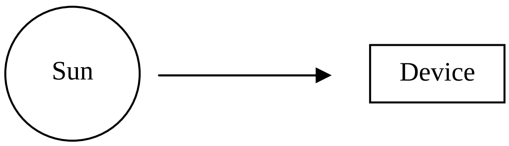
Solar Powered Planetary Positioning Indicator

Abstract:

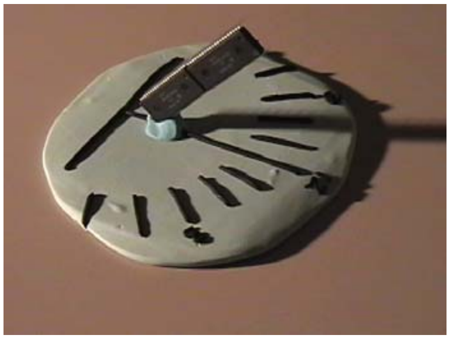
Description:

This entry describes the design and construction of a dual processor digital device which presents a real time indication of the earth's axial angle of rotation relative to the sun. Features of the device include a solar power source, extremely low power consumption, minimal construction costs, flexible design, classic features, ease of use, and a familiar user interface. Central to the design are two Renesas H8/366 CPUs which were programmed using the BASIC language.

Block diagram:



Photograph:



Software code sample:

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STOP
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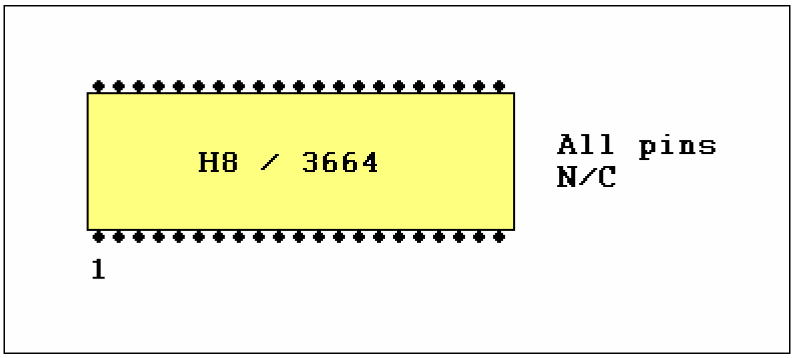
Schematic:



Documentation:

Description:

This project describes a digital device which indicates to the user his or her terrestrial axial rotational angular position relative to the sun. Such devices have enjoyed a long and colorful historical presence and are often known in the common parlance as “clocks.” This particular implementation comprises a dual processor solar powered digital clock featuring extremely low power consumption, long shelf life and mean time to failure, minimal construction costs, flexible design, classic features, ease of use, and a familiar interface requiring little end user training. The design incorporates two Renesas H8/366 CPUs which were programmed using the BASIC language.

Project photograph:

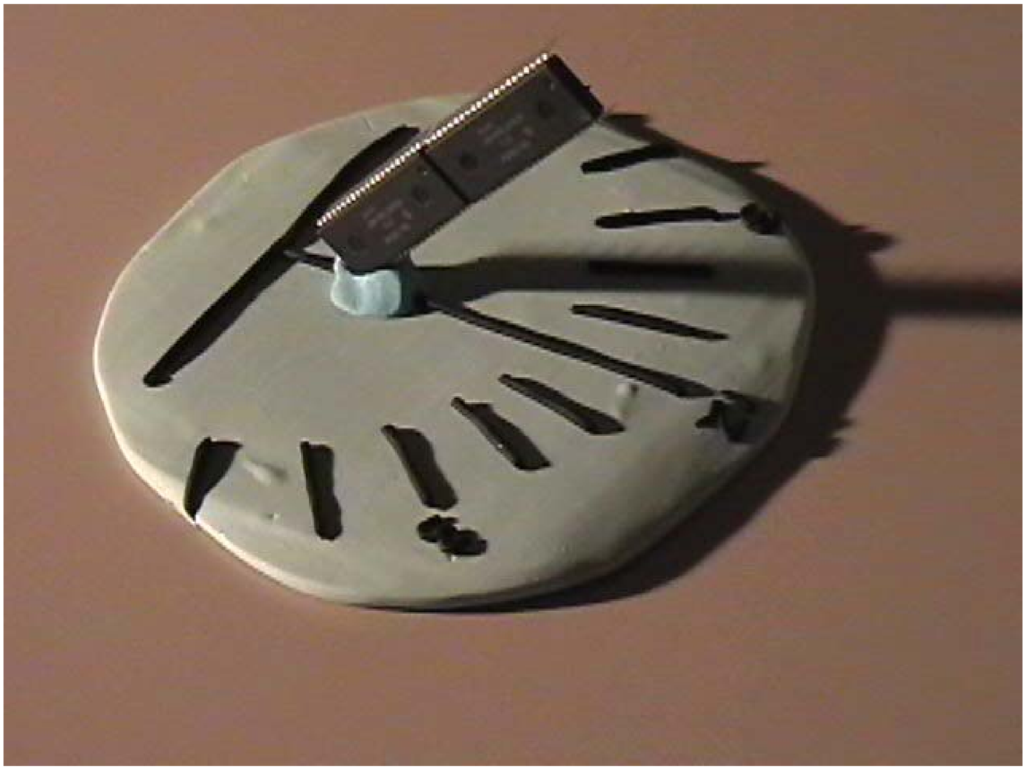


Figure 1 - Dual Processor Solar Powered Digital Clock

Historical perspective:

Throughout and probably preceding recorded history humans have noticed and measured the apparent motion of the sun through the sky. With the fall of the geocentric model of the universe and the recognition of an orbiting and rotating spherical earth, it became understood that the observed changes in solar position actually resulted from variations in the earth’s rotational angle relative to the sun itself. The scientists were ecstatic, with the possible exception of those the church had offed during the transitional period. No longer would such unscientific terms like “sun rise” and “sun set” rule the human race; no, they could now use high class terms like “angles” and “degrees” and, dare they even suggest it, “radians.”

But the peasants were not amused, nor were the masses, and over the loud clamoring of the scientists they retained their primitive axial rotational angle measuring devices which they called “clocks,” preferring to use the established familiar unit of axial rotation, the “o’clock,” which they continued to number, for some strange reason, from one to twelve.

The winner in this scientific revolution and expansion of human understanding was the shadow, specifically the shadow cast by a common stick in the mud. No longer could the shadow’s movement be looked upon as an insignificant curiosity, or ignored completely, for it now reflected the intricate interplay of vast universal forces, the cosmic dance of the heavenly spheres. Provided, of course, that whoever stuck the stick in the mud did so with some skill or considerable luck, as we shall soon see.

Theoretical foundations:

“Any stick doth not a clock make” said Shakespeare’s Macbeth, or at least he probably thought it, and truer words have never been imagined. For a stick to be of interest for this project (of necessity we’re ignoring literally millions of sticks in the implementation of this design), it has to be positioned parallel to the axis of the earth. Unless the user is located on the equator this does not present much of a problem, and there’s usually some flat ground lying around nearby that one or the other end of the stick can be inserted into. If you live in New York City, improvise.

The second useful ingredient is the sun, preferably situated within line of sight of said stick such that the interaction thereof casts a shadow. With some theoretical and/or practical application of mathematics and observation, it is possible to mark out the “o’clocks” around the perimeter of the path of the cast shadow’s movement, thereby establishing a classical terrestrial axial rotational measurement device recognized by billions of people worldwide. In the vernacular, such an arrangement is called a “sundial” from the Latin roots “solas” and “dialus” meaning to telephone the fire gods to ask them what time it is. This project describes a variation on what is commonly known as a horizontal sundial, so named because the output display element of the device is horizontally aligned.

So the necessary components of this project are:

- A stick
- Something to hold the stick rigidly parallel to the earth’s axis
- A sun (sorry, Seattle)
- Something horizontal upon which the stick may cast a shadow
- Some well placed marks on the horizontal surface

These last items, the so called “hour” marks, assist the user in mentally converting the real time position of the cast shadow into the more familiar “o’clock” reference system.

Of course, other things may be substituted for some of these components, as in the case of the current project where the stick has been significantly upgraded and digitally enhanced by replacing it with two serially coupled H8/366 CPUs.

In deference to the subtleties of the English language in which non-English words are frequently utilized to obfuscate and obscure, the stick will henceforth be known as the “gnomon,” a word that cannot be pronounced.

Construction:

Construction of the device is non-critical for the most part, with the two aforementioned exceptions: the shadow throwing edge of the gnomon needs to be aligned parallel to the earth’s axis, and the hour marks on the horizontal surface must be placed accurately. The positions of both the gnomon and the hour marks depend upon the latitude of the installation location, and thus some of the construction requirements are site dependent. This requirement for local customization, long considered by some to be a liability for any project, is actually among the many fine features of this device and assures a personalized and unique installation.

To understand this site (latitude) dependency, first consider how the placement of the earth's axis relates to a user located at an arbitrary point in the northern hemisphere:

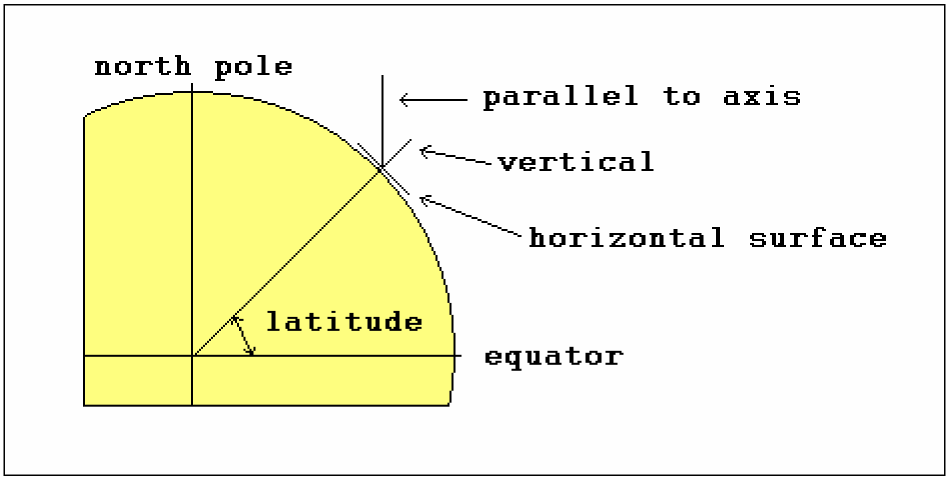


Figure 2 - Where the earth's axis is relative to your house

The shadow casting edge of the gnomon will be coincident with the line labeled "parallel to axis." From a simple application of geometry, you can derive that the angle the gnomon makes with the horizontal surface is the same as the angle of latitude. This means that at the equator (where the latitude equals 0) the gnomon is lying flat on the ground. This situation is known as "gnomon siestus" which is Latin for "broken clock."

You can find your latitude by consulting a variety of sources, including maps, globes, your library, the talking GPS navigation system in your Lexus, the state or federal geological survey, or the internet. Like you're going to believe everything you read on the internet. Like you have a Lexus.

The hour marks on the horizontal surface of the sundial can be laid out via observation or trigonometry, although in the interest of saving a year or so we'll use trigonometry. The most basic of the hour marks, the "noon line," will point due north when the device is installed and lies directly under the gnomon. A "base" line perpendicular to the noon line is drawn where the gnomon intersects the surface, and the west end of this line indicates 6am while the east end indicates 6pm.

The other hour lines are constructed relative to this point of intersection, using the formula

$$\text{tangent}(d) = \text{tangent}(t) * \text{sine}(p)$$

where d is the angle the hour line makes with the noon line, t is the time measured from noon in degrees and minutes of arc, and p is the site latitude. We are interested in solving for d for certain values of t. To select the values of interest for t, each hour contributes 15 degrees (360 degrees divided by 24 hours).

Table 2 gives the hour angles for each hour from 6am to 6pm for the author's latitude. Negative angles are measured to the left (west) of the noon line, and positive angles are measured to the right (east). As the sun seemingly progresses in the sky from east to west, a northern hemisphere gnomon casts a shadow that meanders from west to east in a northerly manner, or "clockwise" as this phenomenon has become known. In an effort to rebuke the hemispherically biased and politically incorrect arrogance of the early scientists and wordsmiths, the technologically savvy GenX has morphed "clockwise" to mean flashing like an unset VCR.

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time	degrees from noon	time	degrees from noon
6 am	-90	1 pm	11.4
7 am	-70.4	2 pm	23.4
8 am	-52.5	3 pm	36.9
9 am	-36.9	4 pm	52.5
10 am	-23.4	5 pm	70.4
11 am	-11.4	6 pm	90
noon	0		

Table 1 – Hour marks for a certain northern latitude

Figure 3 illustrates the use of some of these calculated values. It shows the noon line and the (unlabeled) base line which corresponds to 6am and 6pm, and how two of the hour marks are constructed using the angle values from the table.

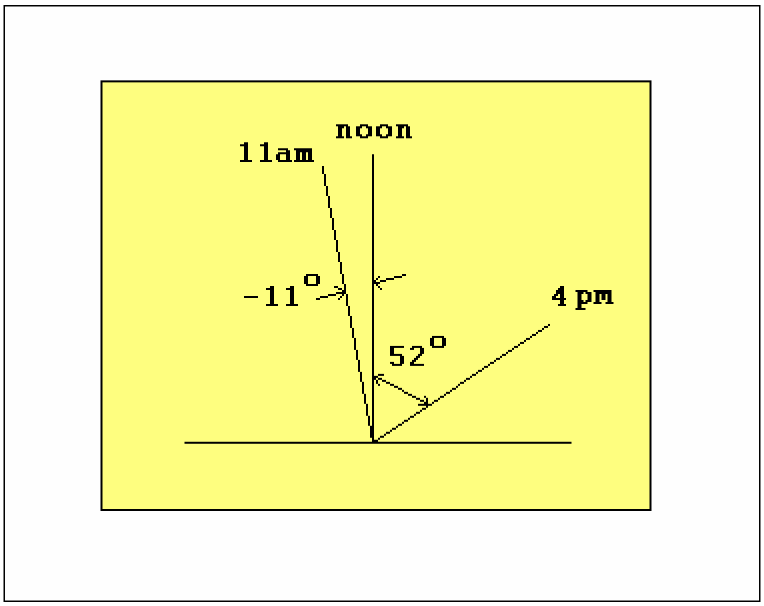


Figure 3 - Selected hour marks

Notwithstanding this theoretical understanding of the orientation of the gnomon and the layout of the hour marks, certain decisions regarding the noncritical portions of the construction of the sundial must also be made. These decisions include the selection of materials, how many and which hours to mark, how and even whether to label said marks, the inclusion of other decorations and adornments, and the like. These details are left to the artistic judgment of the individual, provided in your present position or occupation you've escaped the wrathful vengeance of the gods of micromanagement.

While traditionalists may prefer hefty stone sculptures sporting Roman numerals and a "Tempus Fugit" (capitalized Latin for "tempus fugit") inscription, minimalists may feel an old scrap of unpainted particle board lying on the ground to be too ornate. Research indicates practical minded career oriented personalities show a statistically significant preference for wristwatches.

Using the materials and style of choice, once the sundial is constructed it is ready to install.

Positioning and calibration:

Proper functioning of the device depends upon accurate spatial orientation. To correctly position the completed unit you must:

- Determine where true (polar) north is
- Be able to level the base horizontally

Finding true north can be somewhat tricky but can be done by any of the following methods:

- Using a magnetic compass and applying a correction depending upon your location
- Using the sun to find the direction of a shadow cast by a vertical object when the sun is at its zenith
- Sight toward the north star (Polaris)
- Ask a teenager (they know everything)

The most accurate of these methods is to use the sun. This involves investing some quality mid-day time on a sunny day watching something vertical (like a knotted string with a weight on it) cast shadows and marking where they fall while making lame jokes to passers by about helping your mysteriously absent middle schooler do a science experiment.

Figure 4 - Determining true north

Be that as it may, it is assumed that through fair means or foul you will be able to not only find true north but also to precisely orient the noon line of the device in that direction. It is also assumed that leveling the base of the device will present no obstacle. As a simple visual check of the accuracy of both of these alignments as well as your interpretation of your latitude, a sighting along the edge of the gnomon should point almost exactly at Polaris (easiest to confirm at night).

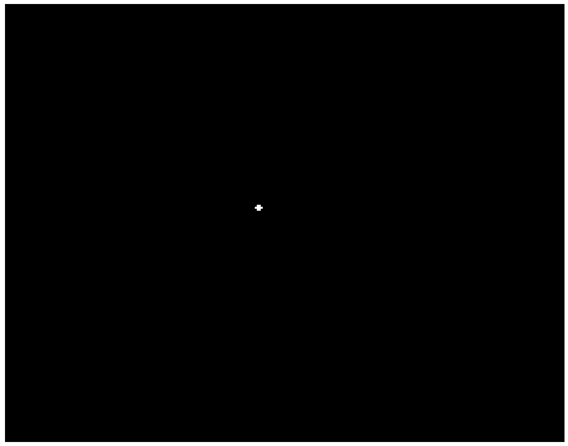


Figure 5 - Polaris, the North Star (not to scale)

Compensations, adjustments, and other considerations:

At this point in the evolution of western civilization the pervasive influence of digital technology might lead the typical user to expect a certain level of precision from such a device as described in this document. Such a user may experience some level of dismay and/or existential ennui when the installed sundial, even one with hour marks labeled in binary, does not always indicate an accurate time of day.

The reasons for the discrepancy are manifold. The sun has little regard for the human convention of time zones, preferring instead to have time flow smoothly across all parts of the earth rather than arbitrarily jumping abruptly every thousand miles or so. Moreover, the author is told (private correspondence) that the sun particularly dislikes daylight savings time.

Consequently the north "noon" line cast by the sun at its zenith will not correspond to noon clock time in part because of the local placement of the sundial within its time zone. An entire thousand mile wide time zone will simultaneously share the same clock time, while each instance of longitude will have its own solar time.

Another reason for the disagreement of sun and clock times is that the accuracy of a sundial depends upon the day of the year. Because of the eccentricity of the earth’s orbit and the tilt of the earth’s axis in relation to the plane of the orbit, daily fluctuations occur which render the theoretical hour markings slightly inaccurate, up to about a 16 minute discrepancy in the worst case. A plot of the sun’s position at its zenith every day of the year yields a figure eight shaped curve called an “analemma.” If you consider that the sun will be somewhere on the analemma at noon on a given day, it is easy to realize that rarely will the shadow cast by the gnomon fall exactly on the noon hour mark.

In addition to the aforementioned time zone and orbital factors, nighttime use of the device can also result in compromised interpretations of readings. Best results are therefore obtained by coordinating the observed value with an external time source such as a wristwatch. Overcast days can be considered “nighttime lite” or “nightlite” for short.

Figure 6 - Suggested nighttime use

Further development and exploration:

Of course, there is nothing to keep the industrious and forward-thinking tinkerer from modifying this design in a variety of ways, one of which that comes to the author’s mind being a portable version of the device. This would surely produce a novel and almost practical timekeeping instrument of distinction that would be the envy of all who encountered it.

Schematics:

Wiring the project was straightforward. A printed circuit board was not used in the construction of the prototype although doing so would have provided substantially greater mechanical integrity for the mounting of the ICs. Electrical noise and signal crosstalk were reduced by keeping wiring runs to a minimum.

A full schematic of the completed project is shown in figure 7.

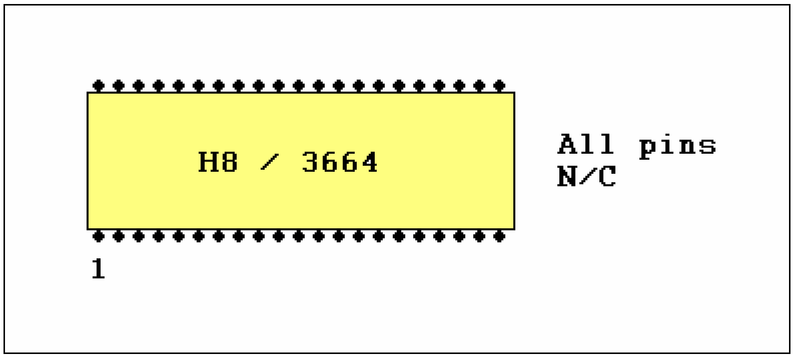
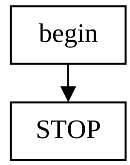


Figure 7 – Schematic (x 2)

Flow chart:

The flow chart of the logic for the device’s software is as follows:



Source code:

BASIC was chosen as the programming language for the development of the prototype of this project because of its ease of use, sufficient level of performance, reduced development time, and inherent debugging features. Prior to the development of a production version of the same device serious consideration would necessarily be given to the appealing features of both C and assembly language as the language of choice.

The complete source code that was written for the project is as follows:

```
STOP                    ‘ wait for reset
```

Please note that while this code was written, debugged, and extensively tested, the virtual nature of the digital characteristics of this device did not require actual loading and execution of the program.

Summary:

This document describes the design and construction of a modern, technologically sophisticated, digital version of a device whose roots are shrouded in the mists of prehistory. While the fundamental considerations of the classic design have not changed for centuries, this project uniquely applies the latest advances in microprocessor technology to enhance and modernize what is unjustly considered by some to be a staid and stolid archaic artifact.

To build such a device is to step back in time, so to speak, to a simpler and more innocent era. To own such a device is to have a trans-temporal bridge connecting a primitive and pre-scientific past to an uncharted and boundless future. To use such a device is to bring into public awareness the possibility that you might personally be a BIOS chip short of a motherboard.