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# Introduction

Welcome to Time - Speed - Acceleration (TSA). This manual is a comprehensive guide to the use of this flexible measuring instrument.

To obtain the best results from TSA work your way through each section of this manual. It won't take you long and it will give you an insight into the versatility of the instrument and its potential areas of application.

## *What can TSA Measure ?*

TSA can operate in a number of different modes.

It can :-

- a) measure time intervals (4)
- b) measure event times (8)
- c) be used as a simple stop clock (999 s)
- d) be used as a fast timer with a resolution of 10  $\mu$ s
- e) measure gap time
- f) measure speed (4)
- g) measure acceleration (2)

## *Power Requirements*

TSA has been designed to run from a plug top power supply set at 9V. Alternatively if you are doing work where there is no mains power then a PP3 battery can be used to power TSA and the **djb microtech** Light Gate. For this you will need our Battery Lead.

# Technical Information

Plug top supply voltage 9-12 V DC.

Digital inputs protected to 15 V.

Digital inputs protected against reverse polarity.

The two digital inputs are TTL compatible i.e.

0 - 1 V (approx.) is logic 0

3 - 5 V (approx.) is logic 1.

The inputs are normally held high.

The red LED is on if an input is taken low.

Time Intervals and Event Times have been rounded to three decimal places.

With the debounce delay set to zero the minimum time between events is < 50  $\mu$ s.

Speeds have been rounded to 2 decimal places.

The error in the Fast Timer is between -0.02 ms and +0.01 ms

The maximum Time interval is 999.99 s.

The maximum time between events is 999.99 s.

The maximum display time on the stop clock is 999 s.

The Gap Time range is 0 — 999.999 s.

# Associated Equipment

From **djb microtech** Ltd:-

TSA Battery Lead

Light Gate cable for Unilab Slave Light Gate

Light Gate Receiver

Light Gate Transmitter

Reaction Timer Switches

Sound Switches

Timing Plate

Projectiles, Energy and Timing apparatus.

# Portability

Using our PP3 Battery Lead it is possible to operate TSA without a laboratory power supply. This could lead to interesting experiments being tackled outside the laboratory.

The current drain of TSA with a **djb microtech** Light Gate connected is  $< 25\text{mA}$ .

It is quite possible to operate TSA with a Unilab light gate from a PP3 type battery but this will place a much heavier demand on your battery. This problem can be circumvented by using a '6 pack' AA cell holder instead of a PP3.

# Teaching with TSA

TSA is a very powerful and easy to use instrument which produces answers quickly. However, before pupils have access to this instrument they should have a basic understanding of the Physics principles involved e.g.

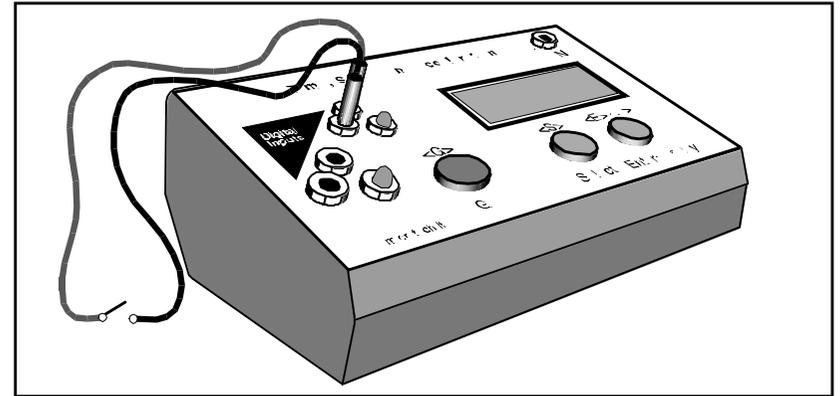
- speed = distance/time
- acceleration =  $\Delta v/\Delta t$

Once the basics are understood and pupils can operate TSA confidently then they can start investigating and exploring their world:-

- Do heavier objects have a greater acceleration?
- Is the acceleration up and down the slope the same ?
- What is the effect of the type of surface on the final speed ?
- How is the acceleration of a radio controlled car affected by battery usage ?

Additional ideas for using TSA are on our website at [www.djb.co.uk](http://www.djb.co.uk).

# Getting familiar with TSA



Connecting a switch

Note that there are two digital inputs which are TTL compatible. Switches and light gates may be connected to these inputs. The inputs are also available at the DIN sockets on the back of TSA. Light gates can be powered from these sockets. To enable you to make some simple measurements connect a switch between the red and black terminals of either digital input.

## Time Interval

This mode measures the length of time a light beam has been cut or a switch closed and will be dealt with in most detail as all other modes are similar in operation.

- Switch on TSA,
- When prompted press the <S>elect button,
- Continue to press <S>elect and cycle through the modes. When you return to Time Interval press the <E>nter button.
- <S>elect how many readings you wish to make, For this first attempt <S>elect 1
- Now press <E>nter.
- The LCD displays <G> when ready. When you are ready to start the experiment press the GO button.

- The LCD displays "Waiting". TSA is now waiting for an event to happen so that it can start its internal clock.
- Close the switch (firmly) and then open it a short while later.
- The time interval will be displayed on the LCD.
- Press <G> to GO again and repeat the experiment.
- After you have repeated the experiment several times press <S>elect and again select Time Interval but this time set TSA to read 3 time intervals.
- Proceed in a similar fashion as before but note that the Waiting message is displayed until all 3 time intervals have been measured.
- To see all three time intervals, keep pressing <D>isplay.

If the displayed time intervals are unreasonably short then this is caused by switch bounce. The best thing to do at this stage would be to replace the switch or use a light gate and cut the beam with your hand.

### Important

An Event is simply a change in state of an input. To measure a time interval there must be 2 events: the first one starts the internal clock and the second one stops it.

TSA has been designed so that the starting and stopping of its clock can be controlled from either input channel independently. For example an event on channel 1 can start the clock and the next event on channel 0 or channel 1 stops the clock.

All inputs are debounced. On shutting a switch the contacts tend to bounce very quickly, generating many events. To get round this problem the software waits for a few milliseconds after an event before returning to look at the inputs to see if another event has occurred. Note that the clock has not stopped and no error has been introduced in the timing. It does, however, limit the minimum time interval to the length of the debounce delay. The default debounce delay is set at 10 ms. A minimum time interval measurement of 10 ms should not impose too many restrictions on general classroom work. However for users having specialist requirements see the section on Changing the Debounce Delay.

The time interval is rounded to 3 decimal places.

## Changing the Debounce Delay

Switch bounce may cause problems when you are trying to measure events. Consequently a default debounce delay of 10 ms has been designed into TSA. This does NOT mean that there is an error of 10 ms in the timing. After an event, 10 ms will elapse before the inputs are again examined to await an event. During these 10 ms the switch should settle and stop bouncing. If an event happens during these 10 ms then it would be missed! In most school experiments a 10 ms debounce delay will not cause problems. However the user can change this delay in the range 0 - 50 ms.

To change the debounce delay

- <S>elect Change Debounce then press <E>nter.
- <S>elect to change the current value of the delay.
- Scroll through the values and <E>nter your required value.

If you are using switches as the inputs to TSA then do not set the debounce delay to zero unless these switches are hardware debounced.

Remember that for most work the default value of the debounce delay will be satisfactory. The default value of 10 ms is set at switch on.

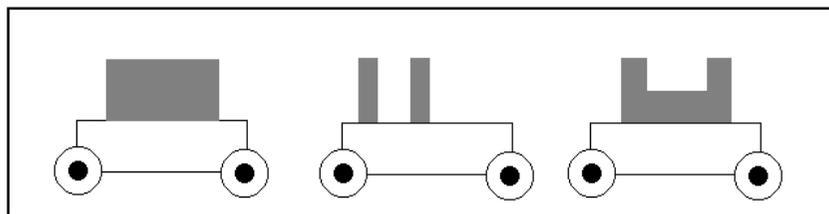
## Connecting Light Gates

The **djb microtech** Light Gate is connected directly into either DIN socket at the back of TSA. It is most sensitive to infra red wavelengths and is powered from TSA. If you wish to use a Unilab Slave Light Gate then the **djb microtech** Slave Light Gate cable will enable the unit to be powered from TSA. The benefit from operating a light gate with only one cable is that pupils simply cannot get it wrong.

Users of the of the older style of Unilab Light gate (414.032) should encounter no problems using it with TSA.

## ***Acceleration***

The setup for this mode is identical to Speed. However, there are several possible mask arrangements:-



Possible mask arrangements

Masks may be attached to the trolley with masking tape.

To measure an acceleration a single mask requires two light gates whereas a double mask requires only one light gate.

Where double masks are used then both sections must have the same width.

## **9.81**

You have done your experiment to measure acceleration due to gravity and you don't get the magic number 9.81 — why not? Where are the errors? Since the microprocessor inside TSA gives very accurate measurements of time, why are the results not perfect?

An excellent article on 'Using Light gates to measure g' is in the SSERC bulletin number 181.

Below are a number of suggestions which may help to minimize errors:-

- measure the size of the mask accurately,
- make a number of measurements with the mask inverted, i.e. the leading edge becomes the trailing edge,
- use a narrow parallel beam of light,
- drop the mask vertically,
- release the mask as close to the detector as possible in order to reduce the size of the shadow,
- release the mask from just above the detector in order to minimize possible air resistance effects.

## ***Event Times***

This mode is used to measure the time at which each event happened. Up to 8 events can be measured and the first event is displayed as happening at Time = 0.000 s.

The Event Timer is set up in an identical fashion to the the Interval Timer.

The Event Timer is the most versatile of all the modes offered. It can be used for many experiments in the study of motion — both linear and rotational. However it may place additional demands on the student e.g calculating the acceleration from 4 event times and a mask length is not recommended in a first level Physics course but would be excellent in promoting a deeper understanding in a second level course.

## ***Stop Clock***

This is a simple stop clock which counts from 0 - 999 in seconds.

The <G> button is used to stop/start the clock.

For a greater precision then use the Gap Time mode.

## ***Fast Timer***

This mode can be used to display a time interval between 50 - 65535  $\mu$ s. Trying to measure an interval larger than the maximum causes the error message "Too big" to be displayed.

This timer could be used to measure the time for sound to travel between two microphones and from this the speed of sound can be calculated.

### **Important**

On selecting this mode the debounce delay is automatically set to zero and it is returned to its original value on exit.

## Gap Time

This mode is used to measure the time interval between events on different input channels. It is set up in a similar way to the Interval Timer. Only one Gap Time can be measured.

Consider a trolley with a mask running down a runway which has two light gates positioned on it. When the first light gate is cut the clock starts and when the second one is cut the clock stops. Gap time is different from Time Interval because here the events must happen on different channels.

The time displayed is the time for the leading edge of the mask to travel from one light gate to the next.

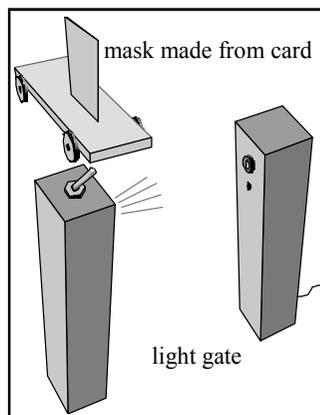
This mode could find application in the teaching of average speed — set two light gates a known distance apart and using Gap Time measure the time for the trolley to travel this distance.

If you require an accurate stop clock then connect a switch to each digital input — pressing one switch will start the clock and pressing the other will stop it. This will give a stop clock displaying to 1/1000ths of a second and with a range of 0 - 999.999 s.

## Speed

This mode is used to measure the speed of a vehicle as it passes through a light gate. If the mask is small then the measurement is a reasonable approximation to the instantaneous speed.

- <S>elect the Speed mode then press <E>nter.
- <S>elect the size of your mask in centimetres. Note that each time the <S> button is pressed the distance increments in 1 cm steps until 10 cm and then in 10 cm steps until 250 cm. Holding down the <S> button results in a rolling display.
- Press <E> to enter your mask size.
- Press <G> when ready.



Trolley with mask

## Important

If very fast speeds are to be measured then the debounce delay must be changed to zero and bounce free switches used.

## Measuring the Speed of Sound

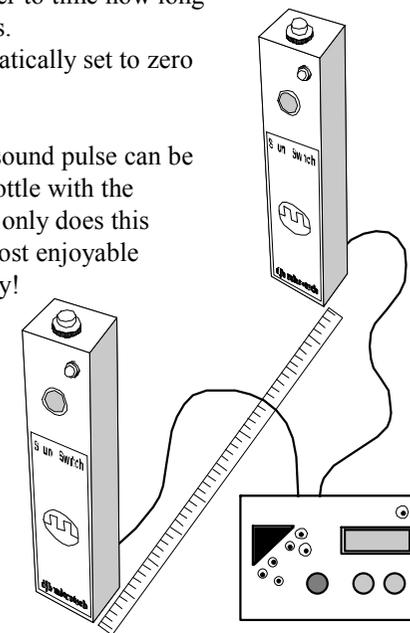
TSA can be used to measure the speed of sound. A typical setup using **djb microtech's** Sound Switches is shown below.

It is important to adjust the switches to be as sensitive as possible. Users are referred to the instruction sheet supplied with the Sound Switches.

The speed of sound is calculated by measuring the distance between the sound switches and then using the Fast Timer to time how long it takes to travel between the switches.

Note that the debounce time is automatically set to zero when using the Fast Timer.

A suitably fast rising and repeatable sound pulse can be produced by hitting an empty wine bottle with the plastic handle of a screw driver. Not only does this fascinate the pupils but it can be a most enjoyable experience getting the apparatus ready!



Speed of Sound using **djb microtech's** Sound Switches