Universal Timer 200270

Frederiksen Scientific's Universal Timer is designed for **timing** and **counting** using a wide range of equipment from Frederiksen Scientific and others:

Microphones, photogates, Geiger sensors, Free fall apparatus, Launch equipment for air track – and any electrical switch you can connect to the 4 mm safety sockets!

We created the Universal Timer with *science education* in mind. Measurements are precise and operation is simple.

Use standard lab leads with shrouded or unshrouded banana plugs for the 4 mm sockets.

Included: Modular cables for microphones, photogates etc., USB communication adapter, power adapter (12 V /1.5 A).

Functions of the Universal Timer

Mechanical experiments:

- Start / Stop
- Collision
- Acceleration

Periodic events:

- Period
- Pendulum Period

Frequency measurements, Doppler effect:

- Frequency
- Sound Frequency
- Frequency, gated

Radioactivity etc.:

- Geiger
- Geiger, continuous
- Hi-Speed events

The Universal Timer speaks ***six different languages*** (configured in the *Options* menu).

Inputs and signals

The Universal Timer reacts on signals in two channels A and B. Each channel is associated with a modular connector, a set of 4 mm safety connectors, and a button.

Modular connector

The modular connector is used for connection to a range of Frederiksen Scientific products like photogates, microphones, or Geiger sensors.

The modular connector features a 5 V power output for the external equipment, an analogue input, a digital input and a digital "external reset" input.

Digital signal levels are 0 and 5 V.

The analogue input is AC coupled and is optimised for sharp, pulse-like signals. It has its maximum gain (x 100) around 5 kHz and is primarily aimed at microphone signals.

The modular connector inputs are only protected against minor overloads.

4 mm safety sockets

The 4 mm safety sockets establish the rugged connection to any equipment that can deliver a logic signal with 0 to 5 V levels.

The red sockets are the signal inputs to the two channels. The black sockets are ground / neutral / 0 V.

There is an internal pull-up resistor to 5 V, meaning that a simple switch can function as a signal source. (Like in our 198010 Free Fall Apparatus.)

These inputs tolerate sustained overloads up to ±50 V DC or 50 V AC.

Buttons

Each channel has one button associated. In some functions, a button press will act just like an input on the sockets.

The ▲ button can also be called "button A". Similarly, the ▼ button doubles as "button B".


Other connectors

On the back panel of the timer there is a DC input for a 12 V power adapter. Use this option to power the timer to save battery.

The last connector on the back panel is a 3.5 mm jack connector for an optional 512565 USB Communication Adapter. Through this connection, data is sent to a spreadsheet on a computer. This is great for instance if you need to show the results on a large display or projector. More on this in the *Data Streaming* paragraph below.

Functions Menu
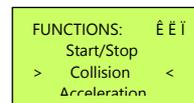
The menu is displayed through a "window" that shows three lines at a time. You scroll up and down in the menu using the buttons ▲ and ▼.

Select the highlighted function by pressing ✓ (Menu/Select).

The following sections describe each of the individual functions in detail.

Start / Stop

This function times the interval from a *Start event* (in either channel A or B) to a *Stop event* (in the opposite channel).

Events can be any of the following:

- A button presses or button release
- A low-to-high or a high-to-low signal on a digital input

- A sound signal that exceeds a given threshold on an analogue input.

If the *Show symbols* option is turned *Off* in the *Options* menu, the result will be presented with the description A Î B (if channel A started the timer and Channel B stopped it) - or B Î A (in the opposite case).

If the *Show symbols* option is turned *On* in the *Options* menu, symbols è, é, É, È or ~ will be shown as the source of the *Start* and *Stop* events.

Example: BÈ Î Aè means that the *Start event* was a high-to-low transition on a digital input of channel B, and the *Stop event* was ▲ (button A) being pressed.

Collision

| Collision |
| Ready |
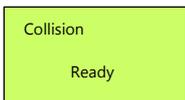
Pass A	625.017 ms
Pass B	93.490 ms
Pass B	265.261 ms
Pass A	1.271077 s

The purpose of this function is to measure *passage times* of two photogates. From the passage time and the dimension of the object passing through the photogate, the speed can be calculated. Only the duration of each passage is measured - the times between passages are ignored.

A collision sequence consists of 4 such passages.

Any type of input may begin or end a passage timing - although digital inputs will probably be the only ones used in practice.

Example: In an elastic collision experiment, the sequence *could* be:

1) The passing of cart A through photogate A
2) The passing of cart B through photogate B (The two carts heading towards a collision between the two photogates) - followed by

3) The passing of cart B through photogate B
4) The passing of cart A through photogate A (The two carts returning away from the collision.)

To accommodate *any* possible collision between two objects, no assumption of the source or the order of events is made, if four passages is involved. Imagine a collision on an inclined plane where both carts are started upwards, collide, and return downwards again, passing the *same*

photogate four times in total. This is still considered a valid sequence.

In case of for instance an inelastic collision, you may want to terminate the sequence manually. This is accomplished simply by pressing and releasing one of the buttons the necessary number of times. (Ignore these "artificial" passage times in the analysis.)

The four passage times will be listed in chronological order of the events that *initiated* the passage.

If the *Show symbols* option is turned *Off* in the *Options* menu, each passage time will be presented with the description Pass A or Pass B.

If the *Show symbols* option is turned *On* in the *Options* menu, details of each passage will be given, like AÈ Î AÉ , meaning that the passage started with channel A going high-to-low and ended with the input going low-to-high.

Any input, included buttons and sound, may trigger a passage timing; however, sound inputs will not give meaningful results in this context.

Acceleration

| Acceleration |
| Ready |
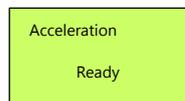
Acceleration	
Pass A	583.164 ms
A Î B	2.11080 s
Pass A	571.683 ms

The purpose of this function is to enable the calculation of an acceleration, based on the velocity of an object at two positions and the time it takes to go from one position to the other. The acceleration is typically assumed to be constant.

The velocities are calculated from measurements of *two passage times.* The *time interval* between the beginnings of the two passages is also measured. Typically, this involves two photogates.

As for the Start / Stop function, the channels are symmetrical: Both channels can measure *either* the first *or* the last passage time. As soon as a channel has been used, it will become inactive.

If the *Show symbols* option is turned *Off* in the *Options* menu, the passage times will be presented with the description Pass A resp. Pass B. The interval time will for example be designated A Î B.

If the *Show symbols* option is turned *On* in the *Options* menu, details of each passage will be given, like AÈ Î AÉ , meaning that the passage started with channel A going high-to-low and ended with the input going low-to-high. Similarly, the interval time will be given like AÈ Î BÈ, describing that the interval timing started when A went high-to-low and ended when B went high-to-low.

Simple use of acceleration measurements

Let us call the two passage times t_A and t_B and let t_{AB} be the measured time interval. The length of the flag that breaks the light in the photogates is called $\triangle x$.

Call the velocities of the cart when passing the two photogates v_A and v_B.

Assuming that the acceleration is constant, we have this approximate formula:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_B - v_A}{t_{AB}} = \frac{\frac{\Delta x}{t_B} - \frac{\Delta x}{t_A}}{t_{AB}}$$

If the relative difference between the velocities is not too extreme, this formula will give good results - in practice this is ensured by letting the cart gain some speed before entering the first photogate.

**Precise use of acceleration measurements**

Still assuming that the acceleration is constant, a thorough analysis of the measurement situation will reveal that the formula given above suffers from a systematic error. In case the cart is started close to the first photogate, this may be too large to ignore. The same analysis can lead to the following corrected version of the formula for the acceleration:

$$a = \frac{\frac{\Delta x}{t_B} - \frac{\Delta x}{t_A}}{t_{AB} + \frac{1}{2}t_B - \frac{1}{2}t_A}$$

If the acceleration is constant, this *formula* is exact. Results based on actual measurements will of course still have experimental uncertainties.

(In case you wonder why the simple formula is wrong: A photogate passage time gives an *average* speed that must lie somewhere between the speed at the entry and the exit of the photogate. The correct *time interval to be used in calculating the acceleration* is the time between the two instants when the cart's instantaneous speed exactly equalled the two measured average speeds. The *time interval measured*, on the other hand, starts at the entry of the first photogate and ends at the entry of the second - these are clearly not the correct two instants.)

Period

Period [B]	Period [B]
Ready	T = 1.3113806 s
	<T>= 1.2994872 s
	N = 19
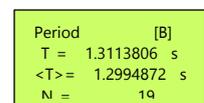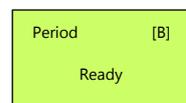
This function measures the period of a signal applied to channel B.

When the function is selected - and when **X** (Reset) is pressed - the state of the inputs of channel B is noted; a change away from this state is considered a *trigger* event.

For every trigger event (except for the very first), the time from the previous trigger event to the latest one is displayed as the period T.

This only holds in principle – very short periods are in practice bundled and averaged over a more manageable time interval.

Also displayed is the average period *<T>* and the total number of periods *N*. *N* is simply given by

N = number of trigger events $- 1$.

If *N* exceeds 10^7, a sliding (decaying) average is applied. Pressing **X** resets the average and number figures.

Any input of channel B can be the source of trigger events – even button presses. It is recommended in practical measurements that only one input is used.

Average period

The average is calculated like this:

$$< T > = \frac{\text{time since last reset}}{N}$$

- Until N exceeds 10^7.

After that, the following formula applies after each trigger event:

$$< T > = \frac{\text{time for the last } 10^7 \text{ periods } + T_{\text{new}}}{10^7 + 1}$$

For very short periods, T_{new} is found as an average over *m* periods and the expression changes to:

$$< T > = \frac{\text{time for the last } 10^7 \text{ periods } + m \cdot T_{\text{new}}}{10^7 + m}$$

(It still boils down to "total time divided by number of periods".)

Pendulum Period

```
Pendulum Period  [B]


     Ready
```

```
Pendulum Period  [B]
  T =    874.6354 ms
 <T>=    868.2017 ms
  N =         42
```
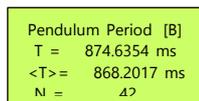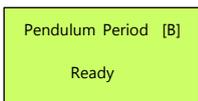
This function is intended for measuring the period *T* of a pendulum that swings through a photogate. In this situation, every other passage must be ignored. This means for instance that the first result is not displayed until the *third* passage of the photogate.

Apart from that, the behaviour is just like the previous function. The average pendulum period <*T*> is displayed along with the number of pendulum periods *N*.

Frequency

```
Frequency        [B]


     Ready
```

```
Frequency        [B]
  f =   50.00734  Hz
 <f>=   50.00346  Hz
  N =       14639
```
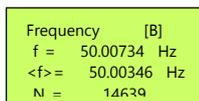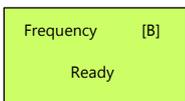
The purpose of this function is to measure the frequency of a signal applied to channel B.

The frequency is the reciprocal value of the period, and this function therefore behaves very similar to the Period function - it just displays the frequency *f* and the average frequency <*f*> instead - along with the number of periods *N*. As before, $N = \text{number of trigger events} - 1$.

This means that the displayed frequency value in principle is calculated for every trigger event. In case of a noise-free signal, this will give a frequency measurement as fast as theoretically possible.

Again, high frequencies are calculated as an average over a number of periods; minimum measurement time is 0.25 seconds.

Except for extremely low frequencies, you will normally wait for a sufficient number of periods to pass and then use the average value. If the frequency is known to have changed, press **X** (Reset) to start a new averaging sequence.

Average frequency

The average is calculated like this:

$$< f >= \frac{N}{\text{time since last reset}}$$

- Until *N* exceeds 10^7.
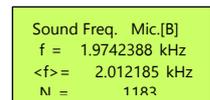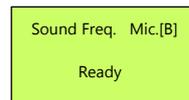
After that, the following formula applies after each update. Updates happen at the first trigger event after a 0.25 seconds' minimum period:

$$< f >= \frac{t_{\text{r}} \cdot f_{\text{new}} + t_{\text{A}} \cdot f_{\text{A}}}{t_{\text{r}} + t_{\text{A}}}$$

Here, t_{r} is the time interval since last update during which the frequency f_{new} was registered. The previous average frequency f_{A} was measured over the time t_{A} - the time for the previous 10^7 periods.

(This is simply the time-weighted average of the latest frequency measurement and the previous average.)

Sound Frequency

```
Sound Freq.  Mic.[B]


     Ready
```

```
Sound Freq.  Mic.[B]
  f =   1.9742388 kHz
 <f>=   2.012185  kHz
  N =        1183
```

This function behaves identical to the previous one - except that the digital inputs are disabled, leaving only the analogue input of the modular connector of channel B active.

This enables the use of e.g., our 248600 Microphone for measuring the frequency of

sounds. If the digital output of the microphone was allowed to interfere, the frequency would not be correct for certain sound levels.

Frequency, gated

Frequency, Gated [B]
Ready
Ê/Á·Gate   G time·Ê

Frequency, Gated [B]
f =   39.98456 kHz
Pass A   93.144 ms
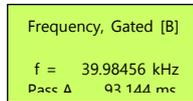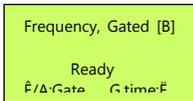
The purpose of this function is to measure a "snapshot" of the frequency of a signal applied to channel B - at a time determined by a *gate signal* on channel A.

The duration of the gate signal is also measured.

The gate signal can simply be pressing ▲ (button A) but could also come from e.g., a photogate.

The frequency is averaged over a certain *gate time* that can be selected in a menu. The actual gate time is extended until the next trigger event in channel B, meaning that the frequency will always be calculated for a number of complete periods.

The gate time menu is reached by pressing ▼ (button B).

After each measurement, **X** (Reset) must be pressed before a new gate signal is accepted.

Geiger

Geiger   [B]
T =   10 s
Ready
Ê·Start   Time·Ê

Geiger   [B]
T =   7 / 10 s
N =   437
Ê·Stop
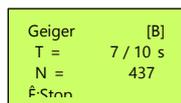
This function counts trigger events happening on channel B during a selected time interval. The purpose is primarily to measure count rates from a Geiger sensor (our item No. 513575).

A measurement is started by pressing ▲ (button A). It may be stopped prematurely by pressing ▲ again, but the registered number of events will then not be related to a precise time interval. (The time is only showed in whole seconds.)

During the measurement, the accumulated number of events *N,* and the time *T* are displayed "live".

If the measurement time is selected as 10 s, time will be shown like "4 / 10 s" (after 4 seconds in this example).

After each completed measurement, the counter will be zeroed and restarted automatically when you press ▲ to start a new measurement. Resetting can of course also be accomplished manually by pressing **X** (Reset).

Measurement time is selected in a menu that is reached by pressing ▼ (button B).

A special timing selection is *Manual*. Selecting *Manual* timing means that you must terminate the measurement manually by pressing ▲ again. This is typically used for very long-time intervals where the 1 second uncertainty can be neglected.

When *Manual* is selected, time displayed will be like "183 / 0 s" (after 183 seconds).

Geiger, continuous

Geiger, cont.   [B]
T =   10 s
Ready
Ê·Start   Time·Ê

Geiger, cont.   [B]
T =   8 / 10 s
N =   523
Prev   694
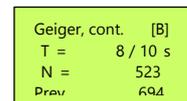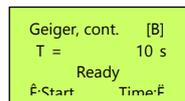
This function is like the previous one, except that when a measurement is completed, the following happens:

> 1) The result is moved to a new line and is designated *Prev*

> 2) A new measurement is started *without any delay*

Select measurement time as 10 s (or longer) to enable you to write down the (previous) result while the new one accumulates. You can of course also use data streaming (through the serial port) to have these data entered automatically into a spreadsheet. (This still requires 10 s periods or longer to work.)

The total time of all measurements will be a multiple of the selected measurement time. There are no tiny pauses that will accumulate to a significant timing error after a long series of measurements. Likewise, no events are "dropped" between measurements.

High Speed Events

```
Hi-Speed Events   BÉ
 COM port 230400 bps
       Ready
É/A·Start    Slope·É
```

```
Hi-Speed Events   BÉ
 COM port 230400 bps
       Active
```

The purpose of this function is to stream *a list of time intervals between trigger events in channel B* to the serial port.

This can e.g. be used with a Geiger sensor to investigate certain statistical properties of radioactive decay processes. (Google the term "exponential distribution" or find our lab manual for the experiment.)

The signal slope that triggers an event can be changed by pressing ▼ (button B). The slope selected is shown in the upper right corner of the display as É (low to high), È (high to low), or & (both slopes).

In order to accommodate a rather high average frequency of events, the signalling speed of the serial port is changed while this function is active. The actual signalling speed used for this function is selected in the *Options* menu and is shown here as a reminder.

The maximum throughput rate is proportional to the communication speed (see *Specifications* for the maximum rates at 230400 bps).

To stop streaming, press **X** (Reset) or ✓ (Menu)

When returning to the main menu, the "standard" speed is re-established. Please note that this change introduces a small delay after pressing the ✓ button. If you impatiently press the button twice, you will end up in the same function again.

In order to maximize performance, the display will only show a static message during the high speed streaming.

The data protocol is described in *High speed streaming* (below).

Options

```
OPTIONS:        Ê Ë Ï
 Save & return
>Language       EN<
 Symbols        No
```

This is a submenu.

Note: In order to leave the *Options* sub-menu, you must scroll to the top line *Save & return* and press ✓ (Menu/Select).

The other items in the *Options* sub-menu will step through a range of possible values each time you press ✓.

Language

The options are *EN* (English), *DE* (German), *FR* (French), *NO* (Norwegian), *NL* (Dutch) and *DA* (Danish). Changes take place immediately.

Symbols

The options are *Yes* and *No*. Selecting *Yes* turns on a more detailed level of event description in the display. See details in previous paragraphs for the different functions.

HiSpeed bps

The options are *57600*, *74880*, *115200* and *230400*. The numbers designate the speed (Bits Per Second) that the communication port operates at. Read more in the description of the *High Speed Events* function (above).

Data Streaming

The 3.5 mm jack connector on the back panel can be used with the included 512565 USB Communication Adapter. Connected to a PC, the adapter constitutes a serial (COM) port.

The output format for all functions - except for *High Speed Events* – Is intended for use with the Data Streamer plugin for Microsoft's Excel 365.

Frederiksen Scientific has published a spreadsheet that emulates a dashboard for the Universal Counter which may e.g., be used to show the contents of the display on a large screen or projector.

For use with Geiger counter data, a special spreadsheet is available that facilitates logging of data as a function of time.

Find the spreadsheets on our web site.

Note: For the spreadsheet to function properly, macros must be enabled. Please also read the instructions on the "Help" sheet available in both spreadsheets.

Communication protocol details

The communication parameters are the standard used with Data Streamer – *normally there will be no need to change anything*: 9600 bits per second, 8 data bits, 1 stop bit, no parity, no flow control.

When using the spreadsheets prepared by Frederiksen Scientific, everything else is taken care of.

If you want to use the data **for other purposes**, the following information may be useful:

Each line of data represents a snapshot of the display. Each line sent consists of three fields per display line. All fields are separated by a field separator that by default is a comma.

After each display line, a code is sent which is used for translating certain special display characters like Ê, é, É etc. These characters may appear in the first and third field in each display line and are transmitted over the serial link as more "normal" characters.

The spreadsheets mentioned above provide translation back to sensible display characters.

The *Geiger, continuous* function has a special datalogging mode, where data is sent only after each *finished count*. This mode is initiated by sending the character stream "b1" through the serial interface. Standard streaming is restored by the command "b4".

The default data field separator is a comma. It is possible to change the field separator character by sending one of the following commands:

Command	Separator
b5	Comma
b6	Semicolon
b7	Space
b8	Tabulator

High speed streaming

The function *High Speed Events* also uses the communication port. However, the DataStreamer plugin for Excel seems to be unable to handle data at these speeds. Instead, we recommend a serial communication program like ***RealTerm***.

RealTerm is highly configurable, but only small changes need to be done to the default setup. The following instructions are suited for RealTerm version 2.0.

1) Go to the ***Port*** tab, select the COM *Port* used and set *Baud* to the communication speed used by Universal Counter. Preferably as high as possible (230400 bps). Check that the rest of the parameters comply with this: 8 data bits, 1 stop bit, no parity, no flow control. Click *Change* to activate the settings.
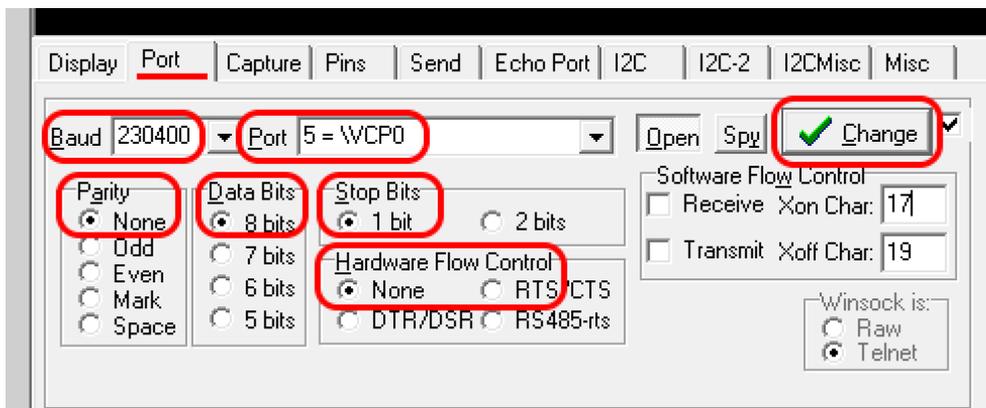
2) Go to the ***Capture*** tab and specify the *File* that you want to use for the data. We suggest that you keep the "txt" file extension to facilitate working with the file later. Click *Start: Overwrite* just before you start the event streaming by pressing ▲ on the Universal Timer. Now you can minimize the

RealTerm window as nothing happens here until your measurements are over.

When finished, stop the function on the timer by pressing ✓, then click *Stop Capture* in RealTerm.
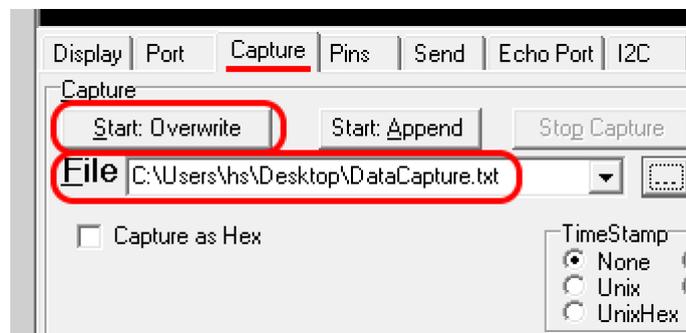
The first sensible line in the file describes which slope is selected. The last line will be a note that the Universal Timer changes back to the standard 9600 bps communication speed.

The data format is one line per event. The number designates the time interval since the previous event, measured in clock cycles. One clock cycle is 50 ns.

If you selected *Both* slopes, each line starts with a "0" or a "1" meaning resp. *falling* or *rising* slope, followed by a field separator (comma by default), followed by the time in clock cycles.

A typical experiment to use the *High Speed Events* function is the investigation of the distribution of time intervals between Geiger counter clicks when measuring radioactivity.

You can find a spreadsheet that can be used in the analysis of such data on our web site. Instructions are placed in a tab of the spreadsheet file. There is also a complete lab manual available for this experiment

Note: This function is intended for high speeds. In case the interval between two events is larger than 2^{32} clock cycles (approx. 3.5 minutes), an overflow will happen which will not be flagged by a warning.

Experiments

Frederiksen Scientific has created a range of experiments using the 200270 Universal Timer:

131412-EN	Speed of sound in air
131422-EN	Speed of sound in steel
134512-EN	Free Fall Measuring *g*
134712-EN	Newtons-second law
134722-EN	Collisions on air track
135710-EN	Circular motion w/ Conical Pendulum
135730-EN	Conical pendulum - Measuring *g*
138410-EN	Alpha Beta and Gamma Radiation
138490-EN	Radioactivity and statistics

Experiment descriptions can be found on our web site along with **lab manuals** to download.

Compatibility of modular port inputs

Microphones:	Our 248600
Photogates:	Our 197550, 197570 PASCO ME-9498 and similar
Geiger sensors:	Our 513570, 513575

These are the most important examples presently – expect the list to be extended.

Compatibility of safety sockets inputs

These inputs will react on a voltage crossing the trigger level (see *Specifications* below).

The input is internally pulled up by a resistor (to 5 V), so triggering will also happen if you make or break a connection between the red and black sockets.

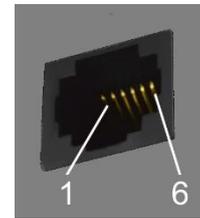The following equipment is specifically suited for the Universal Timer's safety socket inputs:

198010 Free Fall Apparatus

198510 Switch box (f. electric launcher)

Specifications

Pinout, modular inputs

1	Analog in	4	Digital in
2	(Not connected)	5	+ 5 V supply out
3	Ground, 0 V	6	External reset

Voltages

Nominal	trigger	levels
4 mm safety sockets – Modular sockets pin 4. Low-to-high:		2.7 V DC
4 mm safety sockets – Modular sockets pin 4. High-to-Low:		1.8 V DC
Modular sockets pin 1. Frequency 5 kHz:		30 mV RMS

Overload		protection
Modular inputs: Not protected – connect only to 5 V logic levels		(0 to +5 V DC)
4 mm safety sockets:		±50 V DC or 50 V AC

Timing

Fundamental timing precision (internal clock):   0.2 ppm (0.00002 %)

Start/Stop – Collision – Acceleration

Absolute time resolution: 1 µs

Maximum time: 14073748 s

Minimum	pulse	width
Start/Stop:		0.5 µs
Collision & Acceleration:		5 µs

Minimum time between A and B inputs: 0

Period – Pendulum Period – Frequency – Sound Frequency – Frequency, gated

Gate time, single measurement (Note: *Frequency, gated* has selectable gate time):   0.25 s
(The gate time is extended to an integer number of signal cycles)

Display resolution: 7½ digits

Max frequency (4 mm safety sockets, 5 V logic levels):   > 1 MHz

Geiger – Geiger, cont.

Measurement periods: 1, 10, 60, 100, 300 s (+ manual timing)

Max manual counting time: 99999999 s

Max number of counts: 4294967295

High Speed Events

Max sustained input frequency (@ communication speed 230400 bps)		
Single slope:	3.5	kHz
Both slopes:		1.8 kHz

Streaming will become erroneous or stop completely when these rates are exceeded.