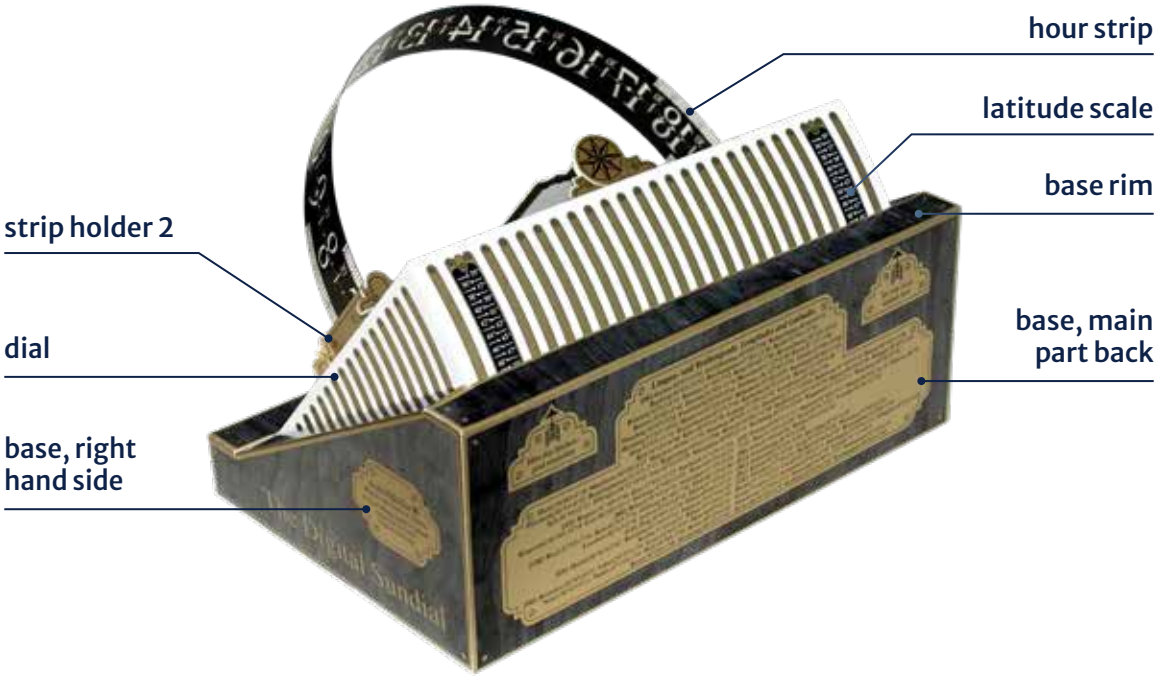
Building instructions

The Digital Sundial



AstroMedia

Hands-on Science Series

The Digital Sundial

Contents:
3 printed and pre-punched cardboard sheets
1 transparent hour strip
These instructions

The sun is the simplest and most natural timepiece that we know. It is therefore not surprising that sundials are the oldest clocks ever to be used by mankind. The time is indicated by a shadow length or by the direction of a shadow. The shadow thrower, known as a gnomon, can have a variety of forms: a rod, a thread, a straight edge, a huge obelisk as can be seen in St Peter's Square in Rome, or even simply a human being standing in the centre of a living sundial and who can read the time by observing his or her own shadow. The large variety of sundials is quite fantastic indeed. Almost all of them have one thing in common: they display the time as given directly by the Sun (true local time) by means of a shadow or a light spot that moves on a scale with hour lines.

The unique feature of this digital sundial is, however, the fact that it not only shows true local time but you can also choose standard time (zone time) and even daylight saving time with the help of digits that are projected onto a reading panel by the Sun.

Hand and straw, a simple sundial, woodcut by Jacob Köbel, 1532

You will also need for assembly:

- A cutting board or mat, made from hardboard, plastic, or wood. Self healing cutting mats are ideal as the material re-closes after each cut.
- A sharp knife with a fine point (thin carpet knife, craft knife, scalpel), to cut the thin holding tabs of the pre-punched parts.
- Standard solvent based all purpose glue, e.g. UHU, Evo-Stik Impact, B&Q All Purpose Glue. Do not use water-based glue: it softens and warps the cardboard, and doesn't stick properly to the printed surfaces. Solvent based glues also dry much faster.
- A thin rod to help applying the glue (toothpick, chopstick, ...)
- A ruler
- A blunt knife or empty biro to re-groove folding lines

Tips for successful construction – Please read before commencing!

- In order to ensure good results and for straightforward construction, the building instructions have been broken down into 29 steps. Read each step from the beginning to the end before commencing and allow yourself plenty of time for the construction (depending on experience). The more care you take, the more accurate your Digital Sundial will be and the better it will look.
- Every part is identified by its name and part number. The part number consists of a letter and a number in a rectangular frame: e.g. A2 . The letter denotes the part of the sundial it belongs to, the numbers denote the order of construction. The numbers are printed on the front and back of the part and sometimes also next to it. Only remove the parts as you need them.
- Before commencing a step, remove all the needed parts from the cardboard and remove all pre-cut slots and disks where required. ***Note:*** *Every part that has a part number printed on it will be needed to complete the sundial.*
- Areas that are to receive glue are printed in grey. On each glueing area is a symbol that shows which part is to be glued in this place, e.g. A2 (part [A2] is glued in this place). The symbol denotes that the part is glued to itself in this place.

- This is how to accelerate the setting of the glue: Apply a suitably thick layer of glue onto one of the parts. Then press parts together so that the glue spreads out on both sides. Now pull the parts apart, blow 2 or 3 times over the surfaces, and press the parts together again. Take care that they fit exactly, as the glue binds immediately.
- We recommend that you do not tear the parts out of the cardboard sheet, but cut through the thin connecting tabs to make sure that the edges stay smooth. Frayed edges can be cleaned with a nail file or with our AstroMedia File Set.
- All folding lines are prepared by grooves. If they are to be bent „forwards", you have to fold them towards you when looking at the printed side of the part. If they are to be bent „backwards", you need to fold them away from you. You get a straighter fold if you position the folding line over a sharp edge.
- Also check the drawings on the back of the title page. They show all parts with their numbers and positions.

Building Instructions – Read through each step completely before commencing.

A. The Base

Step 1 Remove the main part of the base [A1, sheet 2] from the cardboard and fold all grooves backwards.

Tip: *Before folding, add your name and date to the base.*

Step 2 Remove the left [A2] and right side parts [A3, both sheet 1] from the cardboard. Fold the small flaps denoted with a "Y" forwards and all other flaps backwards.

Tip: *The base has a flat rim surrounding the sundial (see cover photo). It is made up from four 14 mm wide parts that are denoted "rim" on the back of the cardboard. The left and right ones are part of the side parts. The top and bottom ones are part of the main part of the base. Before glueing, fold them all back again to make sure they are at right angles.*

Step 3 Glue the flap of the main part of the base that is denoted with a ↓ onto the grey area on the back, also denoted with a ↓ . This way you make a rectangular tube, the top of which is the front part of the base rim.

Step 4 Stand the main part of the base on your work surface and check that the side parts [A2] and [A3] fit in their positions. It is easy to see which flap has to be glued where. Now glue both side parts onto the main part. Finally glue the back part of the base rim in place.

Tip: *The three long locking tabs that are sticking out into the inside of the base are not glued. They will later hold the dial in position when it is set to the correct latitude.*

B. The Dial

The pivoting dial holds the reading panel and the two holders for the hour strip. It is fitted to the base via a glueing flap so that its angle can be adjusted to show the correct time for all locations between 30° and 60° latitude. The current latitude can be read from the back of the dial.

Step 5 Remove the dial [B1, sheet 3] from the cardboard and remove the cardboard from the two slots and the large recess in the middle. Fold the two round flaps in the middle of the recess and all other groove lines backwards. Now draw the unprinted side of the section with the latitude markings lengthwise over a table edge to produce a slight curve.

Step 6 Glue the curved back of the dial onto the flaps at the rounded edges of the sides. Ensure that the rounded edges of the sides are flush with the curved back of the dial.

Note: *Do not yet glue the dial into the base.*

Step 7 Remove the dial recess [B1, sheet 1] from the cardboard. It needs to be formed into a half-cylinder without pronounced kinks. There are several methods to achieve this.

1: Pull the part across an edge with a reasonable amount of force. **2:** Roll it around a round piece of wood or a thick felt pen. **3:** Use the ruler and a folding tool (or blunt knife) and press 9 - 12 grooves parallel to the two groove lines of the glueing flaps, with a spacing of 3 to 4 mm into the back of the part. You can then easily bend it.

Step 8 Fold the glueing flaps backwards and glue the dial recess onto the back of the dial, matching its position with the rectangular cut out with the rounded flaps.

Hint: *The rounded flaps at the ends of the cut-out will later be glued onto the edges of the recess.*

C. The Reading Panel

The reading panel, onto which the digits of the hour strip are projected by the sunlight, has two sides and can be turned by 180° so that either true local time is displayed (panel side with straight line) or conventional standard time (panel side with the 8-shaped loop giving the equation of time). More details are given at the end of the instructions. As the kit is printed in two languages, there are two versions of the reading panel: English [C1e, C2e] and German [C1d, C2d]. Please choose your preferred version before commencing.

Step 9 Remove the two parts of the reading panel [C1 and C2, both sheet 1] from the cardboard. Fold the half-round flaps at the two ends of both parts of the reading panel forwards. With the text the same way up, glue the two pieces back to back. Do not glue the half-round flaps to each other.

Step 10 Detach the two small discs [C3] and [C4] from the axle bearings [C9] and [C10, all sheet 1] and glue them with the print sides together. This forms a round axle block. Allow to dry well. As the surface is lacquered this can take a bit longer.

Step 11 Glue the axle block onto the middle of the inner cover disk [C5, sheet 1]. If any glue is squeezed out, remove it immediately to make sure the axle will be able to turn smoothly.

Step 12 Open the round flaps on one side of the reading panel and glue the inner cover disk of the axle block onto them. Let dry thoroughly.

Step 13 As described in the last three steps, make another axle block from the discs [C6] and [C7] and glue it onto the inner cover disc [C8, all sheet 1]. Glue the other side of the cover disk onto the round flaps at the other end of the reading panel. Let dry well. Now the reading panel has an axle on each end.

Step 14 Remove [C9] and [C10, both sheet 1] from the cardboard. Fold the foot of the outer axle bearing 1 [C10] forwards and glue it onto the back of inner axle bearing 1 [C9]. Make sure that the two holes are exactly flush with each other. Allow to dry well.

Hint: *On part of this print run the glue marking on the back of [C10] should read C9 instead of H9.*

Step 15 Place the axle bearing [C9/C10] onto your work surface so that the folded foot is facing down. Place the reading panel with one of the axles onto it and carefully push the axle into the hole in the axle bearing. Check that the axle can turn inside the bearing.

Step 16 Now glue the outer cover disc 1 [C11, sheet 1] onto the axle, the printed side facing outwards.

IMPORTANT: make sure that no glue gets onto the axle bearing, only onto the axle. After drying, ensure smooth movement of the axle by turning it carefully.

Step 17 As described in the last three steps, make the second axle bearing from the inner [C12] and outer [C13] axle bearing 2, fit it to the reading panel the same way as in step 15 and secure it in place with the outer cover disk 2 [C14, all sheet 1].

Step 18 Test the fit by placing the reading panel with the axle bearings into the dial recess. The rounded ends on the inner side of the axle bearings are slotted into the trough and lie against the rounded flaps at both ends of the dial recess. The folded glueing flaps on the outer side of the two axle bearings are seated on the rim of the trough on the surface of the dial. The reading panel should be aligned so that the months of December and January are located at the top.

Step 19 Glue the axle bearings of the reading panel in this position, with the outer foot flaps of the axle bearings glued onto the dial's upper surface, the round inner sides of the axle bearings onto the flaps which close off the inside of the trough.

Step 20 On the back of the dial, glue the edges of the dial recess butted against the round flaps.

D. The Strip Holders

The hour strip, through which the sunlight projects the time onto the reading panel, is held in place by two strip holders on the dial. The holders are located on the left and right sides of the dial and hold the hour strip in a perfect half circle around the reading panel. They are stuck through the dial and have a wide slot to hold the hour strip in place.

Step 21 Glue the two spacer strips [D2] and [D3] onto the designated places on the back of strip holder 1 [D1, all sheet 1] flush with the edges. The spacer strips have a distance of 25 mm so that the hour strip fits exactly between them.

Step 22 Now glue the second part of strip holder 1 [D4, sheet 1] onto the two spacer strips to form a pocket, open on both sides, with a 25 mm wide open slot. After drying, check that the hour strip can be pushed all the way through.

Tip: *If you cut off the corners of the hour strip at an angle, it is easier to push it into the slot.*

Step 23 Remove the two strip holder supports [D5] and [D6, both sheet 3] from the cardboard and fold all 3 flaps forwards. Glue the two supports onto the marked spaces at one end of the strip holder so that their straight edges are flush with the strip holder opening. Do not glue the long and the two short flaps.

Step 24 Fold the strip holder supports 3 [D7] and 4 [D8, both sheet 3] forwards. Glue the two supports with their curved halves onto the flaps at the ends of the long supports. Move and push the parts a bit until they fit exactly flush.

Step 25 Insert the strip holder into one of the two slots on the dial. Once in place you will feel that there is a slight lateral leeway. Push the holder as far as possible towards the outer rim and glue the flaps of the holder support in this position.

Hint: *The strip holder needs to stand at exactly right angles to the dial.*

Step 26 As in steps 21 to 25, glue the two spacer strips [D10] and [D11] to the holders [D9] and [D12, all sheet 1] to make a second pocket. Attach the long holder supports [D13] and [D14] and then the short supports [D15] and [D16, all sheet 3]. Glue this second strip holder in the other slot on the dial.

E. Assembly of Base and Dial

Step 27 Try fitting the dial into the base (without glueing). The dial sits in the base so that the curved back of the dial lies at the back of the base with the geographical positions. The long glueing flap of the dial lies against its glue marking on the lower rim of the base. The dial can be pushed into the base until its surface is flush with the rim.

Step 28 Draw the dial out again and glue its glueing flap onto the designated area inside the base. This forms the hinge about which the dial turns when it is set to different geographical latitudes.

Step 29 Push the hour strip into its holders so that it describes a perfect half circle around the reading panel.

Tip: *The exact adjustment of the hour strip depends on which time you want to display and will be described later.*

Now your Digital Sundial is finished.

Congratulations! You are now the proud owner of a very special and accurate sundial.

How to adjust your sundial:

1 Choose the displayed time

Decide which time you want to be displayed. Most sundials do not show standard time, the time we read on our watches, but rather apparent solar time (true local time). The two sides of the reading panel of your digital sundial can show you either one or the other.

2 Adjusting the hour strip

Insert the ends of the hour strip into the slots of its two holders so that the digits are the right way up. The end with the "6" is mounted in the right holder and the end with the "18" in the left holder.

- If solar time is to be shown, the large round spot in the "6" must lie exactly on the edge of the right holder, and the large round spot in the "18" exactly on the edge of the left holder.
- If standard time is to be shown, the longitude degree line on the strip corresponding to your position must lie on the edges of the right and left holders.
- For normal standard time (last Sunday in October to the last Sunday in March) the upper longitude degree scale applies. For daylight saving time (summer time, last Sunday in March to the last Sunday in October), use the lower longitude degree scale.

Longitude and latitude of most cities and towns can be found on the internet, e.g. Wikipedia or Google Earth.

3 Adjusting the dial to your latitude

Adjust the inclination of the dial until the geographical latitude of your location on the back of the dial is shown on the edge of the base.

4 Orientation of the sundial

Turn the sundial exactly towards the south, e.g. with the help of a compass, and turn the reading panel so that it is orientated towards the sun.

5 Reading the time

- True local time is read on the middle line of the reading panel for true local time / solar time.
- On the reading panel for standard time, you read the time on the equation of time loop (analemma path of the Sun), i.e. at the point of the current date. The 1st, 10th, and 20th day of each month are given. Intermediate readings can be estimated.

What is the difference between standard time and solar time?

Apparent Solar Time (True Local Time):
When the Sun culminates at one location, which means it reaches its highest point for that day, it is exactly in the south as observed from that location and at this position it is exactly 12:00 hours apparent solar time or true local time.

Note: *On the southern half of the globe the sun has its midday highest point in the north.*

The East-West-Difference:
As seen from the Earth, the Sun circles once every day from east to west. For this reason its culmination at all locations east of your position will be earlier than for you and later at all locations to the west of your position. Even when the east-west-difference of two locations is only small, these places have a measurable different local time. For example: the eastern city periphery of the city of Norwich is only 10 arc minutes (an arc minute is 1/60 of a degree) away from the western city periphery. This minor distance leads to a difference of 40 seconds true local time.

Calculating Local Time Differences:
The difference of the true local time between two locations can be calculated from the difference of the degrees of longitude of these locations:

Of the 360 degrees of longitude of the whole Earth, the 0° line runs through Greenwich, London, and is called the prime meridian.

From that location, we count 180° positive to the west (0° to +180°) and 180° negative to the east (0° to -180°), added together 360°. To circle once around the Earth with its 360°, the Sun takes 24 hours. This means it takes the Sun one hour for 15° or 4 minutes for 1°. For example, if a place is located 2° further to the east, the midday highest point of the Sun happens 4 minutes earlier per degree of longitude, meaning, 4 x 2 = 8 minutes. If a place is located 20° further to the west, it happens by 4 x 20 = 80 minutes later.

An extreme example: The geographical longitude of Warsaw is -21°, that of Barcelona -2°, the difference is therefore 19°. In Warsaw the sun reaches its highest point 4 x 19 = 76 minutes earlier than in Barcelona, even though both cities have the same (standard) time of day (Central European Time).

The Annual Fluctuations of Solar Time:
Solar time varies not just with respect to the longitude of a place but also within a year. Compared with a precise clock, it can be shown that the Sun slows down slightly from the 12th February to the 15th May, and is slow by a total of 18 minutes. It then accelerates its course up to the 27th July by 10 minutes, up to the 4th November it slows down again by 23 minutes, and accelerates by 31 minutes up to the 12th February. This speeding up and slowing down is depicted in the equation of time loop on one side of the reading panel.

The duration of a solar day is therefore not constant. You could say that it breathes with two breaths annually. Our standard time, on the other hand, is a calculated mean time with a fixed length of day, from which the true local time can deviate by up to 16.5 minutes and with which it coincides only on the 16th April, 14th June, 2nd September, and the 25th December: that is at the lowest and the highest point as well as in the vicinity of the intersection point of the equation of time loop.

Well into the 19th century, people all over the world lived their lives according to the pulsating solar time which they read from nature. Every town and city had their own time and set their clocks according to the position of the Sun. Time differences were practically insignificant and were unnoticeable because travel in those days was quite a slow process.

Time of day and time zones:
With the arrival of rail travel, time zones as we know them today were introduced.. In these times zones you have a uniform, averaged and equal time - otherwise it would never have been possible to make functioning train time tables for larger regions. Zone times have a difference of 1 hour between them and are based on the true local time at locations with 0°, 15°, 30°, 45°, etc. geographic longitude. This local time is averaged in order to balance out the annual fluctuations of the Sun's course, and then applies for the whole time zone. The actual limits of the time zones do not just depend on the degrees of longitude but rather in a practical manner also on the boundaries of countries or states.

GMT and BST:
Greenwich mean time is the zone time used in the United Kingdom, Ireland, Portugal, the Canary Islands, the Faroe Islands, Burkina Faso, The Gambia, Ghana, Guinea, Guinea-Bissau, Iceland, Ivory Coast, Liberia, Mali, Mauritania, Sahrawi Arab Democratic Republic, Saint Helena, Ascension and Tristan da Cunha, Senegal, Sierra Leone, and Togo. It is sometimes used as a synonym for Coordinated Universal Time (UTC), but that is not quite correct as the two can differ by up to 0.9 seconds.

As the name implies, it is based on true local time in Greenwich, the location that defines the prime meridian. The furthest west location is Dakar in Senegal with 17.5° geographic longitude and the furthest east location is the eastern border of Mali at -5.5°. Therefore the GMT time zone spans 23 degrees of longitude, or a local time difference of 1 hour and 32 minutes.

The first 5 countries in the list also change their clocks during the summer and use British summer time (BST): They simply pretend that it is an hour later. Originally, the idea behind this was to save energy but this hope did not materialise. Nobody knows exactly why everybody goes to the trouble of changing the clocks every year. The most likely reason: daylight is prolonged for leisure time in the evening.