different from the ultrasonic Motion Detector, which by default uses a fixed origin near the detector.
- The motion encoder is nearly immune to interference, but it cannot work if the IR beam between the cart and receiver is blocked. Keep your hand away from this region.
- Since the zero position (origin) of the encoder depends on where the cart is placed initially, it is often useful to zero the encoder in software. Place the cart in the position you want to declare as zero. On LabQuest, tap the meter display to access the zero command. In Logger *Pro*, use the toolbar button.
- It can also be useful to reverse the direction of the coordinate system, so that values increase as the cart moves toward the receiver. Do this from the meter screen on LabQuest, or by using the sensor popup menu in the Set Up Sensors dialog for your interface on Logger *Pro*.
- High data-collection rates are not useful for the motion encoder. Rates above 30 Hz will produce noisy velocity and acceleration graphs because of few counts during each time period.
- Just like the ultrasonic Motion Detector, it can be useful to adjust the number of points used to calculate derivatives for velocity and acceleration graphs. Higher values create quieter graphs, while lower values result in more temporal detail. Adjust this value in LabQuest preferences or in the Settings for... File menu item in Logger *Pro*.

Photogate Bracket

Photogate Brackets are attached to the side of the track. With the nut loosely on the T-handled bolt, slide the nut into the side channel of the track. Attach the photogate using the supplied wing bolt in the long slot. Adjust the gate height so the beam intercepts the desired portion of the target.



Motion Detector Bracket

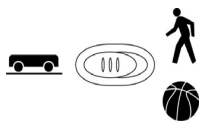
Although we expect that the motion encoder will be used most often to record motion data, it is also possible to use an ultrasonic Motion Detector.

Any Vernier Motion Detector with a hinged head can be attached to the supplied Motion Detector Bracket. The Motion Detector Bracket has a pin to locate the Motion Detector on the bracket.

There is a knob, nut, and bolt to attach the bracket to the track underside, and a threaded hole at the end near the pin. To assemble, place the Motion Detector with the back end over the pin of the bracket. Insert the screw through the slot into the threaded insert on the detector with the hinge toward the track, and tighten. Insert the bracket into the slot in the underside of the track as shown in the photo. When the Motion Detector is not attached to the bracket, its mounting screw can be stored in the threaded hole near the pin.



Newer Vernier Motion Detectors (green or black case with adjustable sensitivity) can be placed so that the sensor is 15 cm from the end of the track. The carts can then be detected properly all the way to the end. The track mode is appropriate for the dynamics system.



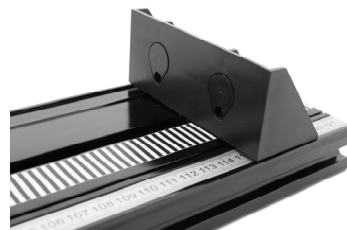
Adjustable Leveling Feet

The Adjustable Leveling Feet slide into the end of the track, with the nut in the center slot of the track underside. Adjust the height as desired. Install the feet before attaching the Motion Detector Bracket.



Adjustable End Stop

The Adjustable End Stop slides into the end of the track. Adjust the position as desired. Insert magnets in the End Stop if desired.



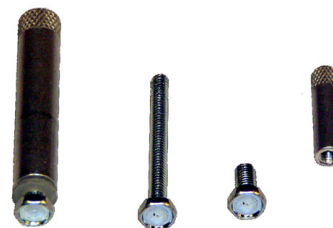
Rod Clamp

The Rod Clamp is used to support the track with a user-supplied ring stand. Insert the Rod Clamp nut into the side of the track. Adjust the height as desired.



Mounting Hardware

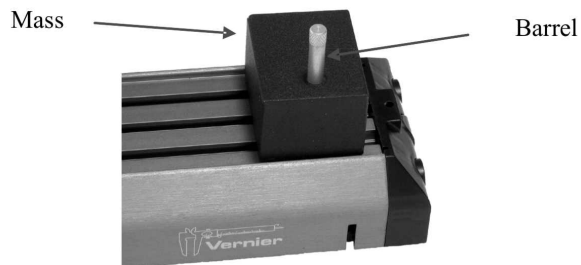
The supplied mounting hardware is used to attach devices to the cart, such as a force sensor, accelerometer, or mass. To attach a Wireless Dynamics Sensor System (WDSS) use the hardware supplied with that device. The hex-head bolts may be attached to any point along the slots in the cart, but the head must be inserted in the flare region of the slots. Tighten the threaded barrels on the bolts.



The Additional Mass (MASS)

The 500 g mass is used to double the mass of the cart.

1. Insert the hex head of the #10-32 x 1-3/4" screw into either of the side slots on the cart from the flared end.
2. Fit the mass over the screw and position the mass and screw as required on the cart.
3. Screw the small barrel onto the projecting end of the #10-32 x 1-3/4" screw and tighten to secure the mass.



Magnetic Bumpers

The Vernier dynamics carts are supplied with magnets and hook-and-pile tabs. You may choose to install either or both on your carts. Since the magnets may interfere with certain experiments using force sensors on the carts, only install the magnets if you need them.

The magnets are useful in studying collisions with the magnets positioned so that they are the same polarity on both sides and on both carts. This way the carts will repel one another, and you can arrange a collision in which the carts never actually touch. The collision will be very nearly elastic, unlike a collision using a spring or any kind of contact.

To install magnets so that carts will repel one another, as well as the Adjustable End Stop, use the following procedure.

1. Remove the teardrop from the cart end or the End Stop.
2. Insert the silver magnet (supplied with the cart) into the teardrop, oriented so that the outside of the teardrop will attract the south-pointing end of a compass needle.
3. Insert a foam plug (supplied with the cart) into the teardrop.
4. Reinsert the tear drop into the cart end or the end stop, and fasten the screw.

If you like, test by holding the compass near the cart or stop, in the same position as an approaching cart, and verify that the south-pointing end of the compass is attracted to the cart.



Carts come with magnets, foam plugs, teardrop inserts, and a hex key to remove and replace the screw holding the teardrop to the cart end. A magnetic compass is not included.

The magnets can be removed at any time by reversing this process. Store the magnets away from computers.

To study totally inelastic collisions, place hook-and-pile tabs on top of the teardrop-shaped plugs. Looking at the end of the cart, place a hook pad on the left-hand plug, and a pile tab on the right-hand side. Center the pad on the round part of the plug. This way any cart with hook-and-pile tabs will stick to any other. Hook-and-pile equipped carts will stick together, creating a totally inelastic collision.

One cart includes a spring-loaded plunger for collisions. To use the plunger, simultaneously press the horizontal button above the plunger and press the plunger in until it locks. To release, press on the pin from the top of the cart. The plunger force can be adjusted. To adjust the plunger release force, rotate the plunger while it is extended.

Both the plunger and encoder carts have a mass of 500 g. Adding accessories will change the mass.

Use of Additional Accessories and Sensors with the Encoder System

The following examples show various sensors attached to a Vernier dynamics cart. Sensors are not included with the Vernier Motion Encoder System.

Attach the Dual-Range Force Sensor (DFS)

1. Insert the hex head of the screw on the bottom of the post into the center slot of the cart at the flare. The flats of the hex head should be parallel to the slot and the washer should be above the slot to avoid marring the cart with the metal post.
2. Slide the post to the desired position on the cart and lightly tighten in place with the knurled end of the post.
3. Place the DFS on the cart with the post through its central hole. Reposition the post if necessary, and tighten. Tighten the plastic screw on the end of the sensor to secure the DFS in place.



The Low-g Accelerometer (LGA)

The LGA is attached to one of the side slots of the cart using the #10-32 x 3/8" hex head screw and the small threaded barrel. The LGA is attached on one side only to maintain the correct orientation of the sensor.

1. Insert the #10-32 x 3/8" hex head screw into one of the mounting holes of the LGA from the bottom and screw on the barrel a few turns, leaving at least half of the screw threads exposed for fitting into the slot.
2. Use the arrow printed on the sensor to decide which of the cart side slots to use so that the sensor is oriented in the desired direction.
3. Slide the head of the screw into the chosen slot from the flared end, position the sensor as required, and tighten the small barrel to secure it to the cart.



DFS and LGA in Combination

The DFS (Dual-Range Force Sensor) and LGA (Low-g Accelerometer) can be combined using the same procedures.

As long as the DFS is positioned so that the attachment to be used is facing in the required direction, the order of attachment is not critical.



MASS and DFS

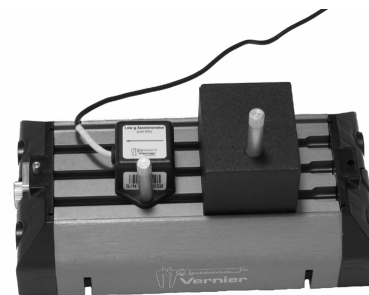
Attach the DFS first, since the plastic screw on the DFS becomes inaccessible when the MASS is attached.



The DFS must be attached at the opposite end of the cart from the slot flares if you want to be able to remove the mass without removing the DFS.

MASS and LGA

For this combination, the order of attachment is not critical.



MASS, DFS, and LGA

This is a similar case to the MASS and DFS, where the DFS must be attached first. There is sufficient room on the new MASS bolt to piggyback the LGA on top of the mass before attaching the small barrel.



Wireless Dynamics Sensor System

For connection to a Vernier dynamics cart use a $5/8" \times 10-24$ binding barrel and a hex-head bolt ($1" \times 10-24$). First place the bolt head in the middle slot of the top of the Vernier dynamics cart. Then lower the WDSS on top of the cart and insert the binding barrel in the large hole of the WDSS. The bolt threads into the binding barrel. Tighten the binding barrel. The process is shown in the series of photos below:



General Hints for Vernier Motion Encoder System

- Do not install the magnets unless you know you want to use them. They will interfere if you perform an experiment with a force sensor riding on the cart, since the force sensor will then not read the total force acting on the cart.
- The magnets can be hard to pull apart if they stick together before installation; slide them across one another to separate.
- The conventional arrangement for magnets is to have the cart ends attract the S end of a compass needle. The key thing is that all magnets repel, so if you use the opposite convention everywhere, no harm is done.
- The magnets are designed for fairly gentle collisions. If the cart is moving too quickly, the magnetic forces may cause the cart to jump off the track to the side. If this happens, use a lower initial velocity for the cart.
- Keep the track clean; if it is very dusty the carts will not roll smoothly.
- Use lower speeds and lower inclines than you might initially choose; the physics is the same and students will have more time to observe what is happening.
- Attach the track feet, sliding at least one in about 30 cm before inserting the Motion Detector Bracket.
- Study the Motion Detector Bracket photo carefully and note that the bracket is attached to the underside of the track. A common error is to attach the bracket to the top slot on the track.
- Some Dual Range Force Sensors come with a plastic bolt that is too long to allow simultaneous attachment of the DFS with a MASS. If your bolt is long, use a wire cutter to remove a few threads at a time.

Suggested Experiments with the Vernier Motion Encoder System

The Vernier Motion Encoder System can be used wherever a Motion Detector could have been used with a cart and track. The encoder depends on the presence of the track, so that *only* cart and track experiments can be performed.

Measure Cart Acceleration

The basic motion of a cart on a ramp can be studied. For example, perform Experiment 3 from *Physics with Vernier*, “Cart on a Ramp.” Or, repeat Galileo’s

experiment of determining g using an object and a ramp. This is Experiment 4, “Determining g on an Incline,” from *Physics with Vernier*.

Newton’s Second Law

Use a force sensor on the encoder cart to record both applied force and acceleration. The two will be proportional.

Or, set up a half-Atwood machine with a hanging mass and a pulley at the track end opposite the receiver. Measure the acceleration of the encoder cart as a function of the hanging mass.

Measure Fan Cart Acceleration

Add a Cart Fan (order code: FAN-VDS) to observe the motion of a cart under constant thrust.

Measure Cart Acceleration with Friction

Add a Friction Pad (order code: PAD-VDS) to the encoder cart and observe the motion of the cart with varying frictional forces.

Momentum-Impulse

Add a force sensor and a Bumper-Launcher Kit (order code: BLK) to observe the relationship between momentum and impulse. Find the impulse by integrating under a force vs. time graph.

Conservation of Energy

Use two Vernier Motion Encoder Systems to observe a change in energy due to a collision between two carts.

Conservation of Momentum

Use two Vernier Motion Encoder Systems to observe a change in momentum due to a collision between two carts. Try different kinds of collision: elastic, inelastic, totally inelastic.

Products Related to the Vernier Motion Encoder System

Vernier Dynamics System (order code: VDS)

Vernier Dynamics System is a low-friction black anodized 1.2 m track and optics bench combination designed for kinematics, dynamics, and optics experiments. It includes two carts.

Vernier Dynamics System with Long Track (order code: VDS-LONG)

The long version of the Vernier Dynamics System includes a 2.2 m track instead of the 1.2 standard track.

Track (order code: TRACK)

The Combination 1.2 m Track/Optics Bench comes with the Encoder System Strip installed.

Bumper Launcher Kit (order code: BLK)

The Bumper Launcher kit includes accessories to integrate the Dual-Range Force Sensor (DFS-BTA) with the Vernier Dynamics System or Vernier Motion Encoder System, allowing for many interesting experiments in momentum-impulse study.

Dual-Range Force Sensor (order code: DFS-BTA)

The Dual-Range Force Sensor measures pushes and pulls up to 50 N.

Wireless Dynamics Sensor System (order code: WDSS)

The WDSS is a wireless force sensor and accelerometer.

Replacement Parts

Motion Encoder Receiver (order code: MEC-BTD)

The receiver attaches to the end of the track and connects to an interface, such as a LabQuest 2.

Motion Encoder Cart (order code: CART-MEC)

This is the complete Motion Encoder Cart, with no assembly required.

Motion Encoder Track Strip (order code: METS)

The strip can be attached to an existing track without an encoder strip, or it can be attached as a second strip for use with two encoder systems. For 1.2 m track.

Motion Encoder Track Strip - Long (order code: METS-LONG)

The strip can be attached to an existing track without an encoder strip, or it can be attached as a second strip for use with two encoder systems. For 2.2 m track.

Motion Encoder Transmitter Parts (order code: MECT)

The transmitter assembly is used to upgrade an existing cart to a Motion Encoder Cart.

Suggested Accessories



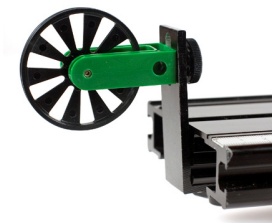
Optics Expansion Kit (order code: OEK). The Vernier-Optics Expansion Kit extends the Vernier Dynamics System or Vernier Motion Encoder System for use in optics experiments.

Color Mixer (order code: CM-OEK). The Vernier Color Mixer Kit consists of a three-color LED illuminator with power supply, a lens, and a double-sided screen. Experiments in additive and subtractive color mixing can be easily and conveniently carried out using this kit. The intensity of the red, blue and green LEDs can be smoothly controlled from the light source.



Ultra Pulley (order code: SPA). The pulley can be attached to the end of a track using the Pulley Bracket to make a half-Atwood machine.

Pulley Bracket (order code: PB-SPA). The pulley bracket allows easy attachment of an Ultra Pulley to the end of a Vernier track. Compatible with a photogate bracket for measuring motion using the pulley.

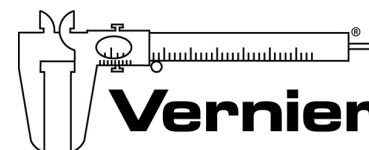


The **Cart Friction Pad** (order code: PAD-VDS) is a variable friction mechanism for use with the Vernier Standard Cart, Plunger Cart, and Motion Encoder Cart. It can be used on any flat surface or, for best results, with the Vernier Dynamics System or Vernier Motion Encoder System to study the effects of friction.

The two-speed **Dynamics Cart Fan** (order code: FAN-VDS) magnetically attaches to the Vernier Standard Cart, Plunger Cart, and Motion Encoder Cart. It can be used on any flat surface or, for best results, with the Vernier Dynamics System or Vernier Motion Encoder System to study motion, force, and momentum.

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.



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Vernier Software & Technology

13979 S.W. Millikan Way • Beaverton, OR 97005-2886
Toll Free (888) 837-6437 • (503) 277-2299 • FAX (503) 277-2440
info@vernier.com • www.vernier.com

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