Description

SpeedGate is a dual-ray photogate with display. Two light rays enables direct measurements of speed. The display eliminates the need for an external counter/timer.

In addition to the two light rays, external signals can start and stop the timer. This allows for timing the interval between passage of two photogates.
External signal can completely replace the light rays. This way, SpeedGate can be used as a universal timer – e.g. with two microphones.

SpeedGate is operated by three pushbuttons; two buttons (Ⅰ and Ⅱ) select the mode of operation, the third (ⓧ) is for zeroing and for powering on and off.

The display is divided in two – corresponding to the buttons Ⅰ and Ⅱ. Gravity makes the display rotate, it will always be upright. A status area continuously displays the state of the light rays and the external inputs.

Typical experiments

The following examples of experiments can be built around one or two SpeedGates. (Additional equipment is necessary.)
Detailed lab manuals can be found on our web site.

- Movement with constant acceleration
- Newton's 2nd law
- Conservation of momentum
- Free falling bodies
- Conservation of mechanical energy
- Mathematical pendulum
- Physical pendulum
- Uniform circular motion
- Speed of sound

  - etc. -

– see also p. 6.

Modes of operation

The table below shows the possible combinations of SpeedGate's operating modes. A detailed description follows.

Primary function (upper display) Ⅰ	Secondary function (lower display Ⅱ	
Front Time	*Previous Value*	
	Interval Before	
	Interval After	
Dark Time (X)	*Previous Value*	
	Interval Before	
	Interval After	
Speed	*Previous Value*	①
	Interval Before	
	Interval After	
	Front Time	①
Period (X)	*Mean Period*	②
	Mean Frequency	②
	Counts	②
Pendulum Period (X)	*Mean Pendulum Period*	③
	Mean Pend. Frequency	③
	Period Count	③

①,② resp. ③: Mutually compatible functions – see the paragraph "Operation").

Frederiksen Scientific A/S
Viaduktvej 35 · DK-6870 Ølgod
Tel. +45 7524 4966
Fax +45 7524 6282
info@frederiksen.eu
www.frederiksen.eu

Operation

SpeedGate is powered on by pressing Ⓧ. The same button is used for zeroing (short push) and for turning off (keep depressed).

When the unit is powering up, the sensitivity of the photocells are calibrated – avoid blocking the light rays at this time.

The two light rays are labelled X and Y. Light ray X is the one closest to the front of the unit.

When measuring *Front Time* or *Speed* the results are displayed with sign. Movement from X to Y is positive. In addition to the signs the direction is also displayed graphically by the symbols X ▸ Y resp. Y ▸ X .

Some functions can use the Aux IN and Chain IN inputs.
Aux IN virtually duplicates the X light ray.
Chain IN is e.g. used for timing the interval between passage of two SpeedGates.
More details in the following paragraph.

With button Ⓘ the primary function of the photogate is selected. For each primary function, Ⓘⓘ is used for selecting the secondary function. Both buttons "roll" through the options: When the bottom of the list is reached the next press goes to the top. Pressing Ⓘ will cancel any ongoing measurements and zero the display.

If a measurement is running – or if a previous result is shown – pressing Ⓘⓘ will *not* stop or reset the measurement. Pressing Ⓘⓘ repeatedly will therefore bring SpeedGate back to exactly the same state as before. Some of the secondary functions are mutually compatible, meaning that the measurement simply continues with a new secondary function. These will be shown in the normal, white letters in the display. In the table above, these states are marked by common numbers (①,② resp. ③).

Other secondary functions cannot replace each other in a meaningful way. Such a function is shown in light blue letters. In order to change to the secondary function shown, reset the measurement by pressing Ⓧ.

Primary functions – select with Ⓘ

Results from these measurements are displayed in the upper part of the display.

Front Time

This designates the time it takes for the front of an object to move from one of the light rays to the other. Front times are signed. The time is displayed during the measurement.

Dark Time (X)

This function is timing how long ray X is blocked. The time is displayed during the measurement.

Speed

Internally, speed is calculated from the front time and the known distance between the light rays. The distance is very close to 20 mm (each SpeedGate is individually calibrated with the precise value).

Speeds are signed values. The speed is displayed during the measurement.

Period (X)

The period of a repetitive phenomenon is the time interval between two consecutive occurrences. It is measured with light ray X.

Used e.g. to find period of revolution.

Pendulum Period (X)

This function is much like the above – but every second event is ignored. It is measured with light ray X.

Normally used for finding the period of a pendulum that swings all the way through the photogate.
In this situation, you want to time the interval between two passages in the same direction.
(In case the amplitude is too small for this, use the function *Period* instead.)

Secondary functions – select with ⓫

Results from these measurements are shown in the lower part of the display.

Previous Value

Each time a measurement (primary function) is started, the previous result is moved to the lower display.

When this secondary function is selected, measurements will run continuously without the need for zeroing between measurements.

Interval Before

Used with Chain IN. Chain In is connected to Chain Out on another SpeedGate which is passed **before** this one.

Passage of the other SpeedGate will start the interval timing.

When the first light ray (X or Y) on this SpeedGate is blocked, interval timing stops.

This secondary function requires zeroing before a new measurement can be made.

The signal received at Chain In is replicated at Chain Out. This way, a single start signal can trigger the interval timers simultaneously in several daisy chained SpeedGates.

With *Interval Before* selected, this SpeedGate will also be reset when the previous one is. If several SpeedGates are daisy chained, the first one will be able to zero the complete chain.

Interval After

Used with Chain IN. Chain In is connected to Chain Out on another SpeedGate which is passed **after** this one.

When the first light ray (X or Y) on this SpeedGate is blocked, interval timing starts.

Passing the other SpeedGate will stop the interval timing.

This secondary function requires zeroing before a new measurement can be made.

Front Time

Speed is calculated based on a measurement of front time. This secondary function displays the underlying measurement.

As with the function *Previous Value,* continuous measurements are made without the need for zeroing between measurements.

Mean Period

This is the sum of the periods measured since last zeroing of the device, divided by the number of completed periods.

Mean Frequency

Shows the reciprocal value of the mean period.

Counts

Number of times the light ray has been blocked since last zeroing of the device (– *not* the number of periods which is 1 less).

Mean Pendulum Period

This is the sum of the pendulum periods measured since last zeroing of the device, divided by the number of completed pendulum periods.

Mean Pendulum Frequency

Shows the reciprocal value of the mean pendulum period.

Period Count

The number of whole, completed pendulum periods since last zeroing of the device (– which is neither the number nor half the number of passages of the light ray).

Status indicator

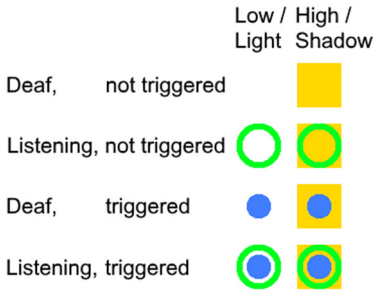
A fixed area of the display is used for the status of the four signals: Light rays X and Y, Chain IN and Aux IN. The status display can be useful during analysis and troubleshooting experiments.

Regardless of function, you can read the *physical* state of the signals; the state SHADOW (light ray X and Y), resp. HIGH (Chain IN and Aux IN) – is shown as a yellow square.

For every combination of primary and secondary functions there will be one or more signals capable of starting or stopping the timer. These signals are in the state LISTENING and will be indicated by a green circle.

A signal which has caused the timer to start or stop is in the state TRIGGERED. This is indicated by a blue dot.

The three states can be combined – see table



Aux IN and Chain IN

Chain IN accepts signals from Chain Out on another SpeedGate. This input can also be used with other equipment like e.g. a 248600 micro-phone.

Aux IN is used in many measurements as an alternative to light ray X – but not in functions that also involves light ray Y (*Front Time*, *Speed*). This input can also be connected to other equipment.

Logic levels

To make SpeedGate as versatile as possible the electric inputs adapt to the equipment that is connected. ***This will normally happen automatic, in an intuitive way*** – as long as you stick to equipment that is described as compatible with SpeedGate.

For the sake of users who wish to use other equipment – possibly home built – here follows a detailed description. This will also provide a background for a thorough understanding of the status indicators

SpeedGate reacts on four signals: Light rays X and Y, Chain IN and Aux IN. On the physical level, a light ray can be blocked or not and an electric input can be HIGH (≈ 5 V) or LOW (≈ 0 V).

The two light rays have a *fixed* translation between their physical state and the logic level used internally: LIGHT = rest state = logic 0. SHADOW = active state = logic 1.
Hence, a *Dark Time* measurement for light ray X always measures how long light ray A is logic 1.

For the two inputs, Chain IN and Aux IN, the translation is *dynamic*. This means that the rest state, logic 0, is defined as the physical state of the input *at the time the SpeedGate is zeroed*.

Example of dynamic allocation of logic levels

Assume that Chain IN is HIGH and Aux IN is LOW when ⓧ is pressed. Then the following applies:

Chain IN:	LOW = Logic 1	HIGH = Logic 0
Aux IN:	LOW = Logic 0	HIGH = Logic 1
	(Only in this example)	

If the function selected is *Dark Time* + *Interval Before*, a possible series of events could be:

1 - Chain IN goes LOW (logic 1)
interval timing starts

2 - Chain IN goes HIGH (logic 0)
no action

3 - Aux IN goes HIGH (logic 1)
interval timing ends, dark time timing starts

4 - Aux IN goes LOW (logic 0)
Dark time timing ends

Aux IN and Chain IN in the different functions

***Front Time* and *Speed*:** Aux IN isn't relevant for measuring front time in itself, but it can be used in some of the related secondary functions. (The upper display will then show a "-".)

***Dark Time*:** This function will measure the time that Aux IN is at logic level 1.

***Period* and *Pendulum Period*:** The Aux input can be used as signal source instead of light ray X. (As soon as timing was started by either light ray X or Aux IN the other signal source is disabled.)

***Interval Before*:** Interval timing starts when Chain IN changes level to logic 1.

Interval After: If the interval timer is running it will stop when Chain IN changes level to logic 1.

Input protection

As mentioned, SpeedGate inputs work with voltage levels 0 V and 5 V. Negative voltages and voltages larger than 5 V may destroy the SpeedGate.

Equipment that works with higher voltages – like e.g. 198510 Switch Box – must be connected through a 198512 Signal Limiter that protects against all voltages from -24 V to +24 V.

The signal limiter has a modular socket for the connection to the SpeedGate, and normal safety sockets for the external signal source.

Error messages

If a function requires a certain sequence of signals, it may happen that a signal arrives too early, even if it actually is part of the measurement in question. As a help for troubleshooting this will briefly be noted by the text "*Not yet started*". For instance, this will happen in the function *Front Time* + *Interval Before* if one of the light rays are blocked before the Chain IN signal arrives.

When a measurement is started (and eventually completed) and you change to another secondary function which is not compatible with the original one, another error message may occur: If a signal arrives which in principle could start the timer in the new function, the text "*Reset to start*" will be shown briefly. The incompatible function will as previously mentioned be shown with light blue heading instead of white.

Battery indicator

When SpeedGate is turned on, the state of the battery is briefly shown.

If the battery voltage during use falls below a certain level, this will be indicated by the text "*Low battery!*" will be shown in small letters at the very top of the display.

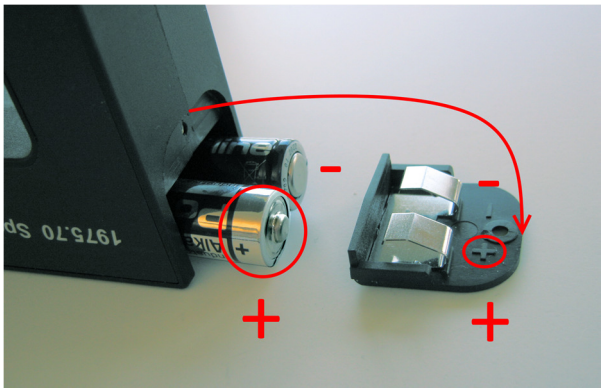
Note that SpeedGate can be powered via the USB connector without any problems – even with a low battery warning.

Important: To ensure that batteries are not drained it is recommended to remove them completely when the unit is powered by the USB connector.

Inserting batteries

Use six identical, fresh, alkaline AA cells. The polarity must correspond to the signs indicated on the inside of the lid to the battery compartment. Be careful not to turn this upside down.

Slide in the batteries two by two.



Protective foil on display

The display may be protected by a piece of transparent, blue plastic foil. This foil should be removed prior to use. It is easy to catch the edge by a fingernail.

Applications

Here the experimental setups are only sketched. Detailed lab manuals for *complete* experiments below are available at www.frederiksen.eu.

One SpeedGate – complete experiments

Uniform circular motion

Primary function: *Period (X)*
Secondary function: *Mean Period*
The mean value is found for many oscillations. Reset (ⓧ) after each change of velocity.

135710 Circular motion with conical pendulum
135730 Conical pendulum – measuring *g*

Mathematical pendulum

Primary function: *Pendulum Period (X)*
Secondary function: *Mean Pend. Per.*
The pendulum must swing completely through the light ray. (In case of very small amplitudes: see the following example.)

135110 Mathematical pendulum with SpeedGate

Physical pendulum etc.

Primary function: *Period (X)*
Secondary function: *Mean Period*
Small oscillations – SpeedGate is placed at one side of the pendulum which swings in and out of the light ray *once* per oscillation.

135610 Physical pendulum
135630 The Bessel pendulum

Speed of sound

Primary function: *Front Time*
Secondary function: *Interval After*
SpeedGate is simply used as an electronic stopwatch. (The light rays are not used.)

131415 Speed of sound with SpeedGate

One SpeedGate – experiment sketches

Free fall

Primary function: *Front Time*
Secondary function: *Interval After*
Again an application where SpeedGate is used only as an electronic stopwatch.

Additional equipment:
198010 Free fall apparatus
197572 Cable, 4 mm plugs to modular (2 pcs.)

Conservation of mechanical energy in the gravitational field (a weight in a string)

Primary function: *Speed*
Secondary function: *(Previous Value)*
The weight is swinging in the thread. The potential energy at the extreme position is determined from how height the centre of gravity of the weight has been raised. The kinetic energy at the lower position is calculated from the speed.
(See experiment 134570 which uses a 200280 Student Timer instead of the SpeedGate.)

Additional equipment:
272502 Specific heat cylinder, Al, 100 g
Thread, ruler, stand material.

SpeedGate as a Geiger counter

Primary function: *Period (X)*
Secondary function: *Mean Frequency*
The GM sensor connects to Aux IN and the measurement starts immediately. The average count rate is displayed.
Reset the average with ⓧ.

Additional equipment:
513575 GM sensor with jack plug
(The 197571 modular cable replaces the sensor's jack cable.)

Two SpeedGates – complete experiments

Newton's 2. law

Primary function: *Speed*
Sec. func. Gate 1: *Previous value*
Sec. func. Gate 2: *Interval Before*

Constant acceleration – e weight pulls a cart (via a thread and a pulley) on an air track.

134710 Newton's second law

Conservation of momentum in collisions

Primary function: *Speed*
Secondary function: *Previous Value*

Classic experiment with two carts on an air track. Different accessories allow for the treatment of both elastic and inelastic collisions.

134720 Collisions on an air track

Two SpeedGates – experiment sketch

Movement with constant acceleration

Primary function: *Speed*
Sec. function, gate 1: *Front Time*
Sec. function, gate 2: *Interval Before*

One end of the air track is slightly raised a few millimetres. A cart on the track will accelerate evenly.

Additional equipment:
195000 Air Track
197060 Air blower
Stand material

Several SpeedGates – complete experiment

Constant acceleration – Air track with electric launcher

Primary function: *Speed*
Secondary function: *Interval Before*

One end of the air track is raised a bit. A cart on the track accelerates evenly.
The electric launcher sends a start signal to the first SpeedGate.

134640 Galileo's incline

Several SpeedGates – experiment sketch

Free fall – several SpeedGates

This setup is a variation over the free fall, except that the start mechanism from 198010 is connected to the first SpeedGate with a cable 197572 the rest respond to the light ray.
All SpeedGates use secondary function *Interval Before*.

Additional equipment:
198010 Free Fall Apparatus
197572 Cable, 4 mm plugs to modular
(The bottom plate from 198010 is not used.)

Specifications

Ranges and precision

Time:	0.001 ms – 999999 s
Relative precision:	0.00025 %
Speed:	0.01 mm/s – 999.9 m/s
Relative precision:	≈ 1 %
Frequency:	0.01 Hz – 999.999 kHz
Relative precision:	0.00025 %
Counters:	0 – 999999999 (= 10^9-1)

Dimensions

W x D x H:	176 x 34 x 114 mm
Mounting rod:	Ø 10 x 140 mm
Gap (W x H):	95 x 85 mm
Pos. of light rays:	10 mm above bottom

Display

Size:	36.7 x 48.9 mm (240 x 320 pixels)
Type:	TFT dot matrix, Colour, Backlit

Power supply

Batteries:	6 stk. 1.5 V ”AA”
Battery life time:	approx. 7.5 hours

Can be powered via mini USB plug (remove the batteries). Current consumption: 300 mA.

External signals

The three connectors use signals in the 0 to 5 V range – except for Enable In, which tolerates up to 8 V. All inputs interpret voltages below 0.8 V as LOW and voltages above 2.0 V as HIGH.

Chain IN and Aux IN		**Chain OUT**	
Pin	**Function**	**Pin**	**Function**
1	n.c.	1	**Master Reset Out**
2	n.c.	2	**Enable In**
3	**Ground**	3	**Chain Out**
4	**Signal In**	4	**Ground**
5	**+5 V Power Out**	5	n.c.
6	**Master Reset In**	6	n.c.

Floating inputs behave like this:

Signal In:	HIGH
Master Reset In:	LOW
Enable In:	LOW

The outputs Master Reset Out and Chain Out are controlled by the level at Enable In:

Enable In	**Mst.Res.Out**	**Chain Out**
LOW or floating	LOW	LOW
HIGH	Enabled	Enabled

The enclosed cable

The included cable no. 197571 is the **crossed** kind. The plugs used is type RJ12 and has a pin-numbering as shown below. The cable is connected as shown:

Connector 1 	Connector 2 
Colour sequence →	Colour sequence ←
1	6
2	5
3	4
4	3
5	2
6	1

Similar cables exist which are wired **straight** (1-1, 2-2, etc. instead of 1-6, 2-5 etc.)
Such cables must not be used with SpeedGate.