The Digital Sundial

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 the shadow length or by the direction of the shadow, and 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 on St. Peter's Square in Rome or even simply the shape of 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 wanders on a scale with hour lines. The unique feature of this digital sundial is, however, the fact that it not only indicates True Local Time but also selectively Standard Time (Zone Time) and even Daylight Saving Time with the help of digits that are projected by the sun onto a display zone.

Assembly instructions

Before you start, read each section to the end. The assembly itself is not difficult because all parts are pre-punched to fit exactly together.
For the assembly, you will need a sharp knife in order to cut out the punched parts accurately from the cardboard sheet, a thin rod to assist gluing (pencil, Chinese chopstick), a plain rule and a folding instrument (or blunt knife) for re-grooving as well as a good all-purpose glue. A solvent-containing all-purpose glue is more suitable than so-called non-solvent glues on a water basis because it does not produce any waviness in the cardboard.
Each part is marked with a part number ([A1], [A2], [B1], [B2] etc.) and with its name in German. The letter of the part number is the same within an assembly group. Remove only those parts from the cardboard plate that you require for assembly, or write the number of the part on its rear side.
"Fold to the rear" means: I fold along the groove away from me when I look onto the printed side. The result is a "mountain" crease. "Fold to the front" means: I fold towards myself. The result is a "valley" crease.
Getting the glue to dry quicker: put a suitably thick layer of glue onto one of the sides to be glued, then press together so that the glue spreads out evenly on both sides, and then take the parts off each other again. Then blow 2 or 3 times over the surfaces and press the parts together again, making sure of a good fit – the glue holds immediately.
Contents of this assembly kit:
4 printed and punched cardboard sheets,
1 transparent hour stripe

The base

Step 1: Detach the main part of the base [A1] from the cardboard and fold all grooves sharp-edged to the rear.
Step 2: Detach the two side parts [A2] and [A3] from the cardboard. Each side part is surrounded on all edges with gluing flaps, four of which consist of peaked triangles. The two peaked triangle flaps at the lower end of the side part must be separated from one another with a knife or scissors cut. After this, fold all flaps sharp-edged to the rear.
Step 3: Glue each of the side parts with its longest gluing flap right and left onto the rim of the non-printed internal side of the base main part. Ensure that the printed sides face to the outside and that the second longest flap of the side parts is lying at that location where the main part has its rear side (with the longitude and latitude details).
Step 4: Then glue the rear side of the base onto the corresponding flaps of the two side parts, then the front side of the base.
Step 5: Finally, the peripheral rim of the base is solidly glued. It is formed from the 4 approx. 1.4 cm wide sections, of which the side parts have one each and the main part has two. The front and the rear base rim are glued to the small triangular flaps at the side parts which are to be bent beforehand into the correct position. It is recommendable to re-fold the base rims once again with sufficient force before gluing so that they form a right angle to the base sides. The long folded flaps, which then project from the rims into the interior of the base, later have the task of holding the console in position when it is set to a particular geographical latitude.

The console

The pivoting console holds the display zone and the two feet for the digit stripe. Its inclination has infinitely variable adjustment whereby the sundial can be adapted for any geographical latitude between 30° and 60°.
Step 6: With the console [B1], detach the cardboard residuals from the two narrow slots and the big recess in the middle, and fold the two round flaps in this recess to the rear. Draw the back of the console, on which the latitude scale is printed, with its non-printed side carefully over a table edge so that it curves somewhat. Fold the two triangular side parts of the console and the tooth-like gluing flaps at the side parts to the rear.
Step 7: Glue the curved back of the console onto the flaps at the rounded edges of the side parts. Ensure that the rounded edges of the side parts are flush with the curved back of the console. At this point, the console is not yet glued into the base.
Step 8: Detach the trough [B2] from the cardboard. In order to give it the best possible uniform curvature, use the rule and the folding instrument (or blunt knife) to press between 9 and 12 additional groove lines with a spacing of 3 to 4 mm into the printed side of the cardboard, parallel to the two groove lines of the gluing flaps.
Step 9: Then draw the printed front side of the trough [B2] over a table edge so that it easily and uniformly curves with the help of the additional groove lines. Here, the printed side is lying inwards. Fold the gluing flaps to the rear and glue the trough onto the non-printed side of the console, at that position where the rectangular cut-out with the two rounded flaps is located. The gluing flaps of the trough should lie exactly at the rim of the cut-out. The rounded flaps at the two ends of the cut-out will later be glued blunt onto the edges of the trough.

The display zone

The display zone, onto which the digits of the hour stripe are projected by the sunlight, has two sides and can be turned by 180° so that either True Local Time is displayed (display zone with line) or conventional Standard Time (display zone with the 8-shaped loop giving the equation of time). More details on this are given at the end of the assembly instructions.
Step 10: Fold the half-round flaps at the two sides of both parts of the display zone [C1] and [C2] to the front. Then glue the two parts against each other in such a way that the lettering on both sides points in the same direction. The half-round flaps are not glued onto each other.
Step 11: Detach the two small disks [C3] and [C4] from the axis bearings [C9] and [C10] and glue them with the printed side onto each other to form a round block-shaped axis.
Step 12: Fold apart the two round flaps at one end of the display zone so that they form a disk and glue onto this the cover disk [C5] with its non-printed side. Allow to dry well.
Step 13: Glue the small axis block [C3/C4] centrally onto the cover disk [C5] which is located at the end of the display zone. Because the gluing location is small, it can be helpful to scrape off some print lacquer beforehand in the middle of the cover disk with a knife. In this way, the glue has a better penetration into the cardboard. If some glue runs out next to the axis block, remove it with a knife. Otherwise the axis will not turn properly in its bearing. Allow to dry well. This end of the display zone now carries an axis.
Step 14: As described in the last three steps, make also an axis block from the small disks [C6] and [C7]. Glue the cover disk [C8] onto the round flaps at the other end of the display zone and, onto it, the axis block [C6/C7]. Now the display zone has an axis on each end.
Step 15: Fold the foot of the outer axis bearing [C9] forwards and glue the part onto the rear side of the inner axis bearing [C10]. Make sure that the two holes are exactly in line over each other. Allow to dry well.
Step 16: Place the axis bearing [C9/C10] onto your working surface in such a way that the folded foot is lying below. Place the display zone with one of the axes onto it and carefully press the axis into the hole in the axis bearing. Check and make sure that the axis on the other side is approximately in flush with the axis bearing. If the axis cannot be pushed fully into the axis bearing, it may be necessary to widen the hole carefully. Check to see if the axis bearing can turn around its own axis.
Step 17: Then glue the cover disk [C11] with its non-printed side onto the axis. IMPORTANT: make sure that no glue gets into the axis bearing, but only onto the axis. After drying, ensure good movement of the axis by turning it carefully as required.
Step 18: As described in the last three steps, make the second axis bearing from the parts [C13] and [C14] and then secure it in the same way with the help of the cover disk [C15] at the other axis of the display zone.
Step 19: Try it out and place the display zone with the turning axis bearings into the recess of the console. The rounded ends on the inner side of the axis bearings project into the trough and touch with the flaps with which the trough closes above and below. The folded gluing flaps on the outer side of the two axis bearings are seated on the rim of the trough on the surface of the console. The display zone should be aligned in such a way that the months of December and January are located above on the side with the timing loop.
Step 20: Glue the axis bearing of the display zone solidly in this position, meaning, the outer foot flaps of the axis bearings are glued onto the console upper surface, the round inner sides of the axis bearings against the flaps which close off the trough.
Step 21: On the inner side of the console, glue the edges of the trough bluntly against its closure flaps.

The feet of the hour stripe

The hour stripe, with which the sunlight projects the digits and lines for determining the time onto the display zone, is located right and left in feet, in which wide slots for accommodating the stripe are positioned and which project into the interior of the sundial.

Step 22: Glue the two distance stripes [D1] and [D2] onto the non-printed rear side of the stripe holder [D3] to flush with the two rims which are just as long as the distance stripes themselves (3 cm). The distance stripes then allow a clearance of 2.5 cm into which the hour stripe exactly fits.

Step 23: Now glue the stripe holder [D4] onto the two distance stripes so that an open pocket on both sides is established with a full-through slot with a width of 2.5 cm. After drying, check and see if the hour stripe can also be pushed all the way through. For this purpose, cut off the corners of the hour stripe with a little slanting so that it can be moved better into the required position.

Step 24: Detach the long foot supports [D5] and [D6] from the cardboard and fold all 3 flaps forward. Glue the two foot supports onto the two sides at one end of the stripe holder in such a way that their upper edges lie there in flush where the stripe holder has its slot-shaped opening. The long and the two short swung flaps at the foot supports are not glued.

Step 25: Fold the short foot supports [D7] and [D8] forward. Observe that the short foot supports have a larger and a smaller half. Glue the smaller half onto the two small swung flaps at the end of the long foot supports. They fit exactly if you push and press the parts a little.

Step 26: Insert the stripe holder into one of the two slots on the console. In there, it has a slight lateral leeway. Push it as far as possible to the outer rim and glue the flaps of the foot supports solidly in this position.

Step 27: As in steps 22 to 26, glue from the distance stripes [D9] and [D10] and the two stripe holders [D11] and [D12] a second pocket with a slot, and attach the long foot supports [D13] and [D14] and the short foot supports [D15] and [D16] and glue the whole lot into the other slot of the console.

The assembly of base and console

Step 28: Try it out and insert the console (without gluing) into the opening of the base in such a way that the curved back of the console lies at the back of the base with the geographical positions and the long gluing flap of the console at the corresponding gluing flap at the lower rim of the base.

Step 29: Draw the console out again and glue the two flaps together in such a way that they match each other accurately and disappear in the interior of the base. Together they form the hinge about which the console turns when it is set to different geographical latitudes.

The cover hood

The cover hood functions as a dust protection when the sundial is not in use and is mounted onto the console that is only slightly drawn out. The digit stripe then lies rolled together in the interior of the sundial.

Step 30: Fold the two grooved lines of the cover [E1] to the rear, also the three gluing flaps at the two side parts of the cover [E2] and [E3].

Step 31: The three flaps of the side parts correspond to the three differently large folding sections of the cover. Similar to the assembly of the base, glue the flaps of the two side parts in flush to the inner side of the cover so that an open box with slanted side walls is established.

Now your digital sundial is completed. Congratulations! You are now the owner of a valuable and wide-range adjustable sun time-measuring instrument with a high degree of accuracy.

In order to set your sundial correctly, proceed as follows

1. Step: Selection of the time indication: decide on the type of time you want to be shown. Most sundials do not show the Standard Time, the time we read on our watches, but rather the solar time ("True Local Time"). The two sides of the turning display zone of your digital sundial can show you, selectively, either the one or the other time.

2. Step: Setting up the hour stripe: insert the ends of the hour stripe into the slots of its two feet in such a way that you can read the digits side-correct from the outside. The end with the "6" is mounted in the right foot, and the end with the "18" in the left foot. If the solar time is to be indicated, the round point at the "6" must exactly lie on the edge of the right foot, and the point at the "18" exactly on the edge of the left foot.

If the standard time is to be shown, the longitude degree line on the stripe corresponding to your position must lie right and left on the edge of the foot. 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), the lower longitude degree scale. The longitude and latitude of random locations can be determined with the card display of most electronic route planners and atlases for the PC. The Internet proves appropriate lists, for example under www.multimap.com.

3. Step: Setting your geographical latitude: adjust the inclination of the console until the geographical latitude of your location is indicated on the console edge.

4. Step: Sundial orientation: turn the sundial exactly towards the south, e.g., with the help of the Big Magnetic Compass of AstroMedia and turn the selected side of the display zone in such a way that it is orientated to the sun.

5. Step: Reading the time: you read the time on the middle line on the display zone for True Local Time / Solar Time. On the display zone for standard time, you read the time at the timing loop, i.e. at the point of the date in each case. The 1., 10. and 20. day of each month is given. Intermediate readings can be estimated.

What is the difference between Standard time and Solar time?

Solar time / True Local Time (TLT): 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 Solar time or True Local Time (TLT), respectively. (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 it has its midday highest point at all locations east of our position earlier than with us and later at all locations to the west of our position. Even though 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 Kassel is only 10 arc minutes (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 the local time difference: the difference of the True Local Time between two locations results from the difference of the degree of longitude of these locations:

Of the 360 degrees of longitude of the earth, the 0°-degree-line runs through Greenwich near London, the so-called zero-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°. For one circulation of the earth with its 360°, the sun requires 24 hours. This is one hour for 15° or 4 minutes for 1°. If a place is located 2° further to the east, the midday highest point of the sun takes place 4 minutes earlier per degree of longitude, meaning, 4 x 2 = 8 minutes. If a place is located 20° further to the west, it takes place later, meaning, by 4 x 20 = 80 minutes.

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 the same time of day (Central European Time) applies for both locations.

The annual fluctuations of Solar time: Solar time varies not just with respect to the east-west-location of a place but also with within a year. Compared with a very precise mechanical watch, it can be stated that the sun slightly slows down from the 12. February to the 15. May, until it is slow by a total of 18 minutes, and that it accelerates its course up to the 27 July again by 10 minutes, up to the 4. November it slows down again by 23 minutes, and accelerates by 31 minutes up to 12. February. This speed-ahead and retardation is expressed in the timing loop on the one side of the display zone.

The duration of a Solar day is therefore not rigid. 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 constancy, from which the True Local Time / Solar time can deviate by up to 16 ½ minutes and with which it coincides only on 16. April, 14. June, 2. September and the 25. December, that is at the lowest and at the highest point as well as in the vicinity of the intersection point of the timing 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 timepieces according to 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 were introduced as we know them today. In these time zones you have a uniform, averaged and equal time – otherwise it would never have been possible to draw up binding travel schedules for major regions. Normally, the zone times have a difference of 1 hour between them and are based on the True Local time / Solar 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 full zone. The actual limits of the time zones do not depend on the degrees of longitude but rather in a practical manner on the boundaries of the states.

CET and CEST: the central European zone time CET is derived from the mean Solar time at the 15. eastern degree of longitude, where the city of Görlitz lies. In former times in Germany, this was also known as "Görlitz Time". Except for the central European states, it also applies today in Norway, Sweden, Poland, Hungary, France, Spain, Morocco, Libya, Tunisia, the central African states and Angola. The furthest east European location in the zone of CET is Strzyzow at the Polish eastern border with –24.1° geographic longitude. The furthest west location is Fisterra on the Spanish west coast with +9.25°. This means a degree of longitude difference of 31.35°, which corresponds to a local time difference of 2 hours and 5 ½ minutes. In the months when the Central European Summer Time applies, an hour is added to the CET. We simply pretend that it is an hour later. Originally, the idea behind it was to save energy but this hope did not materialise. Nobody knows exactly why everybody goes to the trouble of changing the clocks around every year. The most likely reason: daylight is prolonged for leisure time in the evening.