



## Description

The present invention concerns an electronic, digital display watch, in particular a wristwatch, with solar and geographical functions, comprising timekeeping means for the current date and time.

Various watches have already been proposed, which in addition to time and date data (where the more advanced ones count the months and years of a four-year cycle), providing information relating to the sun's trajectory, indicating in particular the time of sunrise and sunset, however with the restriction that this solar information is related to local time which only rarely coincides with official time, the latter being that in the centre of the time zone being considered or even in the centre of an easterly time zone (summer time, double summer time). Moreover, the proposed watches provided proper solar data only for certain geographic latitude zones or for a certain number of selected geographical latitude zones.

Again digital electronic watches with computing functions are also known which in fact amount to small pocket computers. However a major drawback of these watches is the difficulty in providing the relatively large number of push buttons needed for a pocket computer on the relatively small face of a wrist watch. Hence several tens of required push buttons are to be found on the major part of the watch face, inevitably very small, whereby they cannot be finger actuated but demand a pointed object similar to the tip of a pen. Still these computer-watches can only amount to unsophisticated pocket computers, allowing the four basic operations and several similar functions but not allowing complex composite programming involving so many different sequential operations and requiring storage of a complex program.

It should be noted again that, at the present time, there is increased interest in the ability to gather solar position information under

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different circumstances, in particular for the ever more numerous number of people engaged in installing solar energy receiving means, as well as architects and town planners dealing with shade and shade direction and again pilots and aeroplane passengers involved in long distance flights wishing to know where and when night, day, sunset, etc., will occur. In the category of people interested in knowing the solar position parameters, mention should also be made of the followers of the Moslem religion whose prayer hours are governed by the path of the sun. The sixth hour of prayer in particular, defined as the time of complete nightfall, may be physically defined as the time the sun has dropped about 12° below the horizon and the moment this takes place, in relation to the moment the sun sets, varies with latitude and the period of the solar year (the Moslem months shift progressively from summer to winter and vice versa in a cycle of about 30 years).

In view of the above, it is clear that particularly interesting computing functions for integration into a watch are those relating to the sun. Existing computer watches are moreover designed for general use, not particularly for solar computation operations besides the very complex programs of which they would not be able to store.

With the exception of a few previous documents cited purely as technological background, linked to the present patent application we have cited the Japanese patent application JP-A-53 124 478, accessible to the public as well as the American patent specification US-A-4 136 397. It is worth noting that the first publication mentioned above concerns an invention from the same inventor as the present. In order to read the material in this Japanese specification, one may refer to US-A-4 253 169 patent specification which although published later comprises exactly the same material as the aforementioned Japanese document.

The first one of these previous documents concerns an electronic watch which is capable of providing information relating to the sun, in particular Moslem prayer times in terms of the date which the watch shows

21

due to its calendar arrangement and of geographical location, information concerning which can be entered into the watch. However, this watch does not allow information to be processed concerning the time, date, geographical location, the position of the sun and the solar azimuth and to display the results of this processing in all senses of research that is to say to call up any of this information from any of the rest, for example to locate a geographic position and a date in terms of azimuth data and the position of the sun.

The second of these publications concerns a device principally used to determine the time according to the sun in terms of solar data and geographic indications. This device also allows certain geographic indications to be found in terms of the time according to the sun and the date. All the same the possibilities are incomplete. It does not allow for example the possibility of determining the date at the same time as the latitude. On the other hand this device is not, strictly speaking, a watch. It is bulky and is composed of organs in the shape of an arc, pivoting in the three dimensions. Added to that, one notes that the earlier American publication which introduces this device, if it gives some astronomic formulae gives practically no technical indications as to the specific formation of the elements through which these formulae could be automatically translated into directly useful indications.

The device, according to this earlier publication, is not a watch and nothing indicates how it would be achievable in the form of a watch in which it is necessary, by means of a minimum of easily accessible push buttons, logically and appropriately arranged so that their functions are well understood and by means of a minimum of conventional display signs allowing what is displayed to be recognised, to be able to enter a very large number of diverse data on a relatively restricted display surface.

There is no doubt that large electronic calculating machines have already been made to carry out astronomical calculations but the main problem encountered is that of providing a practical and compact construction, in

72

the form of a wristwatch, whilst offering a very large range of possibilities, which can be, for a person mainly interested in certain of these possibilities, operated simply, allowing the repetition of the manipulation of the controls which quickly becomes intuitive. The  
5 earlier publication US-A-4 136 397 does not disclose in all cases one device responding to the demands mentioned above.

The prior art therefore has gaps regarding a computing watch of the very particular type in question and which should, in view of its specialised calculation functions, permit operation by means of a small number of  
10 push buttons easily actuated with a finger without cluttering the watch face and under these conditions permanent or semi-permanent storage of the complex computing programs should be possible again in view of the above cited specialisation. The range of processing possible should  
15 extend to all of those parameters previously mentioned and allow practical results acquisition for all combinations of "parameters introduced/unknown parameters to be calculated and displayed".

Note should also be made that as regards existing computer watches, most of the watch face is taken up by push buttons so that the display area is small which requires either very few digits displayed or else the display  
20 characters must be very small. This drawback should be eliminated in the watch considered above.

It is the object of the present invention to create such an electronic digital display watch fitted with solar functions and meeting the needs and interests described above and eliminating the drawbacks, also  
25 aforementioned, of computer wrist watches with general functions as they are known in the prior art. This object is achieved by the invention by the characterisation cited in the attached independent claim.

The dependent claims define particularly advantageous modes of embodiments mainly regarding the convenience of actuating the solar  
30 computer watch and the convenience in reading the data provided and again

with respect to the grouping of the functions and the function commands, it being understood that from the very large number of functions possible with the watch, each user must be able to easily retain a particular group of functions of particular interest to him without having to necessarily remember the complete operational instructions for the watch relating to all the other functions he is less interested in. The advantageous implementation modes defined by the dependent claims therefore specify on one hand a large number of functions which will be advantageously included in a watch to make it quite universal and on the other hand a rational arrangement of these functions to allow the user, in the light of the above explanations, a selective initiation in the manipulations necessary to those functions especially useful to him.

The attached drawing illustrates, as an example, one embodiment mode offering numerous possible variations in the subject of the invention. In this drawing:

Figure 1 is a front view of an electronic wristwatch with a digital display of the solar and geographical functions of the concept under discussion and showing the watch in the state of table 1.

Figure 2 shows a series of displays C11-C16, C21-C26, C31-C36, which the watch can provide in its various possible modes, in its different states of non-correction, of forward correction, of backward correction and of panel operation for different postulated uses; naturally Figure 2 is not exhaustive.

Figure 3 schematically shows with the aid of Figures 4, 5, 6 and 7, the overall electronics and logic diagram of the watch.

Figure 4 is part of the diagram of the watch according to Figure 1 which shows all of the circuits formulating and storing time, date, place, local time, sun azimuth (AS) and sun elevation (HS) data which were processed or will be and which shall be selectively displayed.

74

Figures 5a and 5b show the watch circuit diagrams comprising the control circuits connected to the operational controls as well as a certain number of auxiliary circuits for different functions.

5 Figure 6 is a diagram showing that part of the watch circuit which constitutes the overall internal control of the watch functions, in particular the control of the computer functions as a function of the operational commands (Figure 5) and of the overall formulated data (Figure 4), this Figure 6 also showing the display control and the multiplex display of the main data.

10 Figures 7a, 7b and 7c diagrammatically show that watch part which is the computer and implemented in the form of a microprocessor, the components shown in Figure 5 mainly symbolising elementary microprocessor programs, i.e. the material components by which the microprocessor carries out these programs, where these elements, in large part, are the same for  
15 most of the programs, and not shown as such.

Figure 8 is a more detailed diagram of one of the six identical "command input" or "push button" circuits shown in Figures 5a and 5b.

Figure 9 shows in detail the logics diagram of an A.M.P. LOGIC bloc shown in Figure 7b and

20 Figure 10 shows in detail the logic diagram of a PREPARATION LOGIC bloc also shown in Figure 10.

We will start by considering the appearance of the watch and its functions as seen solely by the user (without as yet entering into details on internal composition, which will be discussed later in  
25 relation to Figure 4 and following).

As a rule, the watch is likely to be in one of the three modes, namely the normal RN mode, the I RTI screen mode and the II RTII screen mode.

The two mode set, RTI and RTII is called the panel mode RT. In addition, the watch may be in four positions regarding the data processing it displays, namely the no correction SCN position, the forward correction SCAV position, the backward correction SCAR position and the panel operations STT position.

In Figure 1, the watch is shown in the panel I RTI mode and in the panel operation position STT. The 18 examples of Figure 2, C11-C16, C21-C26, C31-C36 (the figure indicating the coordinate positions of each example in Figure 2) first show three watch examples in the normal watch mode RN (C11, C12, C13), then eleven examples of the watch in the I RTI panel mode (C14-C16, C21-C26, C31-C32) and lastly four examples of the watch in the II RTII panel mode (C33-C36).

Example C11 in Figure 2 shows the watch in its ordinary function, which is the simplest, wherein it only shows hours and minutes in a twelve hour cycle plus the indication of A/P. In the example C11 of Figure 2, the watch indicates 10.35 pm.

As shown in Figure 2 the watch may display up to three superposed lines of data, the upper, centre and lower lines and moreover it also shows on the far right a series of symbols indicating the mode, the position and other particulars relating to the three states within the scope of panel operation. Each of the three lines comprises four main display sites of seven segments, an auxiliary display site with seven segments all the way to the left and two display sites separating the main left sites from the main right sites. Six push buttons are distributed on the sides of the watch case, three on the left (BPH', BPM', BPB') and three on the right (BPH, BPM, BPB). To the extent that these push buttons do not control the completely general functions applying to the entire watch, they will always control functions relating to the data displayed on that line at which is located the push button. For instance in Figure 1, the centre line displays the time, 8.46am. The centre button and on the right, BPM, would be used to correct this time information if we are in the

(76)

correction position.

At the top on the left, the display comprises two almost vertical bars indicating the mode. When none is actuated (for instance C11 to C13, Figure 2), the watch is in the normal RN mode; when one is actuated (for instance C21 to C26, Figure 2), the I RTI panel mode applies and when two are actuated (for instance C33-C36 in Figure 2), the watch is in the II RTII mode.

To the left at the bottom, the watch may display an almost vertical bar either with one arrow tip pointing up or two arrow tips pointing up and down. When there is no display at that location, the watch is in the non-correction position SNC; when one arrow pointing up is displayed, the watch is in the forward correction position SCAV; when a downward pointing arrow is displayed, the watch is in the backward correction position SCAR; and when a bidirectional arrow is displayed, the watch is in the panel operational position STT. The meanings of the other symbols displayed to the far left will be made clear later.

To multiply the control possibilities provided by only six buttons, provision is made (as shown later in relation to Figures 5 and 8) for input command circuits discriminating between a push button "briefly pressed then released" (short pressure), "pressed at least for one second before release" (long pressure) and "pressed, then released, then pressed again within one second" (double pressure). Each of these three types of actuation provides a distinct command, whereby it is possible to input eighteen different instructions with the six push buttons. In all modes and all positions (except for a correction being in progress), short pressure on the left push button advances by one step the type of data on the corresponding line. In the normal RN mode, the center line displays only a single type of data, namely the present time, and short pressure on the centre left push button has no effect. On the other hand the upper line as desired either displays no data (for instance C11, Figure 2), or else displays the day of the week and seconds (C13, Figure 2). In

77

the normal mode, each short pressure on the upper left button BPH' causes to appear, then disappear, then reappear etc., the indications of the day of the week and of seconds. The same applies to the lower line concerning the date in months, days, possibly years (0, 1, 2, 3) in a four-year cycle when in the correction situation; the date display appears and disappears in the normal mode whenever brief pressure is exerted on the lower left button BPB'.

When in the panels mode, the cycle of the three lines is as follows:  
upper line: "hour deviation" EH, "sun elevation" HS; centre line: "time zone, latitude" FHL, "hours and minutes" HT; and lower line: "date" DT, sun azimuth" AS. This arrangement is the same for the two panel modes RTI and RTII.

It is seen that in the panels mode, the centre and lower lines once present the same data as in the normal mode and another time another data, and that only the upper line, when in the panels mode, presents two data other than it shows in the normal mode.

The normal mode operation is quite simple, the watch displaying either the present time uniquely or the present time with one of the data "present date" and "day of the week, seconds", or the present time and both of these data. To correct them if necessary, the watch must be set in the forward or backward correction situation. Long pressure on the lower left button BPB' causes the forward correction situation SCAV and the next pressure the backward correction situation SCAR and the pressure thereafter the panels operational situation STT and the next returns the situation for non correction SNC. Once the correction situation has been established (for instance C13, Figure 2), brief pressure on the right push button advances (or sets back) the unit information by one step, that is the last right main digit in the line considered, long pressure advances by one step the digit located just to the left of the two dots, and double pressure, depending on the case, either advances (or sets back) by one step in the auxiliary section to the far right, or else

75

advances by one step the decades in the second main digit from the right.

We will see later, in order to facilitate certain settings, long pressure on the right push button following short or double pressure in this same correction process advances by one step the digit of the decades to the right of the two dots instead of the digits located left of the two dots. Every time a correction is effected but incomplete, it must be acknowledged by short pressure on the left push button of the particular line. As long as the correction is unacknowledged, it will be considered incomplete and it is impossible in particular to pass to a position other than that of forward and backward commands. It is obvious that the brief acknowledging pressure causes no shift in the type of line display, and this is the above cited exception. Moreover, while corrections are being made, it is very easily possible to pass from the forward to the backward correction without each time passing through the operational panel position STT and the non-correction position SNC. The moment all the initiated corrections are acknowledged, the four-position cycle to command the corrections (long pressure on the lower left push button which is monitored by the lower left arrows) again applies.

The (normal RN, I RTI and II RTII panel) mode is selected by long pressure on the upper left button BPH'. The sequence is: RN, RTI, RTII, RN... The panel symbol, imitating the I and II characters at the top left, appears correspondingly. A special consequence of the presence of a correction as yet in progress and not yet acknowledged is that it is no longer possible to pass from the normal to the panels modes and vice-versa. Thus, if in the normal mode, this will remain to be the case, regardless of any long pressure on the upper left button and if in the panels mode, long pressure on the upper left button causes a transition from panel I to panel II, then from panel II to panel I, etc.

It must be noted that the corrections undertaken always apply to the data being displayed.

In C13 of Figure 2 for instance, there is the situation of backward

(22)

correction. At C12 of Figure 2 a small line which may subtend an angle with the RTI symbol bar, indicates that the I RTI panel mode which might be called up will be of a special type "without automatic alignment", which is a peculiarity discussed later.

5 After long pressure on the upper left button BPH, the I RTI panel mode is acquired and the display of a bar appears at the top left. When the RTI panel mode appears, always the first cycle data will be displayed, that is, the time deviation EH will appear on the top line, the time zone and latitude FHL on the centre line and the date DT on the bottom line.

10 Regarding the time and the date, a distinction is made between the DT panel date and the DN normal mode date and between the HT panel time and the HN normal mode time, even though they are displayed on the same lines (but not under the same conditions).

15 The centre line indicates the time zone from zero to 24 in accordance with convention. The latitude is given in degrees by the two main right display sites and in tenths of degrees by the auxiliary display site entirely to the right; the upper of the two dots indicates a northern latitude and the lower one a southern latitude.

20 The time deviation (upper line) directly shows in hours and minutes the longitude of the point considered with respect to the centre of the time zone indicated. When the official time at the point considered is that of its own time zone, the maximum time deviation is +/- 30 minutes, the deviation at the centre of the time zone being 00. On the other hand, when a point is at the official time of a time zone other than the one it is located in (for instance in summer, Brittany is at the time of time zone 2 whereas it is located west of time zone 0), it may incur time deviations exceeding one hour. The advantage of expressing this longitudinal position in this way is that the measurement is independent of latitude and more familiar to the user. It also offers the advantage that changing to summer time is implemented by merely adding a time zone rank and one hour of time deviation. When looking for geographic

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6

positions as a function of the solar data, as discussed more comprehensively below, use again is made of time deviation; for the sake of convenience however the time deviation has been limited to  $\pm 6$  hours 59 minutes. Thus the regions which may assume the official time of a given time zone as permitted by the watch extend across six time zones on either side of the particular time zone, that is, over half the earth's circumference. To express the other positions it will be necessary in any event to refer to the antipodal time zone. Thus for instance every site in the world may be designated by reference either to the Greenwich meridian (time zone 0) or to the 180 meridian of the Aleutian Islands (time zone 12). In fact, the official time zone rarely deviates more than three hours from local time; it is known in any place what the time in the local time zone is and it is further known how much the actual noon is late or ahead with respect to the centre of the time zone.

Thus the three data EH, FHL and DT determine the place in longitude and latitude and the date of the place considered. When passing to the second position of the display cycle, while still in the panels mode, the sun elevation will be obtained on the upper line, the time on the centre line and the sun azimuth on the lower line. Under these conditions, if the time remaining on the centre line is the actual time and if the geographic point of the watch is set for the place where the user is located, the upper and lower lines will automatically respectively show the sun position in height and azimuth at the very instant and present place. The two data of azimuth and solar elevation, AS and HS will be corrected every minute, simultaneously with the data of current minutes. However it is possible to decouple the display time from the current time and to cause to appear for instance on the centre line another time of the day by means of forward or backward correction. The moment this correction has been confirmed (acknowledged), the computer part of the watch enters into operation and automatically realigns the AS and HS data (azimuth and elevation of the sun) in terms of the new time. Similarly, the azimuth data AS or the solar elevation data HS can be corrected, the two other data realigning automatically with respect to the one that was

81

just corrected the moment the correction was acknowledged. This constitutes the wholly original peculiarity of the watch functioning in the I RTI panel mode. In this mode too the sun elevation for instance may be made to appear on the upper line, the time on the centre line and the date on the lower line. If the last realignment was made with respect to the time, or if there has not yet been a realignment, any modification of the date will automatically cause a realignment of the solar elevation data in terms of the the date, the time being retained. At the same time, the solar azimuth data, which temporarily is not displayed but is nevertheless present is also realigned taking into account the new date. In this manner for instance it becomes possible to know the solar elevation at a given point in any day of the year. If the last alignment prior to the date correction for instance was made with respect to keeping the solar elevation and redetermining the time at which, for the new date, the sun will be at the set elevation (for instance 26.4°, fourth prayer hour of the Moslems).

In the I RTI panel mode, the MONOBLOC corrections offer a singularly interesting possibility. Particular predetermined solar elevations HS are involved, which are made to appear all together without the need to correct the HS value step by step. There are three, main, monobloc positions, namely sunrise, the sun at its meridian (maximum elevation) and sunset. These three particular positions can be displayed, the first one, i.e. sunrise, by long pressure of the upper right BPH button, the second i.e. noon, by long pressure of the centre right BPM button and the third, i.e. sunset, by long pressure of the lower right BPB button. These three particular positions will be of interest to practically all users. Moreover, there are three positions most important to the faithful of the Moslem religion, namely the "dawn" position, where the rising sun is 12° below the horizon, the position "descent" where the setting sun is 26.4° above the horizon still and "dusk" when the setting sun is 12° below the horizon. These three positions may be respectively summoned, the first one, namely dawn, by short pressure on the upper right BPH button (the position adjacent to sunrise, same button), the

second, descent, by short pressure on the lower right BPH button (the position adjacent to sunrise, same button) and the third, dusk, by short pressure on the lower right BPH button (position adjacent to sunset, same button). These positioning "monoblocs" occur in the panel I mode in the operational position on panel STT regardless of the displays that are present at the time the corresponding buttons are actuated. The displays on the centre and lower lines remain as before, that is, if by chance and for instance the lower display is the date, the date will remain displayed, while the solar azimuth AS will be in position and appear the moment the azimuth and not the date shall be displayed on the lower line. The same applies to the centre line. On the other hand, the monobloc corrections mandatorily display on the upper line the solar elevation HS, as this display allows the monobloc positions to be recognised.

It is appropriate here to mention how to display the solar elevation depending on the sun rising or descending or yet being at apogee or perigee. In case solar elevation HS is displayed on the upper line, the two main right display digits denote the solar elevation in degrees (maximum 90°) and the auxiliary digit to the right shows the tenths of a degree. The digit located directly to the left of the two dots (which do not appear in this display) is reserved for the symbol "-", for the elevations below the horizon. The last digit on the left displays " " when the sun is ascending and nearer noon than midnight, i.e. in the morning. When the sun is rising but still closer to 00h than to noon, the is provided with an upper horizontal stroke as shown in Figure 2 at C21 for instance. Thereafter, as the sun reaches its maximum position (meridian), the symbol becomes "H" as shown in Figure 2 at C23 for instance. Next, as the sun redescends, still being closer to noon than to midnight, the "h" inverts to become " "; this is shown in Figure 2 at C24 for instance. Lastly, as the sun drops and when closer to the end of the day than to noon, the " " is provided with an upper stroke to become " " as shown in Figure 2 at C25. Next when the sun is at the minimum below the horizon (true midnight), the "H" is given a lower stroke, assuming the shape of "H" as shown for instance at C16 of lower Figure 2.

It is worth noting that regarding the positions "H" and " " there is no need to indicate the elevation value, merely the maximum or minimum is indicated, the watch takes care of computing the elevation.

5 The monobloc corrections are restricted to applying the desired value of the solar parameter HS, together with the desired sign, the computer taking care of the rest.

10 The centre column of Figure 2, i.e. the positions C21 to C26, illustrates the six successive monobloc positions. These can be recognised by the following HS values: " " (or ) - 12.0"; dawn, "h" (or ) 00.0"; sunrise, "H...(any value computed by the watch)"; noon, sun at meridian, "26.4"; descent (or ) 00.0"; sunset and " (or ) -12.0"; dusk. This corresponds to the six positions of the central column in Figure 2.

15 In the panels mode, the time and the date may correspond to the present time or be desynchronised. On the far left and slightly above the centre line (likely to display the time) and the lower line (likely to display the date), symbols either being "p" or "o" are shown. Passing from one symbol to the other is implemented by adding or erasing the vertical bar. This display takes place only in the screen mode. The "p" denotes the present time, for the time and/or the date depending on the case. The  
20 other symbol "o" denotes the time is desynchronised, regarding date or time depending on the case. Obviously the moment a time correction or solar elevation correction HS to realign the hour or an azimuth AS correction to realign the hour or else a "monobloc" correction to realign the hour are undertaken, the time indication in the panel mode I is  
25 automatically put out of synchronisation. With regard to the date, it will be desynchronised only if subjected to a correction (or a memory recall, i.e. a function discussed further below). It is worth noting that it is possible to desynchronise and resynchronise the time and the date respectively in the panels mode by pressing the left centre and the  
30 lower left buttons twice respectively.

84

Regarding operation in the panels mode, the time and the date are supported by operational registers distinct from the counter registers that determine the current time and date. In this manner it is possible to modify the position of the time and date for instance to ascertain the sun elevation three months hence at 7.30 am without any loss of the current data of hour and current time which will automatically return by resynchronising the date and/or the time and which will mandatorily reappear when returning to the normal RN mode.

If, when using the watch under discussion, one passes from the normal mode (and in the non correction situation SNC) into the panels mode, the time and date data which first appear are not those from the operational registers but those from normal time registers. By a very simple manipulation it is therefore possible to know the solar positions at the very time of inspection. If it is attempted to carry out a time and date correction in this situation, this correction will not take place, but instead, the time and/or the date are desynchronised. The next correction will be effective. Thereafter, when the date and the time are resynchronised (by means of pressing twice on the corresponding left button), the operational register is aligned with the time or current date counter, but the data are not taken directly from the current time and date counters. Desynchronisation from the particular above-mentioned initial position can also be implemented by pressing twice on the corresponding left button. The symbols "p" or "o" appear on the far left on the watch corresponding to that previously indicated. It is worth noting that these matters of synchronisation and desynchronisation of the time and date data in the panel mode are dealt with in the same manner in the II RTII panel mode discussed later.

The question of place remains to be discussed. In principle the watch memorises three different locations each defined by a time deviation EH, a time zone FH value and a latitude value L. The watch includes three location memories "LOC A", "LOC B", "LOC C". The information "LOC A" is that of the "home port", namely (except for one case to be discussed

85

later) the location for the ordinary time in the RN normal mode. While the location is not displayed in this mode implicitly however, it is the location of the home port which matters.

5 In the panels mode, maintaining the home port LOC A intervenes at the beginning in the same manner as the ordinary time and date as already mentioned. Thereafter, the moment it is desired to make a location correction or the moment a change in place is intended, it will be the location operational mode which provides location information. Changes in location are implemented in a cycle of four or five, by long pressure  
10 on the middle, left BPM' button. They are monitored by a set of four dots located to the left at the centre between the two "p" marks. The four dots of this set take up approximately the three apexes and the centre of the base of an isosceles triangle resting on its base (the slanting sides are equal). In principle one dot mark indicates LOC A, two dot marks next to each other indicate LOC B and three dot marks next to one another indicate LOC C. Three dots as a triangle indicate that the operational location is no longer determined by one of the three memories, LOC A, LOC B, LOC C. With regard to the single dot denoting LOC A, if it is at the top (upper apex of the triangle), it means that  
20 this LOC A is that of the home port taken by itself at the beginning of the panels mode, whereas if this dot is all the way to the left on the base, it means the operational location is synchronised with LOC A (as it might also be synchronised with LOC B or LOC C or also unsynchronised). Except for the fact that the register of the home port LOC A is not  
25 subjected to an automatic change every minute or every 24 hours, it assumes the same role as the ordinary time and date counters.

In theory, accurate timekeeping is carried out in relation to the time most retarded time of the planet, i.e. of time zone 12. In the registers, the time zones are numbered in such a manner that time zone 12  
30 has the value zero, that time zone 0 (Greenwich) has the value 12 and that time zone 11 (Australia, New Zealand) has the value 23. Moreover, to take into account the fact that the last time zones might introduce

86

summer time, even double summer time, or time in advance by three hours, provision has been made for time zones 24, 25, 26 denoted as 12', 13', 14' in the display, where the ' in this case occurs in front of the 1 of the figure 12, 13, 14, on the left centre line of the watch.

5 The transformation of the time zone notations takes place in simple manner in the display, a weighting bit 12 being inverted. When the time zone to be considered has been modified, the ordinary time, always computed for the time zone with the greatest lag, is increased by a number of units equal to the rank of the time zone (depending on the particular above-mentioned series). Thus, the home port data, even  
10 though it is not supplied in the normal mode underlies providing the current time and date data of the home port location, that is the hour information provided in the normal mode. However without leaving the normal mode, it is possible to provide briefly, by means of the centre display line of the watch the time, not at the home port location but at  
15 the present location in the operational register. To that end it is enough, when in the normal mode, to exert long pressure on the left centre button BPM' which, in the panels mode is used to change locations and which, in this instance, as long as it is pressed longer than the first second, causes the displayed replacement of the home port location  
20 by the location contained in the operational register. This provides a convenient way of always knowing and without other actuations of the watch what time it is in an important location, for instance in New York for a Swiss businessman having interests in New York or in Cairo for an  
25 Egyptian resident of Hong Kong.

We have roughly seen the role of the eighteen command means in the normal RN mode and the I RTI panel mode. However the purpose of pressing twice on the upper left BPH button has yet to be discussed. In the normal mode pressing twice causes the preparation of the special panel I mode and  
30 then, where called for, its release etc. This is denoted by a short stroke at the top left, as shown in Figure 2 at C12. In the panel I mode, pressing twice has only one effect, namely to suppress the special

57

panel I mode to return to the normal panel I mode. Moreover, pressing twice in either of the panel modes and when all the displays are at the second cycle position (HS, HT, AS), will cause the return of all displays to the first position (EH, FHL, DT). When not all the displays are in the second position, a first double pressure on the upper left button brings them back to the second position and the next double pressure returns them to the first, etc.

In addition, the role of double pressure on one of the right-hand push buttons in the panels mode and in the STT panel transfer position remains to be discussed. Such a command induces a "memory-recall" of the data displayed on the line in question. The term "memory-recall" designates feeding data previously memorised into the corresponding operational register, the operational time, date, AS azimuth and HS sun height registers, all comprising an auxiliary memory from which at any time the desired content may be retrieved if desired. The write-in for the auxiliary memory of the registers is possible only in the panel II mode as explained later. The memory recall on the other hand applies to both panel modes provided the situation is one of transfer into STT panels (denoted by a double arrow at the bottom right). It will be remembered that the special panel I mode (RTIS) is similar to the panel I mode except that the automatic alignments do not occur. If then with this special mode in effect a monobloc call for instance is made, the solar elevation data will be written on the upper line, but the two data of time and azimuth will not be realigned.

It is also worth noting that the panel I mode allows introducing unacceptable values. For instance as shown at C15 in Figure 2, there may be no solar azimuth 232.7 (measured from the north towards the east) for a latitude 6.4° south if during the summer. This is so because at such a latitude and during the summer months (May, June, July, August) the sun remains day and night in the northern hemisphere and its azimuth will never be between 90° and 270° but always on this side of 90° or beyond 270°. In the case illustrated at C15 in Figure 2 the watch detects the

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information is impossible to process and indicates this by flashing the two lower vertical segments which are at the extreme left on the upper and lower lines as indicated by the dotted lines in the field C15 of Figure 2. Other possibilities of "operation impossible" or "banned" exist and the watch translates all of them into these two segments flashing.

When in the II RTII panel mode, the functions of the left-hand buttons remain the same as for the panel I mode (except that pressing twice on the upper left button can no longer call up the special mode I as its effect at this point is inexistant in the RTII mode; however its assembling effect in position I or II of the display cycle is just as active for the II RTII panel as for the I RTI panel. Regarding the right-hand buttons, their functions differ from the panel II mode. First, in this panel II mode, there is no automatic readjustment between the three variables "time" (HT), "solar elevation" (HS) and "solar azimuth" (AS), the date and the time acting as parameters but in this panel II mode, all values can be written in and corrected at will without mutual realignment. On the other hand, it is possible in the panel II mode to search on the basis of solar azimuth AS and elevation HS data at a given instant not necessarily but advantageously known. In this panel mode, three searches are possible, namely the date search RD, the laltitude search RL, and the date and latitude search RDL. When the latitude is assumed known, the date search permits calculating the effective date on the basis of solar data (AS, HS). This date search is triggered by brief pressure on the lower right button. The latitude search RL allows, the date being known and accepted as exact, for searching for the latitude on the basis of solar information. It is triggered by means of brief pressure on the right centre pushbutton BPM in the panel II mode with the operational situation in panels STT. Lastly the search for date and latitude RDL is commanded by means of brief pressure on the BPH push button in the RTII mode and in the operational situation in STT panels on the basis of two solar data, both the date and the latitude being assumed unknown and have to be found.

59

Regarding this last search, initially the first data "HS, AS" is established on the upper and lower lines, whereupon these two values are stored (in a manner explained later) and the HS and the AS values of the second data are introduced, whereupon the upper right button is briefly pressed. If the centre line then displays the time zone and the latitude, the latitude of the location where the data were taken will be automatically marked. Otherwise it will be present waiting only for the display of the latitude to appear. The date is processed in the same manner. It is worth noting that once the azimuth of the second data has been introduced on the lower line, it is possible to display the date on this line, the azimuth present but not displayed being similarly used for the search. The formulae used for the various alignments and searches are contained in the computer which will be discussed further later, in conjunction with the discussion of the internal watch circuits.

For the II RTII panel mode in the operational situation in RTT panels double pressure on a right-hand button causes a memory recall similar to the case for the panel I mode. Long pressure of these buttons causes data displayed on the corresponding line to be stored to the extent such data can be stored. The values of sun elevation HS, operational time HT, operational date DT and solar azimuth AS can all be stored in an auxiliary memory of the corresponding register. The values of time deviation EH and of time zone latitude FHL, which together are the location data, can be stored in the three location memories LOC A, LOC B, LOC C, to the extent that simultaneously the two data, EH on the upper line and FHL on the centre line, be present. When this is the case, long pressure on the upper button BPH establishes the choices between the location designations to be resupplied into location data, that is between LOC A, LOC B, LOC C and long pressure on the centre right button BPM causes the transfer to this location of the location data displayed up to that time. In this manner it is possible, after a certain location has been established, for instance by a latitude search, to store this location for example in LOC C or LOC A.

Regarding the date and/or latitude searches, after it has found the date and/or the latitude, the watch determines at which time this information should have taken place and whether it was carried out at a longitude corresponding to the EH value contained in the watch with respect to the centre of the time zone shown in the watch. If the watch shows an hour close to that which was effectively read as the current time at the time of gathering the information, it means that the EH value and the initial longitude are correct. If there are differences, the longitude position is incorrect which then can be reestablished by an EH search. This is done by bringing the EH display back on to the upper line and in writing in on the centre line not the time computed by the watch but that at the moment gathered. Within the watch the local times register keeps the time computed by the watch. Brief pressure on the upper right button BPH causes a time search EH, i.e. causes the watch to store a time deviation such that the local time stored within the watch (but displayed nowhere) does indeed correspond to the official time displayed and determined at the same time as the solar elevation and azimuth for position finding. It is clear then that if an EH of approximately 6 o' clock is obtained, it is proof that the correct time zone is not on the watch and that the time zone will be so corrected that EH be next to 0h or 1h.

An EH search may also be carried out, not following a search or alignment operation but after positioning the local time register by the official time, which is implemented automatically when official time is stored. Regarding the other conditions, an EH search is not required. It is worth noting that if the EH search were to result in a time deviation exceeding 7h, this would be reflected by a banned operation flash whereafter it would be necessary to use the antipodal time zone and start the operation again. It is also worth noting that with reference to date or latitude searches, it is possible to introduce fictional data into the watch corresponding to no latitude and no date. In this case the watch itself detects these fictional data and provides an "inadmissible" indication as shown in Figure 2 at C36. As a matter of fact, there cannot be an azimuth exceeding 180° when the sun is rising, in this

(91)

instance the sun is still at an elevation of  $-3^{\circ}$  and the watch, having considered that one of the data is a morning data while the other is an afternoon data, refuses to undertake this impossible search and indicates this by the flashing shown in dotted lines on the screen C36 of Figure 2.

5 As regards the LOC selection where the place inscription must be made, it is indicated by flashing dots which otherwise show the location controlling the operation, that is one flashing dot for LOC A, two flashing dots for LOC B, (as shown in Figure 2 at C34) or three flashing dots next to each other for LOC C.

10 The watch functions as they look to the user have been shown almost in totality. Presently the internal structure of the computer watch will be considered. In the course of these explanations, certain external functions, so far not mentioned, will be considered, either in relation to the discussion of the drawing or in the drawing itself. Figure 3  
15 shows how the various watch circuit groups are subdivided. However, the subdivisions of the drawing being approximate, the interdependence of the circuits making it possible to place them precisely in one group or the other. In general, the watch is provided with a double integrated circuit, i.e. an integrated circuit in two parts, one comprising  
20 approximately what is shown in Figure 4, 5a, 5b and 6 and the other in the form of a microprocessor comprising the desired components to implement the programs symbolically shown in Figures 7a, 7b and 7c. The integrated circuit may be either a large-scale circuit comprising one part of the type "LSI clock" for the components other than the computer  
25 and the other part a "microprocessor" for the computer or a two-level integrated circuit, one for one part and the other for the other part with numerous interconnections however made directly on the double integrated circuit. As a variation, two separate integrated circuit chips may be provided with multiple interconnectors of the mille-feuille  
30 type automatically ensuring proper connections provided the two integrated circuits be sufficiently precisely superposed.

92

In figure 4 we see a quartz crystal oscillator Osc, a type known in itself, feeding a frequency divider. This frequency divider feeds a clock circuit generating all the pulses needed for the watch operation in the proper time relations. This clock circuit in particular generates second pulses for the operation of the current time counting circuitry. These second pulses are sequentially counted in a second counter, a minute counter, an hour counter, followed by a binary A/P counter, a date counter comprising a counting means for the number of days, a month counter and a year counter in an annual cycle (Ancy) for the leap year cycle. The date counter automatically sets up the count of the day of the month as the number of days as a function of the month and as a function of the year for February. The date counter is followed by an "1 GREG" counter counting an 11-year cycle for the "Gregorian corrections" affecting the precise time of the spring equinox. In this respect it is known that the Gregorian calendar, which skips three leap years in 400 years, advances the precise spring equinox time with respect to a leap year (a respective shift of 6, 12, 18h for the three years) by about 2h every 11 years. The "11 GREG" counter provides two pulses every 11 years which update an adequate memory contained in the computing part. Lastly, the counting chain for time comprises a days-of-the-week counter with a seven-cycle and receiving one pulse a day like the date counter. All these counters are shown in the upper part of Figure 4. In front of each counting stage we see a stage denoted T which receives the clock pulses, the correction data for the next counter and also data reporting a backward correction situation. These stages set up the appropriate time relations for the transmission of pulses to all the counters which are synchronous. The clock signals are based on periods precisely 1/8 of a second and which due to binary division comprise 128 periods of about 1 ms (1/1024 sec precisely). These "ms" themselves divide into " $\mu$ s", this unit being the operational scale for a computer. The first of the 128 ms is set aside to implement various circuit conditions for the various functions. The following ms cover the transmission of the normal advance data for the ordinary time counting chain. Thereafter the corrections applied by each preceding stage T to each counter are implemented, i.e.

during the third ms or during the fourth ms depending on whether a forward or backward correction is involved. The counters of the current time counting chain are bidirectional and inherently forward counting. They receive information (the input shown on top of the counters in Figure 4) whereby they pass into the backward counting position during the fourth ms where there exist simultaneously the normal RN mode (permitting the current time counting chain to be corrected), the backward correction position SCAR and the certification that a correction is in progress (CEC). In this case, the corrections will act backwards, no matter what they are. The fact of making the counters pass into the backward counting situation only when absolutely necessary avoids having very many switching operations that for most cases would be superfluous anyway. Such synchronous counting chains have been sufficiently described and therefore there is no need to discuss them more comprehensively. Regarding the "11 GREG" counter, the four weighting bits 1, 2, 4 and 8 and the gates combining them to obtain a positive pulse for 0 to 1 and 6 to 7 transitions are shown and for the case of counting backwards, a negative pulse for 1 to 0 and 7 to 6 (COPEQ pulses).

In Figure 4 the time zone FH' data (starting at 0 at time zone 12, which is the most retarded is applied to a static adder receiving the hour information. The hour information, which initially was set up for the most retarded time zone, therefore is advanced in the desired degree to provide the time of the time zone under consideration. It was noted that there are time zones 12', 13', 14' which as regards the count starting from the time zone 12 respectively provide 24, 25 and 26 hours advance. The FH' data is a twelve cycle plus a weighting bit 12, plus a weighting bit 24. Therefore on occasion there may be two instead of one addition carry. They are fed to incrementing stages which increment by one or two the data of date and day of the week. These incrementors, just like the adders are of known type (they consist of three input stage adders, one weighting output identical with the inputs and one weighting output double that of the inputs), however preparation circuits P being

94

required for these incrementors in view of the cycles of the days of the month and days of the week being shortened by a power of two. For instance the days of the week counter is an octal counter (0 to 7) designed so that the position 1, not 0, automatically follows position 7.

5 When one or two units must be added to the position 7 or when two units must be added to the position 6 a third unit must be added so that incrementor also skips the position zero. The P stage for the incrementor of the days of the week therefore is an ordinary "three inputs-two outputs" adder furthermore comprising a gate admitting the  
10 input from the counter 7 position only when one of the other two inputs (adder carry) commands an increment of one unit. A similar design is present in the preparation stage P of the date incrementor; the latter receives adequate commands from one of the positions 28, 29, 30 or 31 depending on the length of the current month.

15 The hour and date set-up as just explained offers the advantage that when increasing the information of the time zone to be considered, the hour information automatically advances, the time therefore always remaining adequately retained.

On the left in Figure 4 we see the memories for data LOC A, LOC B and  
20 LOC C. These memories are fed by means of gate-circuits allowing location output data to be introduced under the respective commands mmLA, mmLB and mmLC. The drawing shows blocs in the middle of which is represented a double ET gate (forming a B where vertically arranged) and which are ET gate circuits with a plurality (as many as needed to  
25 transmit all the required bits) of ET gates, all controlled by the input of the gate circuit. The location data output is provided by an arrangement of selection gates formed by two complementarily controlled ET gates followed by an OU gate. One of the ET gate circuits passing into the RN normal mode and possibly at the beginning of the RT mode,  
30 transmits the LOC A data (home port location), while the other, conducting when the first is not, transmits the location data from an operational location counter (CTlieu). We see therefore that provision

is made for various gate circuits and connecting input circuits allowing this location counter to assume independent values or also to align itself with one of the three LOC or again to detect data from the computer ( $EH_r$ ,  $L_r$ , ( $\lambda_r$ , Latt.)). The computer processes the data from the transformed time zone (0 west of Alaska, 12 at Greenwich). On the other hand, the display shows the time zones in the conventional numbering. To that end, the data FHaff is obtained by directly transmitting the bits 1, 2, 4, 24 of the time zone signal and by transmitting inverted the bit 12 of this signal.

Figure 4 also shows an hour counter for panels (CT HT) operation and a date counter for panels (CT DT) operation. Here again a system of gate circuits similar to that described for the locations and at once understood by a person skilled in the art in relation to Figure 4 allows these counters to have their contents synchronised with those of the current time counter or to have their proper value which is either drawn from the auxiliary memory (amHT, amDT controls) or obtained from corrections or due to alignment with data from the computer (UHT, UDT controls). Storage is also assured by adequate command signals acting on the gates.

Figure 4 furthermore shows the solar azimuth values (CT AS) which may be aligned by memory recall, by correction or by implanting the contents from the computer (from two of its sites,  $AS_{r1}$  and  $AS_{r2}$ ). It is worth noting that the information about the backward correction SCAR is applied not to the command stage T but directly to the counter in order to set the desired count, for all the operational elements which need not ensure the advance of the ordinary time simultaneously with the corrections.

Again Figure 4 shows the operational counter for the solar elevation (CTHS). Whereas the azimuth counter counts from 00.0 to 359.9 and always in positive values, the solar elevation counter counts in tenths of a degree from 0.0 to +90.0 and -90°. Also this solar elevation counter is associated with an SHS counter (HS sign) operating in hexacycle for the

six symbols "h", "h", "H", "h", "h", "H", allowing to recognise the various segments of the solar path. The arrangement of the sun elevation counter is similar to that of the solar azimuth counter, except for the SHS part (also present in the joint memory) providing data  $\oplus$  which distinguishes the "h"; "H"; "h" from the "h"; "H"; "h" group and also the A,M,P information (ante meridian, meridian, post meridian in English) bounding the path segments in the east (h,h), the two meridian positions (H,H) and the path segment in the west (h,h). This six-position circuit SHS can be reset by a large number of data (SHS<sub>r1,2</sub>...  $\oplus$   $\ominus$  and by a data SHS<sub>r AMP</sub>). Also the reset  $\oplus$ ,  $\ominus$  affects the SHS part of the memory; this is the only case for the watch where an adjacent memory receives external commands other than the setting for normal memory.

To be aligned, the solar elevation counter CT HS receives two distinct data from the computer HS<sub>r1</sub>, HS<sub>r2</sub> and it also receives the six monobloc commands: "dawn", "sunrise", "noon", "descent", "sunset", and "dusk". Every time and by means of connections internal to the counter, the desired sun elevation position (for noon, the position SHS=H) is set in a manner equivalent to what would be obtained otherwise by step by step value corrections, i.e. a much more laborious procedure.

The circuit of Figure 4 also comprises a local time register REG HL which only receives data from the computer and provides it with them; it is worth noting that this register is so designed that it will supply the computer (and receive from it) on the one hand the hour and minute information in hours and minutes and on the other hand this information is transmitted in the form of angles (15° for one hour, 1/4° for one minute). Figure 4 also shows a flip-flop providing data, (SD\*) distinguishing the possible dates when a search is underway. Moreover, another RS type flip-flop is provided which is made up of two gates, receives data R<sub>d</sub> and R<sub>d</sub> and provides an R<sub>d</sub> data where this information, coming from the computer which uses it in some cases and being displayed jointly with the time information when presented, indicates that the time found is not that of the particular day in question but of the solar path.

for the day in question wherever this distinction is required by a significant time deviation EH. This case is illustrated at C16 in Figure 2. Here the sun at perigee position was sought. By definition the day begins at perigee, local time 00h 00 and ends just before the next perigee, local time 23.59. In this case, the sun passes perigee at 21.0° below the horizon (northern country on 19th June) and if the shift were zero, the official time 00.00 would be obtained in harmony with perigee transit. The place considered being located 36 min east of the time zone centre at the official time at which it is, this perigee transit takes place at 23h 24 (11h 24P in the US notation used here) and this is 11h 24 pm on 18th June and not on 19th June in spite of the indication on the bottom line. This distinction is provided by the lower vertical bar to the left of the centre line (never used to indicate hours in this manner). Its activation is provided by the  $R_d$  signal seen at the bottom of Figure 4. It is worth noting that for a conventional 24h display the discriminating mark in question might be placed to the far right as the A/P indication would not be required.

In Figures 5a and 5b we see to start with six circuits of input push buttons with the same designations as the push buttons of Figure 1. Internally these circuits all comprise the arrangement shown in the diagram of Figure 8. This logic diagram, easily understood by a person skilled in the art and ensures absolute discrimination between the three LP controls (long pressure), CP (short pressure) controls and DP (double pressure) controls. It allows as we see an interlock by six VM lines, one determined by the circuit and the other five controlling it in such a way that no matter what there can never be two input circuits simultaneously delivering a command. In principle the first push button that is actuated has priority; in the case of an absolutely simultaneous actuation, a cross locking would take place which would merely prevent both commands from being carried out. In Figures 5a and 5b the interlock is shown by a line in bold type connecting six similar circuits, each feeding one of these six lines and receiving the signal from the five others. At the input of the circuit control a flip-flop prevents any

mechanical chatter from the mechanical push buttons. An output  $FS_1$  "Q" is used for the commands, as for instance the display of the time in another location, as previously considered which requires prolonged pressure of one push button.

- 5 The circuit receives a clock output of 8Hz and discriminates against this kind of pulse for eight steps of this clock output and delivers the desired command just after one second.

Figures 5a and 5b show separately and correctly so, the three control outputs CP, DP, LP for each of the six push button circuits.

- 10 Using conventional graphics for gates and flip-flops, Figures 5a and 5b will be easily understood by an electronics person skilled in the art. Figure 5b shows the selection of the modes RN, RTI and RTII and also the selection of non-correction, forward correction, backward correction and panels operation situations. Figures 5a and 5b are again arranged in
- 15 summary form by display line and it is seen that the left push buttons deliver pulses  $\beta_1, \beta_2$  and  $\beta_3$ , which in the correction situation suppress a signal output LB1, 2, 3 that indicated that this line was free of correction. In this case, an overall signal LB, denoting release, vanishes to be replaced by a general signal CEC (bottom of Figure 5)
- 20 indicating "correction in progress". It is easily understood in the light of the set of gates and flip-flops how a short pulse on the considered line terminates the correction mode and reestablishes the clear condition. A similar circuit CIBL1, 2, 3 implements the acknowledgement of the corrections on each line, only one internal
- 25 arrangement of such a circuit being shown, the other two being identical. Figure 5a also shows how the LB function, or its inverse CEC, acts to restrict the choice of modes and to maintain only the SCAV and SCAR correction positions in conformity with the above. Lastly the functions of the circuit of Figure 5 consist in providing the display commands in
- 30 conformity with the display cycle previously indicated. An additional control cq, cq is provided when the push button controlling the change in

mode is kept pressed more than one second. The purpose of this control  
cq will be further explained later in relation to the computer operation,  
as it deals with the redetermination of the equinox time data. A set of  
flip-flops and of gates at the bottom right of Figure 5 also functions  
together with certain computer circuits the operation of which will be  
explained later.

Looking at Figure 5a, it is easily understood in which circumstances the  
various commands are issued and it will also be seen, mainly in relation  
to Figure 6 and also Figure 5b, what the purposes of these various  
commands are.

Figure 5b represents the arrangement of the nine different commands that  
may be issued by the three right push buttons. The diagram mainly covers  
ET gates and clearly shows how these commands are arranged as a function  
of the SC correction position or the operation STT panels position, the  
same in terms of the RTI and RTII modes and again for the display modes  
which are controlled by the commands from the circuits of Figure 5a. The  
various commands are denoted by their names on the left of Figure 5b and  
relate either to the overall diagram of Figure 4 or to the general  
command diagram of Figure 6, certain commands being applied to the  
circuit components of Figure 5a.

Figure 5b also shows a certain number of commands joined by OU gates; the  
resulting signals are mainly applied to points of the control circuits of  
Figure 6 to desynchronise the operational date and time and the place.  
The six commands "DAWN", "SUNRISE", "NOON", "DESCENT", "DUSK", are joined  
in one signal "MONO" which in particular acts on the two flip-flops shown  
at the top of Figure 5a to ensure the display of the sun elevation on the  
first line.

It was seen that in conjunction with the external operation of the watch  
for corrections, a short impulse acts on the first main digit to the  
right, a long impulse acts on the first main digit on the left (just left

(100)

of the two display dots) and a double impulse acts either on the decade digit (located just right of the two dots) or on the auxiliary digit which as a rule, stands for tenths. For instance, regarding the correction of the data "time zone, latitude", a short impulse acts on the digit of the units of latitude degrees. A double impulse acts on the command of tenths latitude degrees and a long impulse acts on the units of the time zone if the first one to take place since initiating the corrections, otherwise it acts on the digit of the decades of degrees if previously the units and tenths of degrees have been corrected. To that end, a PDC circuit shown at the bottom of Figure 5b in detail is used, which splits the correction command by a long impulse in the manner indicated above. The diagram within the PDC frame is easily understood, an RS type flip-flop formed with two inverted OU INVERSE gates, (passing into the operational position a short impulse or a double impulse is sent and returns to the rest position during release taking place when all the corrections have been acknowledged, switches the long pulse control either to the decades (second main digit from the right) or to the following digit (in the case of azimuth, the hundreds of degrees, in the case of time zone and latitude display to the units of the time zones).

We also see that the RDL command, date and place search can only be implemented if, considering that the watch is in the panel II mode, both storage of the sun elevation HS and of the solar azimuth AS have taken place, which is done by the set of gates appearing at the bottom right in Figure 5b.

In addition, the REH command to search for time deviation can only take place if the last setting of the register of local time HL was made from the computer, or else if a storage of the local time (mmHT) was previously carried out. This is carried out by the set of gates shown at the bottom centre of Figure 5b.

We will now consider Figure 6, which shows the overall control of the watch and mainly of the computer, also the display control. At the top

left there is a set of three flip-flops and of different gates which ensure date synchronisation and desynchronisation as already discussed. A similar set located just below ensures time synchronisation and desynchronisation, (in the panels mode). This set issues a TPDT signal for the date and a similar TPHT signal for the time whereby at the beginning of the panels mode, the time and the date coming from the time counting chain are maintained in order to operate the computer if necessary (determining the sun elevation and the solar azimuth at the present instant). A similar tPDT signal for the date and tPHT signal for the time reestablishes the date and time synchronisation but in this case by the intermediary of the operational register for the date and the time. It will be noted that the maintenance of the date and time data directly from the counting chain at the beginning of the panels mode will be assured only if in preceding normal mode the non correction position SNC was jointly present so that three flip-flops denoted respectively 61, 62, and 63, passed into the operational state. If this was not the case, that is, if there was transition from the panel II mode into the panel I mode by the intermediary of the normal mode but in the correction position, the panel I mode is directly re-established by the date, time and place data from the operational registers. It will also be noted that the first desynchronisation, reactivating the operational registers, will be immediate in the event of a memory recall for the time or a memory recall for the date (amHT, amDT), or if a computer operation makes the operational date and time register assume a particular position (impulses UDT or UHT), on the other hand if the desynchronisation is due to an attempted date and time correction, there will be no other effect than the desynchronisation itself but without correction. This is necessary because the first desynchronisation modifies the display in question and to implement a correction the initial position must be known. To that end the signal to move the operational register return flip-flop is applied to the flip-flop input by means of one OU gate of which the other received a Fip signal which takes place only at the end of the process. The top left of Figure 6 also shows the arrangement of gates which in the panels mode causes the display of the symbol "p" or

"o", indicating that the date or the time is synchronised or desynchronised. Towards the centre of Figure 6, on the left, a cascade of four flip-flops controlled by the location changing pulse CML and accessorially by the Dip impulse occurring at the beginning of the process and by the Fip impulse occurring at the end of the process establishes the commands LA, LTA, LTB, LTC controlling the call for the location data stored in the memories LOC A, LOC B, LOC C. The structure of the gates shown easily demonstrates how this flip-flop cascade works. Below, four ET gates, one OU INVERSE gate and one OU gate determine the excitation of the dots u, v, w and x, arranged in a triangle which indicate the situation of the location as indicated previously. To the right of these gates, a three flip-flop cascade allows the selection of a LOC memory to introduce into it location data. Obviously this will be possible only in the panel II mode, the three flip-flops being mandatorily reset to zero in the normal mode RN and in the I RTI panel mode. The command "mmLOC choix" allows choosing one of three flip-flops and by means of it one of the three LOC memories and thereafter the command "mmLOC act" implements the entire location data displayed in the selected memory. By the intermediary of OU and ET gates, these same flip-flops ensure the flashing of one dot, two dots or three dots at the time a memory reset is possible in LOC A, LOC B and LOC C respectively.

The main function of the circuit shown in Figure 6 is to control the general and individual computer programs. A certain number of IPS circuits (single) and IPD circuits (double) the internal design of which is shown in Figure 6 reshape different signals that then are connected by an OU gate and cause the realignments in the panel I mode to the extent that there is no corection in progress (signal Lb) and there be no special panel mode (signal  $\overline{\text{RTS}}$ ). As can be seen, these IPS and IPD circuits deliver a command which in the case of IPS, depending on the positive or negative case, begins with a jump of the signal applied to the circuit input and terminates at the next Fip pulse and which in the case of the double circuits IPD begins at the next Fip pulse and terminates at the one thereafter. Due to this design every time a

realignment with respect to the panel time HT or the solar azimuth AS or solar elevation HS must take place, a signal appears at one of the three inputs controlling the general program CPG1, CPG" or CPG 3 of the program control block. The selection of these three inputs is carried out by a set of three OU gates and of three inverted OU INVERSE gates shown at the top right of Figure 6 and which switches the signal from the big fourteen-input OU gate to one of the three inputs previously indicated as of the program control as a function of the last correction or memory recall operation which took place, whether with respect to the time, the solar azimuth or elevation. This constitutes the program control in the panel I mode.

In general, in the panel II mode, the search commands RL, RD, etc., directly actuate IPS circuits which in a variation might be bypassed and provided that no correction is in progress and that indeed the mode be panel II, pulses lasting about  $1/7s$  (until the next pulse Fip) are applied to the inputs CPG 4-10 of the program control.

Depending on these input commands, the program control sends pulses which actuate the different elementary programs of the computer. The program control also emits pulses at the end of a general program ordinarily comprising a plurality of individual computer programs, a pulse U (UHT, UDT...UHS2) which, as seen in relation to Figure 4, causes the recordal of the data obtained by the computer from the operational registers corresponding to the data obtaining circuits of Figure 4. These controls have still to be discussed in detail in conjunction with the computer operation.

The bottom of Figure 6 also shows the display which in this case is of the "segments/lines" multiplex type. This multiplexing type is known, each line comprising 37 segments including the two dots and each of the three lines in turn may receive a drive voltage on the selected segments; in this manner the number of connections with the display is substantially reduced. The principle is known, the rear electrodes of

(104)

two lines out of three are at zero voltage (see bottom right of Figure 6), whereas the third line is at a voltage  $S_{+-}$ . As regards the segments, either selectively the same voltage  $S_{+-}$  is applied to them, in which case there is no drive or the potential  $S_{+-}$  (see bottom right of Figure 6) and then the corresponding segment is driven in that line from which the zero potential is absent. The  $S_{+-}$  potential, instead and in place of the zero potential is cyclically permuted at a high rate on each of the three lines while the multiplexer circuit MPX Segm selects the data for the corresponding line (upper, centre, lower). It is clear that many other multiplexing systems can be used. Then multiple gates then transmit the data selected by the circuits of Figure 5a (same notation as the data, but small letters, for instance  $s_{+js}$  to command the display of data  $S_{+JS}$ ) on each of the lines. In the watch being described, one decoder per data was chosen, taking into account that the data present a certain apparent disparity. It is obvious that also a single decoder might be anticipated, though relatively more complex, at the input of the multiplexing display command.

As was seen during the explanations concerning the overall external operation of the watch, flashing will be required in some cases. Such flashing applies to the corresponding decoder, in the matter shown in Figure 6. It will be noted that in the normal mode and also in the screen mode with synchronised hours, the two dots flash between the hour and minutes information. On the other hand they are constant when a non-synchronised time is involved. The command "flashing, no flashing of the dots" is supplied to the HNHT decoder for hours on the centre line by a signal from an OU gate at the inputs of which are RN, TPHT and tPHT signals.

As regards the data, the year indication (0, 1, 2, 3) will be provided only in the correction solution or else in the panels operation situation in the panel II mode. This is ensured by an adequate signal applied to the date decoder.

The "Clign 1, 2, 3, 4" signals cause the AS data and in some instances the date, the time deviation and the sun elevation data to flash in various manners as was seen in relation to Figure 2. These signals are properly applied to the decoders. A general flashing signal CLIGN from the clock circuit is applied to all the decoders which must flash under certain circumstances.

We will now consider, in relation to Figures 7a, 7b and 7c, the operation of the computing part. As a rule except for several OU gates and two logic circuits (LOG.A.M.P., LOG.PREP.), all of the computer operation can be explained by acknowledging that it is a microprocessor. These being the conditions, no concrete components carrying out operations are shown, but instead program-blocs performing various operations upon command from programs stored at various locations in the microprocessor and each time causing the operation of the same central processing unit for the most diverse mathematical and logic operations and data processing. In an overall way, each program block comprises a vertical frame representing the data input (input interface), a frame denoted "PROCESS" and which comprises arrows symbolising data processing, one or several inferior frames in its length symbolising program data for the operations (addition, multiplication, comparison, etc.) and a certain number of frames sometimes individually subdivided and at the same level as the "PROCESS" frame which symbolise the output data after processing which shall be stored in buffer memories for possible different uses for the desired duration, that is at most a general program. A certain number of individual programs are shown in this manner. It is worth noting that Figures 7b and 7c show several individual programs bordering on one and the same input interface in order to simplify the drawing as much as feasible. All the individual programs carry an individual notation. Except for the special case of the programs PSEQ1 and PSEQ2, all the general programs comprise a plurality of individual programs. Among these a certain number are preliminary programs PPR1 to PPR6. The selection of the preliminary necessary programs is directly implemented in the program control (Figure 6), while on the other hand the various

100

general programs each include thereafter their own series of controls and as regards the subsequent elementary programs, certain controls of different general programs are combined with the help of gates in a manner symbolised in the diagrams of Figure 7.

5 Before considering the main computer programs, it is only proper to discuss the data determination program COREQ. To be able to compute solar data, the computer must in particular know the dates, not starting on 1st January but from the instant of the equinox (the Spring equinox was chosen). However, besides the fact that with respect to the instant  
10 there occurs a leap year, the equinox falls back by 6, 12 and 18h respectively, during the following years, the equinox instant itself related to a leap year lags approximately 2h every 11 years. Moreover it is necessary to write in the equinox data "REGISTRE COMPTEUR MEMOIRE COREQ" (COREQ memory counter register) and this in a convenient manner.  
15 To that end the elementary COREQ Program has been created which for the input data requires indication of the year (0, 1, 2, 3), the day of the month on which the equinox takes place (presently on the 20th or 21st of March) and either the time zone within which the equinox occurs near noon or GMT (Greenwich Mean Time) at the precise instant of the equinox  
20 (minutes may be ignored). Once these data have been entered in the watch, the PSEQ1 program must be engaged if the noon equinox ( $FH'_{eqmid}$ ) time zone was introduced or the PSEQ 2 when the GMT equinox ( $HGMT_{eq}$ ) was introduced. To that end a command for passing from the panel I mode into the panel II mode must be effected, keeping the upper left push button  
25 BPH' pressed more than one second and then, while this button is still pressed, as the indication of panel II appears, the push button opposite BPH must also be pressed. This is the purpose of the cq signal (and non inverse  $\overline{cq}$ ) which was mentioned in relation to Figure 5a. Figure 5b shows that pressing the right-hand button in question for a long time in  
30 the presence of the signal cq sets up either the REQF or the REQH command depending on whether the display command is that for the time or for the time zone. These commands are channelled through a circuit IPS in Figure 6 and result in command signals CREQH and CREQF fed to two programs

(107)

selectively providing the COREQ data. Once the program has calculated the COREQ value, in turn emits a pulse causing the recordal of its data in the "REGISTRE COMPTEUR MEMOIRE COREQ" (COREQ memory counter register). From that time on, this memory register advances the time by one hour every five or six years, more precisely by two hours every 11 years.

The COREQ data is data on the time in hours from the time of the equinox instant of a leapyear to the first hour of 24th March in the most retarded time zone and it is evident that this time is always positive, its value increasing as the equinox instant lags. This COREQ value will then be combined with the time zone indication and then, in a later program, with the Ancy year data in order to obtain a date determined in quarters of a day from the equinox instant.

The drawings of Figures 7a, 7b and 7c clearly show the data circulation between the different computer programs; it will be noted that the circulation of the multiple data is shown by a thick line while the information comprising only a single bit (a single conducting wire) is shown by a thin line.

As a rule, the data first require to be converted before being amenable to processing; this is the purpose of the preliminary programs, most of which are shown in Figure 7a. This is followed by the processing operations proper to determine for instance the sun elevation and the time as a function of the azimuth at a given date and latitude, or to determine, for example, the latitude in terms of a given sun elevation and azimuth at a given date. To the extent possible the various data are directly entered in the diagram of Figure 7c, however the very nature of the programs carried out will be the subject of a table listed below.

It is worth noting that it is very important to know whether the sun positions are of the morning or of the afternoon, namely eastern or western positions, or also meridian positions. This is established by the AMP logic for each of the six general programs CPG1-CPG6 which

108

require this AMP discrimination. As regards the searches, where the two data of sun height and azimuth are used as the input, the AMP logic must check that the two data are in fact on the same side. If this is not the case, it will reject the Rposs data which indicates the search is possible. On the other hand, regarding the alignments, the A.M.P. data is taken from base data (time, azimuth, elevation) and superposed on the other two parameters.

It is worth noting in particular that the P4 program is likely to recognise that a solar elevation, given as of the morning or of the afternoon, may correspond to the maximum and minimum elevation; in this case a pulse is transmitted to the SHS register to bring it into the meridian position. Different individual programs come into play; the P3, P3' programs in particular compute the solar elevation (by means of its sine) in the case where the base data is the non-meridian azimuth. But the base data "meridian azimuth" also may come from sun elevation data with the symbol H (maximum) or the symbol  $\bar{H}$  (minimum). In the case where one of these symbols is introduced, the solar elevation data need not be entered as this is taken care of by the computer.

It must also be taken into account that depending on the latitudes, at certain dates the sun passes north and south and at other dates constantly stays south or north. Consequently there may be two different solar elevations for the same azimuth. The computer always firstly indicates which is the higher one, but the display indicates that there are two elevations for the same azimuth by flashing the upper small stroke of the A of the azimuth data (C31, Figure 2). In these conditions, the deliberate elimination of the azimuth display (to replace it by the date) and its reappearance by implementing a cycle advance by brief pressure on the lower left button causes an alignment repetition but this time introducing the lesser solar elevation corresponding to this azimuth, most of the time a negative solar elevation. In such a case, it will be the centre horizontal stroke of the A indicating "azimuth" which flashes. A new and similar operation causes the higher

subtracted, but it is a question of "-(+1)". Also a logic magnitude with a bar at the top is an inverted logic value which will be 0 when the direct logic value is 1 and which will be 1 when the logic value is 0, there being no question of the -1 value.

5 Frequently there are ( $\dots\overset{+}{0}$ ) values in the programs, which are resolved into logic values. If the + is immediately behind the frame, a line starting from that point of the frame is considered bearing the logic value ( $\dots+$ ); if the line starts from that point of the frame where the - sign is located, it is considered bearing the logic value ( $\dots-$ ).

10 Furthermore it is worth noting that the data being moved towards processing are given with the sign d (data) whereas the data coming back from processing have the sign r (result, response) and if several data of the same nature come back from processing, there will be the signs r1, r2, (for instance  $AS_{r1}$ ,  $AS_{r2}$  for the azimuth data coming back  
15 respectively from an alignment operation depending on the solar elevation and from an alignment operation depending on the time).

The various partial programmes have been set up in such a manner as to ensure that there will be no uncertainty regarding certain values. For instance a solar azimuth computed from the time using solely sine  
20 functions becomes very imprecise when it is 6 o' clock, local time, i.e., when the sun is midway between perigee and apogee. The eight following pages will successively give the individual program indications with diagrams of Figures 7a, 7b and 7c; these programs will explain how the computer works. It is worth noting that, for the sake of economy,  
25 certain programs include variations denoted by ', even ". The signals applied to program frames at locations marked by a small square and a ' are not program control signals but program allocation signals modifying the program. Thus programs " ' " are often set up for meridian conditions, whereas the basic program is set up for non-meridian  
30 conditions. It is then data ( $M^+$ ) which controls the assignment " ' ". In some cases there are even assignments " " ", which however never come

(110)

understood how the  $E^+$  data is determined in the general CAS program, i.e., the "azimuth-based alignment command". In the CHS general program, i.e., the "sun-elevation based command", no such complex problems are encountered. There might of course be banned solar elevations (the sun never rises to  $80^\circ$  elevation at Berne for instance). Before discussing the individual programs in detail, it is appropriate to state which convention was adopted in denoting the values to be processed in some special cases.

A value denoted by one or several letters, or one or several digits, may assume all possible mathematical values. However there are values (directing bits for certain values) which can have no other value than +1, 0 and -1. These are mathematical sign values. To denote these, or to denote the part "sign magnitude" of a complete value, the parentheses include the value notation followed by three signs  $\overset{+}{0}$  just before closing the parentheses. Thus the value  $(HS \overset{+}{0})$  denotes the value corresponding to the sun elevation sign and equal to +1 or 0 or -1. Certain values, for instance the cosine of the latitude, may only have two of those three values, for instance the values of  $(\cos \lambda \overset{+}{0})$  values possible +1 and 0. There are also cases in which two of the three values are ranked alike with respect to each other and for instance  $(SMSN \overset{+}{0})$  will have a sign value of +1 when SMSN is positive or zero and -1 when SMSN is negative. If the zero and the + had been crossed, the sign value would be zero for positive values or zero of SMSN and -1 for negative values of SMSN.

In addition, there are logic values which by definition can only be 0 or +1. These are denoted by a letter with signs only at one level. For instance the value  $(U^+)$  is a logic value of 1 when U is positive and 0 when U is not negative (zero or negative). Moreover the value  $(U^-)$  is a logic value of +1 when U is negative and 0 when U is not negative. A three value sign  $(\dots \overset{+}{0})$  magnitude can be denoted by two logic magnitudes, namely  $(\dots^+)$  and  $(\dots^-)$ . The logic values are introduced without difficulty into mathematical equations, but they may never assume any other magnitudes than 0 and +1. If preceded by the - sign, they will be

(111)

azimuth to reappear and so forth. In the computer this determination intervenes in the logic preparation after under the command of pulse Clog (Figure 5a). The proper parameters are fed to the preparation logic which determines the cases when two azimuths are possible. It also  
5 determines the case of no azimuth existing for the indicated value, whereupon it emits the "PRO" (banned) signal. The formula for calculating the sun elevation includes a coefficient ( $E^{\pm}$ ) which may assume the value +1 or -1 and in some instances the value zero. The preparation logic calculates this coefficient. Near the equator and when  
10 approaching the equinox, the solar path may be uniquely an east-west path. In these conditions an azimuth other than  $90^{\circ}$  or  $180^{\circ}$  automatically results in the signal PRO. However a meridian azimuth,  $0^{\circ}$  or  $180^{\circ}$  does not cause the PRO signal considering that when the sun passes its zenith, it is assumed by definition to be at the meridian.  
15 Lastly if the sun's path is "east-west" and if the azimuth is  $90^{\circ}$  or  $270^{\circ}$ , the condition is indeterminate; this is a special banned situation which is detected by the preparation logic through the PROSP signal and which results in flashing of the whole A of the azimuth display. Furthermore it must be borne in mind that there are cases when the sun  
20 passes through its zenith (or through the nadir), which is the limit between a northern and a southern path and a path remaining either north or south. Regarding the azimuths other than 00, 90, 180 and 270 and with respect to the azimuth based alignment, the zenith value will be banned and only the other value corresponding to the azimuth will be kept, if it  
25 exists. If it does not exist (the sun then being on the wrong side), the data PRO exists. On the other hand, regarding the azimuth values 00 and 180, the zenith value is admitted and on one hand there will be two possible elevations, (one  $90^{\circ}$  and the other between  $-45^{\circ}$  and  $-90^{\circ}$ ) and the two possible elevations are displayed, while on the other hand only  
30 the zenith elevation may be considered. Similarly with respect to the 90 and 270 azimuths, the zenith value is indicated when the zenith path is not east-west; there are no other points on these azimuths.

The preparation logic diagram is shown in Figure 10 and will be easily

simultaneously into play with an assignment " ' ".

Some programs are split for instance into a program 5 and a program 5' depending on the latitude, in order to have shorter computations.

5 All of the computer logic is based on that view we would have of the observer viewed completely from the east or completely from the west, with the sun rotating about the earth, for the sake of simplicity. The solar trajectory takes place in a vertical plane if observed from the equator, in a horizontal plane if observed from the pole and in an oblique plane if observed between the two. At the equinox, this  
10 trajectory passes through the centre and at the solstice it passes tangentially to a circle of which the radius equals the sine of the inclination of the earth's axis. The effective solar trajectory does not take place in a plane that, when intersected offers a straight line but a very fine pitch helix. It is assumed to be a plane with the inclination  
15 modified at noon and midnight. In the spring in the northern hemisphere the line representing the solar trajectory under the above cited conditions is made steeper by  $\Delta\varphi$  in the morning, from 00h to 12h and made even steeper by  $\Delta\lambda$  in the afternoon, from 12h to 00h. As the solstice nears,  $\Delta\varphi$  decreases, is nil at the solstice and inverts thereafter. This  
20 is the reason the  $\lambda$  values (latitude) and  $\varphi$  (the complements to the angle formed by the earth axis and the earth-sun line become  $\lambda', \varphi'$  which are slightly modified in one direction in the morning and slightly modified in the other direction in the afternoon.

25 The pages containing the formulae below show the functions of the various individual programs and thereafter the distribution of the controls of the individual programs in the overall programs is indicated.

30 One notes that in order to avert indeterminacy at the north and south poles, the latitudes can only be set up to a maximum of  $\pm 89^\circ$ . The latitude registers in the LOC memories as well as in the operational locations register comprise locking means preventing counting beyond

89.0°. However the computer might issue values exceeding 89°. Still the input through the gate controlled by the UL pulse at the location counter is designed in a manner that any count exceeding 89, from 89.1 to 90.0 has the value 89 and moreover will change the state of a flip-flop which will modify the zero of 89.0 in the latitude display in such a way that it will be known that the latitude should be still higher. When this value is used as data, it will however be simply 89.0.

In the 89 position, the counter prevents any correction of the absolute latitude value, it does however release any lock against a lower count for this absolute value. For this reason the location counter receives the two data SCAR and SCAV. The other counters only receive the SCAR data because the corrections will be emitted only in the correction position and it is enough to distinguish between the SCAR and SCAV.

The overall programs may be composed in a different manner regarding the individual programs they launch. In all cases the results must be those indicated.

#### Individual programs

##### PSEQ1

$$\text{COREQ} = (24 - \text{Deq}) \cdot 24 - 12 + \text{FH}'_{\text{eqmid}} + (\text{Ancy } 0, 1, 2, 3) \cdot 6$$

Deq = date of spring equinox (March date)

$\text{FH}'_{\text{eqmid}}$  = (operational) time zone where the spring equinox is at noon

(Ancy 0, 1, 2, 3) = 0 for leap year; = 1 for next year = 2 for second year after leap year = 3 for third year after leap year

##### PSEQ2

$$\text{COREQ} = (24 - \text{Deq}) \cdot 24 + 12 - \text{HGMTeq} + (\text{Ancy } 0, 1, 2, 3) \cdot 6$$

HGMTeq = GMT at spring equinox

Deq, Ancy 0, 1, 2, 3: see PSEQ1

PPR1

5

BLOCOR (in quarters of a day) = (EHd - FH'd + COREQ): 6 (integral quotient)

BLOCOR (in hours) = remainder

PPR1'

= as PPR1 but EH always assumed to be 00:00

PPR2

10

HLG = (HTd - Ehd) mod 24 hours with positive (+) and negative (-) carries

PPR3

15

$D_{TRd} = [4 \times \text{BLOCOR quot} + 4 \times \text{date of month} + 120 \times \text{month} - (\text{Ancy } 0, 1, 2, 3,) - 114 \times 4 + (0 - 5 \text{ per ROM}) \times 4 + 4 (\text{rep. HLG}^+) - 4 (\text{rep. HLG}^-)] \dots \text{mod } 1461$

PPR3'

= as in PPR3, but (rep. HLG<sup>+</sup>) and (rep. HLG<sup>-</sup>) always assumed to be 0

PPR4

20

HLd' = (HLG - ES) mod 24 hours with positive (+) and negative (-) carries ES provided from  $D^{TRd}$  by DECODEUR  $D^{TR} \rightarrow ES$

115

PPR 5 and PPR 5'

for PPR 5:  $D_{TR}' = [D_{TRd} + 4 (\text{carry HLD}^+) - 4 (\text{carry HLD}^-) + (1/6) \text{BLOCOR} (\text{hours})] \bmod 1461 (\text{in } \frac{1}{2} \text{ day})$

for PPR 5':  $D_{TR}' = [D_{TRd} + (1/6) \text{BLOCOR} (\text{hours})] \bmod 1461 (\text{in } \frac{1}{2} \text{ day})$

5 the following operations are identical for PPR 5 and PPR 5' starting from  $D_{TR}'$ .

$\tau_d (\text{rad}) = D_{TR}' \cdot (2\pi)/1461 \text{ +/- correction in ROM}$

$\sin \phi_d = (\sin \phi_{\max} \text{ of ROM}) \cdot \sin \tau_d$ ; interim computation of  $\sin \tau_d$ .  
( $\sin \phi_{\max} \approx 0.4$ )

$\Delta \sin \phi_d (= \sin \phi (\tau_{15+1/4j}) - \sin \phi (\tau_1)) = \sin \phi_{\max} \cdot \cos \tau_d \cdot 2\pi/1461$  interim computation  $\tau_d$

$\phi_d = \arcsin(\sin \phi_d)$  natural value =  $\phi_d$  in rad; natural value  $\cdot (360/2\pi) = \phi_d$  in

10  $\Delta \phi_d = \sin \phi_{\max} \frac{[\cos \tau_d] \cdot (2\pi)/1461 (\text{rad})}{\cos \phi_d} = \sin \phi_{\max} \frac{[\cos \tau_d] \cdot (360/1461)}{\cos \phi_d} \text{ in } ^\circ$

interim computation of  $\cos \phi_d$

dom  $\sin \phi_d = \text{about } (-0.4/0.4)$

dom  $\Delta \sin \phi_d = \text{about } (-0.0017/0.0017)$

dom  $\phi_d = \text{about } (-23.45^\circ/23.459) = (-0.41 \text{ rad}/0.41 \text{ rad})$

15 dom  $\Delta \phi_d = \text{about } (-0.116^\circ/0.116^\circ) = (-0.002/0.002 \text{ rad})$

PPR 6 ,6', 6"

PPR 6 applies to all parameters while PPR 6' and PPR 6" only to those respectively marked PPR 6' and PPR 6".

$\phi'd = \phi_d + (1 + 2[p^+])/\Delta \phi_d$  (in rad or  $^\circ$ )

20  $\lambda'd = (\lambda_d + 2[p^+] - 1)\Delta \phi_d (\text{in } ^\circ)^\circ = (\lambda_d \cdot \frac{[360][2(p^+) - 1]\Delta \phi_d (\text{in rad})}{2\pi}) \text{ rad}$

$$\text{PPR6"} \quad \text{POLd} = ((|\lambda| - 45^\circ)^+)^+ \quad \text{POLd} = 1 \quad \text{for } |\lambda| > 45^\circ, \\ \text{POLd} = 0 \quad \text{for } |\lambda| \leq 45^\circ$$

(116)

$$\text{PPR6"} \quad Kd = \text{tg } \lambda'd \quad \left( \text{for } \text{POLd} = 0 \right) \quad K'd = \text{ctg } \lambda'd \quad \left( \text{for } \text{POLd} = 1 \right) \\ Q = \sin \phi'd \cdot 1 / \cos \lambda'd \quad \left( \text{for } \text{POLd} = 0 \right) \\ Q' = \sin \phi'd \cdot 1 / \sin \lambda'd \quad \left( \text{for } \text{POLd} = 1 \right)$$

only one of these exist  $\left( \begin{matrix} Kd, Kd' \\ Q, Q' \end{matrix} \right)$  and only one of these

$$\begin{aligned} (\cos \text{Asma}^+) &= \left[ ((Q - K)_0^+ + \frac{1}{2}(Q_0^+ - \frac{1}{2})^+) \right] \quad \left( \text{for } \text{POLd} = 0 \right) \\ (\cos \text{Asma}^+) &= \left[ (-\lambda)^+ \right] \quad \left( \text{for } \text{POLd} = 1 \right) \\ (\cos \text{Asmi}^+) &= \left[ ((Q + K)_0^+ + \frac{1}{2}(Q_0^+ + \frac{1}{2})^+) \right] \quad \left( \text{for } \text{POLd} = 0 \right) \\ (\cos \text{Asmi}^+) &= \left[ K^+ \right] \quad \left( \text{for } \text{POLd} = 1 \right) \end{aligned}$$

$$\text{PPR6"} \quad \cos \phi'd = \cos (\phi'd) \\ \sin \phi'd = \sin (\phi'd) \\ Ksd = \sin \lambda'd \\ Kcd = \cos \lambda'd$$

$$15 \quad \text{Pl} \quad \sin \text{ASd} = \sin (\text{ASd}) \quad \cos \text{ASd} = \cos (\text{ASd}) ; (\text{bit}(\cos \text{ASd}^+) \text{ and } \text{bit}(\cos \text{ASd}^-))$$

$$\text{Pla} \quad \sin \text{ASr1} = \sin (\text{ASr1}), \quad \cos \quad \left\{ \begin{matrix} \text{not computed} \end{matrix} \right.$$

$$\text{Plb} \quad \sin \text{ASd} = \sin (\text{ASd}) \quad \cos \text{ASd} = \cos (\text{ASd})$$

double bit not required

$$20 \quad \text{P2} \quad K^2 + \cos^2 \text{AS} = Kd^2 + (\cos \text{ASd})^2 \\ K^2 - Q^2 + \cos^2 \text{AS} = Kd^2 - Q^2 + (\cos \text{ASd})^2 ; (\text{bit}(\dots^+) \text{ and } \text{bit}(\dots^-)) \\ ((K^2 - Q^2)_0^+) = ((Kd^2 - Q^2)_0^+)$$

$$\text{P2'} \quad 1 + K'^2 \cos^2 \text{AS} = 1 + K'd^2 (\cos \text{ASd})^2 \\ 1 - Q'^2 + K'^2 \cos^2 \text{AS} = 1 - Q'^2 + K'd^2 + (\cos \text{ASd})^2 ; (\text{bit}(\dots^+) \text{ and } \text{bit}(\dots^-)) \\ ((K - Q)_0^+) :$$

$$\left( \dots^+ \right) = 1 \text{ and } \left( \dots^- \right) = 0$$

no computation, always

P3

$$\sin HS = y = \frac{Q \cdot Kd}{K^2 + \cos^2 AS} + (\sigma_0^+) \left| \frac{\cos ASd}{K^2 + \cos^2 AS} \cdot \sqrt{Kd^2 - Q^2 + \cos^2 AS} \right|$$

( $\sigma_0^+$ ) given by LOG.PREP  
^

$$HSr_1 = \arcsin Y = \arcsin (\sin HS) \quad \text{dom. HS} = (90^\circ \div + 90^\circ)$$

5 P3'

$$\sin HS = y = \frac{Q'}{1 + K'd^2 \cos^2 AS} + (\sigma_0^+) \left| \frac{K'd \cos AS}{1 + K'd^2 \cos^2 AS} \cdot \sqrt{1 - Q'^2 + K'd^2 \cos^2 AS} \right|$$

$$HSr_1 = \arcsin Y = \arcsin (\sin HS)$$

(also see fig. 10)

( $\sigma_0^+$ ) + ( $\sigma^+$ ), ( $\sigma^-$ ); (LOG.PREP.)

^

10

$$(\sigma_0^+) = +1 ; (\sigma^+) = 1 ; (\sigma^-) = 0$$

$$(\sigma_0^+) = 0 ; (\sigma^+) = 0 ; (\sigma^-) = 0$$

$$(\sigma_0^+) = -1 ; (\sigma^+) = 0 ; (\sigma^-) = 1$$

\*"forbidden"

$$; (\sigma^+) = 1 ; (\sigma^-) = 1$$

15

\* = wrong manoeuvre, computation stopped

( for instance: AS does not exist  
for date and  
latitude

P4

20

$$OC = (\sin \phi' d + \Delta \sin \phi d (1 + (P^+))) \cos (\lambda d + (2(P^+) - 1) \Delta \phi)$$

$$U' = (\sin HSd - OC); \quad (U'^+), (U'^0), (U'^-)$$

$$(U'^\pm) = (U'^+) + (U'^0) \overline{(P^+)} - (U'^0) (P^+) - (U'^-)$$

for flip flop

$$\begin{aligned} SHS \oplus \ominus : (U^+) &= (U'^+) + (U'^0) \overline{(P^+)}, \\ (U^-) &= (U'^-) + (U'^0) (P^+) \end{aligned}$$

25

$$AC = \phi - \lambda (U'^\pm) + \Delta \phi [1 + (U'^\pm) + 2(P^+) (1 - (U'^\pm))]$$

$$V' = 90^\circ - |AC| - (U^+) HS; \quad (V'^+), (V'^0), (V'^-)$$

$$(V_0^+) = (V'^+) - (V'^0) (P^+) (U^-) - (V'^-)$$

5  $\left\{ \begin{array}{l} \text{"MS" sur SHS (AMP)} \\ \text{for rectifier} \end{array} \right. \quad (A^+) = 0, (M^+) = 1, (P^+) = 0 :$

$$(V^0) = (V'^0) \overline{(P^+)} (U^-)$$

$$(V^-) = (V'^0) (P^+) (U^-) + (V'^-)$$

$$\sin HS_d = \sin(HS_d)$$

$$\cosh HS_d = \cos(HS_d)$$

10 P4a :  $\sin HS$  not computed,  $\cos HS_r = \cos(HS_r), (U^+), (V_0^+)$   $\left\{ \begin{array}{l} \text{not computed} \end{array} \right.$

P4a'  $\sin HS_r = \sin(HS_r), \cosh HS_r = \cos(HS_r)$  " " " "

P4b  $\sin HS_d = \sin(HS_d), \cosh HS_d = \cos(HS_d)$  " " " "

P5

$$\cos ASr_1 = \frac{\sin(\phi'd - (\sigma^+) \lambda'd) + Kd((\sigma^+) \cos(\phi'd - (\sigma^+) \lambda'd) - \sin HS)}{\cos HS}$$

15  $ASr_1 = \text{tarc} \cos(\cos ASr_1) \bmod 360$   
 $= 180 + ((P^+) - (\overline{P^+})) \text{arc cos}_{\text{nat}}(-\cos ASr_1)$

P5'  $\cos ASr_1 = \frac{K'd \sin(\phi'd - (\sigma^+) \lambda'd) + (\sigma^+) \cos(\phi'd - (\sigma^+) \lambda'd) - \sin HS}{K'd \cosh HS}$

20  $ASr_1: \left\{ \begin{array}{l} \text{as for P5 starting from } \cos ASr_1 \\ (\sigma_0^+) = (\sigma^+) \wedge \quad \text{-- as for P5 and P5'} \\ (\sigma^+) = 1 \ \& \ (\sigma^-) = 1 : \wedge \quad \text{-- forbidden} \end{array} \right.$

P6

$$\cos ASr_1 = (\cos ASna^+) (\sigma^+) + (\cos ASni^+) (\sigma^-) = +1 \text{ ou } -1$$

25  $ASr_1 = 90^\circ (1 - \cos ASr_1) = 000^\circ \text{ ou } 180^\circ$

$(\sigma^+)$ : same remark as for P5, P5'

P7

$$HS = (\sigma^+) (90^\circ - |\lambda' - (\sigma^-) \phi|) \quad (\sigma^-): \text{m\^eme rem. que p. P5, P5'}$$

$\left\{ \begin{array}{l} \sin HS \\ \wedge \end{array} \right.$  not computed by P7 but by P4a'

30 P8a, P8b, P8c

$$GAl = \cosh HS \cdot \sin AS$$

$$GA2 = \frac{\sin HS - (Ks^{\dagger}) \cos HS \cdot \cos AS - \sin^{\dagger} (Ks - (Ks^{\dagger}) Kc)}{Kc + |Ks|}$$

$$(\sin \alpha^{\dagger}) = ((|GA1| - |GA2|) \alpha^{\dagger})$$

identical computations, data are from different inputs

8a, 8b, 8c:

$$3a: \cos ASr1, \sin ASr1, \cos HSd, \sin HSd$$

$$5 \quad 8b: \cos ASd, \sin ASd, \cos HSr, \sin HSr$$

$$8c: \cos ASd, \sin ASd, \cos HSd, \sin HSd$$

P8a', P8b', P8c'

inhibited programs  $\left( \begin{smallmatrix} P8a, P8b, P8c \\ \text{(meridian)} \end{smallmatrix} \right)$

P9

$$HLr = 180^{\circ} + ((P^{\dagger}) - (\overline{P^{\dagger}})) \cdot 90^{\circ} + \arccotg \frac{GA1}{GA2}$$

P9'

$$HLr = 180^{\circ} + ((P^{\dagger}) - (\overline{P^{\dagger}})) \cdot 90^{\circ} + \arctg \frac{GA2}{GA1}$$

$$(SHS^{\dagger})_{r3} = (GA2^{\dagger}) + (GA2^{\circ}) (\overline{P^{\dagger}}) - (GA2^{\circ}) (P^{\dagger}) - (GA2^{-})$$

for P9 et P9'

15 P9'', P9''sp

$$HLr = 90^{\circ} ((SHS^{\dagger}) + 1)$$

$$(SHS^{\dagger})_{r3} = (\sigma^{\dagger}) \quad \text{for } P9'', \quad (\sigma^{\dagger}) : \left\{ \begin{smallmatrix} \text{same remark as for P5, P5'} \\ \end{smallmatrix} \right.$$

$$(SHS^{\dagger})_{r3} = \text{"given" for } P9''sp$$

P10E

$$\sin Hld = \sin (Hld)$$

$$\cos Hld = \cos (Hld)$$

$$\left. \begin{array}{l} \sin Hld = \sin (Hld) \\ \cos Hld = \cos (Hld) \end{array} \right\} * = \text{bit } (..) ^{\dagger} \text{ and } \text{bit } (..) ^{-}$$

$$Hld, HLr \text{ in } (0), \quad HLr', Hld' \text{ in } (H+Min.)$$

P10

$$\sin PSr2 = \sin \phi' d \cdot Ksd - \cos Hld \cdot \cos \phi' d \cdot Kcd$$

$$PSr2 = \arcsin (\sin PSr)$$

natural value  $\left( \begin{smallmatrix} (-90^{\circ} \div +90^{\circ}) \end{smallmatrix} \right)$

$$TAS = \frac{\cos Hld \cdot Ksd + \tg \phi' d \cdot Kcd}{\sin Hld}$$

$$(PAS^{\dagger}) = ((\cos Hld \cdot Ksd + \tg \phi' d \cdot Kcd) - |\sin Hld|) Q^{\dagger}$$

P10'

$$HSr_2 = (\cosh Ld^{\pm}) (|\phi'd + (\cosh Ld^{\pm}) \lambda'd| - 90^{\circ})$$

(120)

5

$$TAS \text{ et } (PAS^{\pm}) = \text{meridian} : \cosh L = (\cosh L^{\pm})$$

$$\text{not computed} \quad (PAS^{\pm}) = +1, (PAS^{-}) = 0$$

P11  $(PAS^{-}) = 0$

$$ASr_2 = 180^{\circ} + ((P^+) - (\overline{P^+})) \cdot 90^{\circ} - \text{arc ctg } 1/TAS; \quad (\text{arc ctg} = \text{natural value})$$

10

P11'  $(PAS^{-}) = 1$

$$ASr_2 = 180^{\circ} + ((P^+) - (\overline{P^+})) \cdot 90^{\circ} - \text{arc tg } TAS; \quad (\text{arc tg} = \text{natural value})$$

P11'' meridian,  $(PAS^{-}) = 0$

$$ASr_2 = 90^{\circ} \cdot \frac{1}{2} [(1 - (\cosh Ld^{\pm})) (1 - (\cos ASma^{\pm})) + (1 + (\cosh Ld^{\pm})) (1 - (\cos ASmi^{\pm}))]$$

$$ASr_2 = 000^{\circ} \text{ ou } 180^{\circ}$$

15

P12

$$PRO = (R_{poss}^+) + ((y_1^2 + x_1^2 - \sin^2 \phi'd)^{-}) + \dots + ((|y_1| - |\sin \phi'd|)^{-}) \cdot ((x_1^{\pm}) - (\sin \phi'd^{\pm}))^{\pm}$$

i.e.  $(PRO^+) = 1$  : not "Rposs", or  $(y_1^2 + x_1^2 - \sin^2 \phi'd) < 0$ , or  
if  $(|y_1| - |\sin \phi'd|) \leq 0$   $(x_1^{\pm}) \neq (\sin \phi'd^{\pm})$

20

$\lambda_c, \lambda'r, (SHSr_5^{\pm}) / \sin \phi'r_1$ , computed only if  $(PRO^+) = 0$ , and  $(PRO^+) = 1$  i.e.

$$\lambda_c = \text{arc ctg } \frac{y_1}{x_1} - (SHSd \oplus \ominus \pm) \text{arc cos } \frac{\sin \phi'd}{\sqrt{x_1^2 + y_1^2}} \quad * = \text{if } y_1 > x_1 : \dots$$

$$\lambda'r = \lambda_c - ((n_1^{\pm}) + (n_2^{\pm})) \cdot 90^{\circ} \quad \dots \text{arc tg } \frac{x_1}{y_1}$$

$$(n_1^{\pm}) = ((\lambda_c - 90^{\circ})^{\pm}); (n_2^{\pm}) = ((\lambda_c + 90^{\circ})^{\pm})$$

$$(SHSr_5^{\pm}) = ((y_1 - |\sin \phi'd|)^{\pm}) - ((y_1 + |\sin \phi'd|)^{\pm})$$

$$(SHSr_5^+) = ((y_1 - |\sin \phi'd|)^{+})$$

$$(SHSr_5^-) = ((y_1 + |\sin \phi'd|)^{-})$$

$$(SHSr_5^0) = ((|y_1| - |\sin \phi'd|)^{-})$$

30

$$\sin \phi'r_1 = \sin \phi'd$$

unprocessed transmitted value

P13

$$y_1 = \sin HSd; \quad x_1 = \cosh HSd \cdot \cos ASd$$

P13M

35

$$y_2 = \sin HS'd; \quad x_2 = \cosh HS'd \cdot \cos AS'd$$

P14

$$PRO = (\overline{R_{poss}^+}) + ((y_1 - y_2)^0)$$

$$(POLr^+_{O-}) = ((|x_1 - x_2| - |y_1 - y_2|)^+_{O-}); \quad (POLr^+) = 1 \text{ if } |x_1 - x_2| > |y_1 - y_2|$$

(121)

P15

$$K_r = \text{tg} \lambda' r = \frac{x_2 - x_1}{y_1 - y_2}$$

$$P15 \quad \checkmark \quad \checkmark \quad (POLr^+_{O-}) = 1; \quad (POLr^+) = 0$$

is for

P15'

$$K'r = \text{ctg} \lambda' r = \frac{y_1 - y_2}{x_2 - x_1}$$

$$P15' \quad \checkmark \quad \checkmark \quad (POLr^+) = 1$$

is for

P16a, P16a'

$$PRO = (\overline{R_{poss}^+}) + ((|\sin \phi' d| - \sin \phi'_{\max} \text{ de ROM})^+)$$

10 the following five computations take place only if  $PRO=0$ ,  $\checkmark$   $\checkmark$   $(PRO^+) = 0$   
i.e. if

$$\lambda' r_2 = \text{arc tg } K_r$$

for  
P16a

range

$$\lambda' r_2 = \text{arc ctg } K'r$$

for  
P16a'

$$\lambda' r_2: (-90^\circ \div 90^\circ)$$

$$\sin \phi r_2 = (x_1 + y_1 \cdot \text{tg} \lambda' r_2) \cdot \cos \lambda' r_2 = (x_1 + y_1 \cdot \text{tg} \lambda' r_2) \left| \frac{1}{\sqrt{1 + \text{tg}^2 \lambda' r_2}} \right|$$

$$(SHS r_4^+) = ((y_1 - \sin \phi' r_2 \cdot \sin \lambda' r_2)^+_{O-})$$

$$(SHS r_5^+) = ((y_2 - \sin \phi' r_2 \cdot \sin \lambda' r_2)^+_{O-})$$

P16, P16'

$\checkmark$  P16a, P16a',  $\checkmark$  POLD, Kd, K'd ( $\checkmark$  PPR6)  $\checkmark$   $\checkmark$   $\checkmark$  POLr, Kr, K'r  
same as with of in lieu of

P 17 a, b, c only determinant for the data sources, the operations on the homologueous data are similar when taking place

the ten computations below only apply for  $(R_{poss}^+) = 1$

$$\Delta \sin \phi r (= \Delta \sin \phi' r) = (SD^+) (\sin \phi_{\max} \text{ de ROM}) \cdot RP \left| \sqrt{1 - \frac{1}{RP^2} \sin^2 \phi' r} \right|$$

(pour a, b, c)  
for

$$RP = 1461/2\pi \text{ for } \phi' \text{ en rad}$$

$$RP = 1461/360 \text{ for } \phi' \text{ en } ^\circ$$

$$\sin \phi r = \sin \phi' r_2 - (2 + (P^+) - (P^-)) \cdot \Delta \sin \phi r$$

( $\checkmark$  .p.a, b)  
only

$$\phi r = \text{arc sin}(\sin \phi r); \quad \text{also } \text{arc sin}(\sin \phi' r) - (2 + (P^+) - (P^-)) \Delta \phi r$$

( $\checkmark$  .p.a, b)  
only

$$\Delta \phi r = (SD^+) \cdot RP \cdot \left| \sqrt{\frac{\sin^2 \phi_{\max} - \sin^2 \phi r}{1 - \sin^2 \phi r}} \right|$$

( $\checkmark$  .p.a, b)  
only

$$I_r = (270^\circ + (SD^+) \cdot \text{arc cos } \frac{-\sin \phi r}{\sin \phi_{\max}}) \text{ mod } 360^\circ$$

( $\checkmark$  .p.a, b)  
only

$$\text{don. } 000^\circ \div 359^\circ$$

$$D_{TRr} = [(Z_r - \text{ROM corr.}) \cdot RP] \bmod 1461$$

(only for a,b)

entire part. = number of quarters of a day  
fract. part/6 = number of hours

$$\lambda_r = \lambda'_{r1,r2} + [(P^+) - (P^-)] \cdot \Delta\theta_r$$

5 (only for b,c)

$$Ks_r = \sin \lambda'_{r1,r2}$$

(for a,b,c)

$$Kc_r = \cos \lambda'_{r1,r2}$$

(for a,b,c)

$$10 \quad \sin \theta'_{r1,r2} = \sin \theta'_{r1,r2}$$

transmitted, unprocessed value

(for a,b,c)

for P17a, P17b :  $\sin \theta'_{r2}, \lambda'_{r2}, \sin \lambda'_{r2}, \cos \lambda'_{r2}$

for P 17c :  $\sin \theta'_{r1}, \lambda'_{r1}, \sin \lambda'_{r1}, \cos \lambda'_{r1}$

#### P18

15 DSM (= date with respect to 1 March) =  $[D_{TRr}, \text{ in } \frac{1}{2} \text{ days} - \text{BLOCOR}, \text{ in } \frac{1}{2} \text{ days} - \dots$   
 $\dots (\text{round-off, } \frac{1}{2} \text{ days, "remainder in hours: } \text{BLOCOR}_H - D_{TRrH} ") + \dots$   
 $+ (\text{Ancy } 0, 1, 2, 3) + (23 \cdot 4 \text{ deROM}) \bmod 1461$   
 (in  $\frac{1}{2}$  days)

20  $DSM_j$  (in days) = "4" and higher DSM binary weightings

$DSM_q$  (remainder in  $\frac{1}{2}$  days) = "1" and "2" DSM binary weightings

#### P 19

$DSM_j$  discrimination

$DSM_j \geq 306$ , 1 January to end February,  $(g1^+) = 1$

25  $DSM_j > 306$ , 2 January to end February,  $(g1^+) = 1$

$< 306$ ,

$DSM_j > 152$ , 1 August to 31 December,  $(g8^+) = 1$

$DSM_j \leq 152$ , 1 March to 31 July,  $(g3^+) = 1$

#### 30 INCR, DECR

Increment and/or decrement for remaining quarter days and the position of the year in the 4-year cycle (Ancy 1,2,3,4); the remaining quarter days are processed differently in the leap years (Ancy = 0) than in the three other years (Ancy = 1,2 or 3).

35 Function: according to the logic gates shown in fig. 7c, it provides

$DSM_{jr} = \text{rectified } DSM_j$ .

P 20 DSMjr discrimination

JG ("range" day) = 306 for  $(g1^+)$ , 153 for  $(g8^+)$ , 0 for  $(g3^+)$

Poseg = DSMjr -  $(g1^+) \cdot 306 - (g8^+) \cdot 153 - (g3^+) \cdot 0$

the Poseg/61 division provides the integral quotient + the remainder,

5 MOC = short month

$\overline{MOC}$  = long month (31 day month)

Poseg/61 quotient = [rank of period ( $\overline{MOC}$ -MOC) in the "range"] - 1

Remainder of Poseg/61 = [rank of day in the period  $\overline{MOC}$ -MOC] - 1

Remainder  $> 30 \rightarrow \overline{MOC}$ , remainder  $< 31 \rightarrow \overline{MOC}$

10 Complete or incomplete ( $\overline{MOC}$  - MOC) periods: "January-February", "March-April",  
"Mai-June", "July" (incomplete), "August-September", "October-November"  
and "December" (incomplete).

Ranges: "Beginning of January to end of February", "Beginning of March to  
end of July", "Beginning of August to end of December".

15 P21 for  $\overline{MOC}$  (long months)

date of the month for DTr = (remainder of Poseg/61) + 1

month for DTr = 2(quotient of Poseg/61) +  $(g1^+) \cdot 1 + (g3^+) \cdot 3 + (g8^+) \cdot 8$

P21' for MOC (short months)

date of the month for DTr = (remainder of Poseg/61) - 30

20 month for DTr = 1 + 2(quotient of Poseg/61) +  $(g1^+) \cdot 1 + (g3^+) \cdot 3 + (g8^+) \cdot 8$

P22

HTr = (HLr' +/- ES - EHd) mod 24 H, (or 2.12H); with carries: .. (carry<sup>+</sup>) and  
(carry<sup>-</sup>)

P23

EH' = HTd +/- ES - HLr' (in hours and minutes)

25 EH' discrimination

$(e_1^+) = ((|EH'| - 1700 H00)^{0-}) \cdot ((EH' - 7H00)^{0+})$ ;  $(e_1^+) = 1$  PRO (prohibited)

$(e_2^+) = ((|EH'| - 7H00)^-)$

$(e_3^+) = ((EH' + 17H00)^-)$

$(e_4^+) = ((EH' - 17H00)^+)$

$(e_3^+) = 1$  R ⊕

$(e_4^+) = 2$  R ⊖

30  $EHR = EH' + 24H00 \cdot ((e_3^+) - (e_4^+))$

A.M.P. LOGIC: see fig. 9

PREPARATION LOGIC: see fig. 10

# Program control

124

## General Program Control

CPG1 Dip, Dip' <sup>CHL</sup>CPR1,2,3,4 <sup>UHL</sup>CHL1 <sup>Mip</sup>CPR5,6 <sup>CHL2</sup>UHS <sup>CHL3</sup>UAS <sup>CHL</sup>Fip

5 CPG2 Dip, Dip' <sup>CAS</sup>CPR1,3',5',6' <sup>Mip</sup>CAS1,2,3 <sup>UHS</sup>CAS4,5,6 <sup>UHL</sup>CAS7 <sup>CAS'</sup>UHT <sup>CAS'</sup>Fip

CPG3 Dip, Dip' <sup>CHS</sup>CPR1,3',5' <sup>CHS1</sup>CHS1s <sup>Mip</sup>CPR6 <sup>CHS2,3</sup>UAS <sup>CHS4,5,6,7</sup>UHL <sup>CHS8</sup>CHS <sup>CHS</sup>UHT <sup>CHS</sup>Fip

10 CPG4 Dip, Dip' <sup>CRL</sup>CPR1,3',5',6' <sup>Mip</sup>CRL1,2,3 <sup>UA</sup>CRL4,5,6,7 <sup>UHL</sup>CRL8 <sup>CRL</sup>UHT <sup>CRL</sup>Fip

CPG5 Dip, Dip' <sup>CRD</sup>CPR6" <sup>Mip</sup>CRD1,2,3,4,5,6,7 <sup>UDT</sup>CRD8,9,10,11 <sup>UHL</sup>CRD12 <sup>CRD'</sup>UHT <sup>CRD'</sup>Fip

CPG6 Dip, Dip' <sup>CRDL</sup>Mip <sup>CRDL1,2,3,4,5,6</sup>UA <sup>CRDL7,8,9,10</sup>UDT <sup>CRDL11,12,13,14</sup>UHL <sup>CRDL15</sup>CRDL <sup>CRDL</sup>UHT <sup>CRDL</sup>Fip

15 CPG7 Dip, Dip' <sup>CPRI'</sup>2,3 <sup>Mip</sup>CREH <sup>UEH</sup>Fip

CPG8 Dip, Dip' <sup>CPRI</sup>2,3,4 <sup>Mip</sup>UHL <sup>Fip</sup>

20 CPG9 Dip, Dip' <sup>CREQF</sup>Mip <sup>Fip</sup> no U (internal)

CPG10 Dip, Dip' <sup>CREQH</sup>Mip <sup>Fip</sup> no U (internal)

125

The different program commands mentioned above control the programs in the manner shown by Figures 7a, 7b and 7c; however the correlations are provided below.

5 The lasting or extended commands CHL, CAS, CHS, CRL, CRD, CRDL control the AMP logic. Moreover CAS and CHS control the preparation logic.

10 The CPR1 command controls the PPR1 program, the CPR1' command controls the PPR1' program, the CPR2 command controls the PPR2 program, the CPR3 command controls the PPR3 program, the CPR3' command controls the PPR' program, the CPR4 command controls the PPR4 program, the CPR5 command controls the PPR5 program, the CPR5' command controls the PPR5' program, the CPR6 command controls the PPR6 program, when there is CRL it becomes CPR6' and controls the PPR6' program and when there is CRD, it becomes CPR6" and controls the PPR6" program.

15 The CHL1-CHL3 commands respectively control the P10E, P10 and 10', P11, P11', P11" programs.

The CAS1-CAS7 commands respectively control the P1 program, the p2 and 2' program, the p3, p3' program, the p4a, p4a' program, the p8b, the p8b', the p9, p9', p9" program, the p22 program.

20 The CHS1 and CHS8 commands consecutively control the P4, P7, P6, P4a, P4a', P1a, P8a, P8a', P9, P9', P9", P22 programs.

The CRL1 and CRL8 commands consecutively control the P13, P12, P17c, P4b, P1b, p8c, p8c', P9, p9', p9", p9"sp, P22 programs.

25 The CRD1-CRD12 commands consecutively control the P13, P16 and P16', P17a, P18, P19, P20, P21, P4b, P1b, P8c, P8c', P9, P9', P9"sp and P22 (with the decoder  $D_{TR}$ -ES) programs. Lastly the commands CRDL1 to CRDL15 consecutively control the programs P13; P13M, P14; P15; P16; P17b; P18; P19; P20; P21; P4b; P1b; P8c, P8c'; P9, P9', P9", P9sp" and P22 with the

(176)

decoder  $D_{RT}$ -ES.

5 The computer programs include ROM memories which are shown in the drawing only when particular values must be retained, for instance transfer values  $D_{TR}$  - ↑ or when storing a different number of days depending on the month involved, as with dates in the ROM memory (Figure 7a).

10 The computer comprises particular elementary programs for the general search programs whereby it is possible to ascertain the date (by the intermediary of the longitude  $\lambda$  and latitude  $\Phi$ ). Once these two data have been established, either the solar elevation or azimuth would allow computing the effective time of the solar plot. However these two values are used jointly at the very level where, for the solar elevation or azimuth alignments, the local time is computed, after having calculated the azimuth as a function of the elevation or vice versa, i.e., at the level of program P8a, P8a', P8b, P8b', P8c, P8c'.

15 One notes that for the values which may be negative, the forward corrections result in an increase in the absolute value even in the negative direction. Any correction becoming or exceeding zero causes a change in sign instead of a change in value. However an exception is made in favour of latitude; indeed all latitude counting is carried out  
20 as if the south pole were zero and the north pole were 180° and a decoder took 90° off the north side and a complement of 90 on the south side. This is a wholly practical way to proceed, the decoding however should always take place at the output of the latitude data  $L_d(\lambda_d)$ .

25 Other functional peculiarities may still appear whilst studying the formulae and programs in detail, for instance the program control in the case of the "PRO" signal. When a PRO signal is applied to the program control (Figure 6), this control terminates the cycle but without commanding new individual programs and without emitting write-in pulses  
30 U.... during or at the end of the overall program. One notes that an overall program lasts at most one hundred ms or so, each particular

(27)

program can last several ms or equally may be resstricted to less than  
lms, even several nanoseconds.

In Figure 4, we can still see the transmission of two impulses ImM and  
ImJ, which indicate respectively minute and day changes. These pulses  
5 come from circuits shown in Figure 6 and inasmuch as the conditions be  
fulfilled cause a realignment of the solar elevation and azimuth with the  
local time derived from the official time HT.

In this manner, by setting his watch in the panel I mode and leaving the  
hour and the date synchronised, the user will be able to follow the sun's  
10 progress minute by minute and in all cases, at any instant will have hour  
information at his disposal. Obviously the realignment every minute will  
take place only if the panel hours are synchronised with the current  
hours and if the realignment has not been commanded for a factor other  
than the hourly one. As the start of cycle pulse Dip may possibly yet  
15 modify the hour synchronisation, there will be realignment only on the  
pulse Dip' which follows immediately after the pulse Dip. It is also  
worth noting that the synchronising circuit, in addition to the pulses  
Dip and Dip' and the pulse Fip also emits a pulse Mip which must occur  
only after the command CHL1 when the AMP logic is already in the correct  
20 position. This pulse also becomes effective in the set of gates and  
flip-flops at the bottom of Figure 5a where the various flashes are set,  
in particular for the case of double azimuth. The operation of this part  
of Figure 5a is explained by the logic diagram illustrated.

With regard to Figures 9 and 10 respectively, showing the AMP and  
25 preparation logics, the same data input configuration has been adopted as  
far as possible and accordingly it will be easy to pass in simple blocs  
in the representation of Figure 7b to the more detailed representations  
in Figures 9 and 10 respectively.

Regarding the commands, it is worth noting that there can be only one at  
30 a time and that all commands, except those from the current time counter,

(118)

can take place only at second intervals.

#### WATCH FUNCTIONS SUMMARY

|    |                    |                                                  |
|----|--------------------|--------------------------------------------------|
|    | BPH' CP RN SNC,STT | :appearance/disappearance day + seconds          |
|    | BPH' CP RN SC      | :1 correction acknowledged                       |
| 5  |                    | 2 appearance/disappearance days + seconds        |
|    | BPH' CP RT SNC,STT | :display EH-HS                                   |
|    | BPH' CP RT SC      | :1 correction acknowledgment                     |
|    |                    | 2 display EH-HS                                  |
|    | BPH' DP RN         | :appearance/suppression/preparation of RT1       |
| 10 |                    | special                                          |
|    | BPH' DP RT         | :suppression of RT1 special, panel regrouping    |
|    | BPH' LP            | :switching RN, RTII (from RTI to RTII); prep.    |
|    |                    | COREQ                                            |
|    | BPM' CP RN SNC,STT | :- (always displays current time)                |
| 15 | BPM' CP RN SC      | :correction acknowledgment                       |
|    | BPM' CP RT SNC,STT | :display FHL-HT                                  |
|    | BPM' CP RT SC      | :1 correction acknowledgment                     |
|    |                    | 2 display FHL-HT                                 |
|    | BPM' DP RN         | :-                                               |
| 20 | BPM' DP RT         | :desynchronise, resynchronise HT                 |
|    | BPM' LP RN         | :extended pressure, display of the time in other |
|    |                    | locations                                        |
|    | BPM' LP RT         | :location change, LOC A, LOC B, LOC C            |
|    | BPB' CP RN SNC,STT | :appearance/disappearance of current date        |
| 25 | BPB' CP RN SP      | :1 correction acknowledgment                     |

(121)

2 appearance/disappearance of current date

|    |                        |                                             |
|----|------------------------|---------------------------------------------|
|    | BPB' CP RT SNC,STT     | :display date DT-AS                         |
|    | BPB' CP RT SC          | :1 correction acknowledgment                |
|    |                        | 2 display date DT-AS                        |
|    | BPB' DP RN             | :-                                          |
| 5  | BPB' RT                | :desynchronise/resynchronise date DT        |
|    | BPB' NP                | :switch SNC, SCAB, SCAR, STT                |
|    | BPH CP RN SNC,STT      | :-                                          |
|    | BPH CP RN SC S + JS    | :correct seconds unit                       |
|    | BPH CP RT SNC          | :-                                          |
| 10 | BPH CP RT SC AFF.EH    | :minute unit correction EH                  |
|    | BPH CP RT SC AFF.HS    | :degree unit correction HS                  |
|    | BPH CP RTI STT         | :mono bloc AUBE control                     |
|    | BPH CP RTII STT AFF.EH | :search EH (if authorised by sit. HL)       |
|    | BPH CP RTII STT AFF.HS | :date latitude search RDL (if authorised by |
| 15 |                        | memory)                                     |
|    | BPH DP RN SC,STT       | :-                                          |
|    | BPH DP RN SC S + JS    | :tens of seconds correction                 |
|    | BPH DP RT SNC          | :-                                          |
|    | BPH DP RT SC AFF.EH    | :tens of minutes correction EH              |
| 20 | BPH DP RT SC AFF.HS    | :tenth of a degree correction HS            |
|    | BPH DP RT STT AFF.EH   | :-                                          |
|    | BPH DP RT STT AFF.HS   | :memory recall HS                           |
|    | BPH LP RN SNC,STT      | :-                                          |
|    | BPH LP RN SC S + JS    | :day of the week correction                 |
| 25 | BPH LP RT SNC          | :-                                          |
|    | BPH LP RT SC AFF.EH    | :time correction EH                         |
|    | BPH LP RT SC AFF.HS    | :tenth of a degree correction HS or sign HS |
|    | BPH LP RTI STT         | :sunrise                                    |
|    | BPH LP RTII STT AFF.EH | :if AFF.FHL, ms LOC choice                  |
| 30 | BPH LP RTII STT AFF.HS | :storage HS                                 |

130

BPH LP RTII STT :if bbh' LP maintained, COREQ

BPM CP RT SNC,STT :-

BPM CP RT SC :minute unit correction, current time

BPM CP RT SNC :-

5 BPM CP RT SC AFF.FHL :latitude unit correction

BPM CP RT SC AFF.HT :minute unit correction, time display (HT)

BPM CP RTI STT :descent

BPM CP RTII STT :if AFF.HS, search latitude RL

BPM DP RN SNC,STT :-

10 BPM DP RN SC :tens of minutes correction, current time

BPM DP RT SNC :-

BPM DP RT SC AFF.FHL :tenth of a degree latitude correction

BPM DP RT SC AFF.HT :tens of minutes correction HT

BPM DP RT STT AFF.FHL :-

15 BPM DP RT STT AFF.HT :memory recall time display

BPM LP RN SNC,STT :-

BPM LP RN SC :hour unit correction, current time

BPM LP RT SNC :-

BPM LP RT SC AFF.FHL :latitude tens correction or FH unit

20 BPM LP RT SC AFF.HT :hour unit correction HT

BPM LP RTI STT :noon

BPM LP RTII STT AFF.FHL :if AFF.EH, mm. LOC Act.

BPM LP RTII STT AFF.HT :display time storage

BPB CP RN SNC,STT :-

25 BPB CP RN SC AFF.DN :day of the month unit correction DN

BPB CP RT SC AFF.DT :day of the month unit correction DT

BPB CP RT SC AFF.AS :degree unit correction AS

BPB CP RTI STT :dusk

BPB CP RTII STT :if AFF.HS, date search RD

30 BPB DP RN SNC,STT :-

BPB DP RN SC AFF.DN :current date correction, Ancy DN

BPB DP RP SNC :-

BPB DP RP SC AFF.DT :Ancy display date correction DT  
BPB DP RP SC AFF.AS :tenth of a degree correction AS  
BPB DP RP STT AFF.DT :memory recall, display date  
BPB DP RP STT AFF.AS :memory recall, solar azimuth  
5 BPB LP RN SNC,STT :-  
BPB LP RN SC AFF.DN :month current date correction DN  
BPB LP RT SCN :-  
BPB LP RT SC AFF.DT :month display date correction DT  
BPB LP RT SC AFF.AS :tens or hundreds correction AS  
10 BPB LP RTI STT :sunset  
BPB LP RTII STT AFF.DT :display date storage  
BPB LP RTII STT AFF.AS :storage AS

A Swiss patent application, relating to a similar but not identical  
object, namely application CH 1 636/77 was already filed by the same  
15 initial applicant. This application, in content similar to patent  
application JP-A-53 124 478, already cited, but still not published as at  
the date of the present application contains drawings and explanations  
concerning watch circuits of which at least some may be suited for use in  
the present invention. The contents of this patent application CH 1  
20 636/77 should be considered jointly with the present regarding adequacy  
of disclosure for implementation by a person skilled in the art.

(132)

# CLAIMS

1. An electronic digital display watch, in particular a wrist watch, with geographic-solar function, comprising timekeeping means for the current time and date and means for: receiving and/or establishing by counting of the time, storing and displaying as data and/or results of calculations, several and at any one moment at least one, items of information amongst the items of information of time, date, geographical location, height of the sun with the auxiliary indication "sun ascending/sun at the meridian/sun descending", and azimuth of the sun, in such a manner that a plurality of said items of information are used to determine others, digital display means distributed in lines and means of control from the outside disposed facing these lines, being established in correlation so as to ensure a suitable selection of the parts to be modified of the displayed information, at the time of orders for modifications thereof, permitted by the said means of control from the outside, characterised in that it comprises processing means for effecting by logic operations and calculations, a processing of the said information as a function one of the other, at least three said items of information being used as input information and the other being automatically calculated on their basis, these processing means being capable of using, as input information, one or more said items of information of height and or/azimuth of the sun which may have any values which are introduced at will into the watch or are established beforehand by the latter on the basis of other data, the said means of control from outside being arranged to permit likewise the control of different processing operations to be carried out on the said data, processing control means which respond to particular actuations of the said means of control from outside, being established according to an arrangement, the structure of which ensures the storage of programs and calculation routes which, selectively, lead the said processing means to cause them to produce, as the result of a said processing each of the aforementioned items of information according to choice.



(123)

2. Watch according to claim 1, characterised in that the said means of control from the outside comprise a plurality of push buttons located for instance on the flanks of the watch so as not to encumber the face of the watch, each of these push buttons permitting different controls distinguished by different methods of manipulating the push button, one of the push buttons controlling a state selection arrangement acting upon means which selectively put the watch either in a normal state of conservation and display of the current time or in one or more table states in which several others of the said items of information are displayed, said processing means being arranged to intervene then so as to determine certain of the said items of information, not known, as a function of others, known, display control means being arranged to control the display of the result of these calculations.

3. Watch according to claim 2, characterised in that the said selection arrangement is capable of establishing two different table states, one ensuring, by the intermediary of the said processing control means and the processing means, an automatic continuous alignment of two of the variables, solar height, solar azimuth and time, with the third any one of these latter, each time it undergoes a modification, the date and the place being parameters and the other table state permitting the search for the place and/or the date by operations controlled by the processing control means and carried out by the said processing means, on the basis of the variables, then given, of solar height and solar azimuth.

4. Watch according to one of the claims 2 and 3, characterised in that one of the said push buttons controls an arrangement for controlling a situation of non-correction in which no correction is possible of a situation of forward correction in which corrections of the displayed information are possible forward, of a backward correction situation in which corrections of the information displayed are possible backward, of a work-on-tables situation in which, in tables-state, date and place searches are possible as a function of values introduced into the watch



134

in agreement with one or more solar readings of solar height and solar azimuth.

5 5. Watch according to one of the claims 2 to 4, characterised in that some of the said push buttons control an arrangement for selection of prestorable geographic locations, involving the determination of a time zone, the said timekeeping means comprising means for automatically adapting their hours information as a function of the chosen time zone.

6. Watch according to claim 5, characterised in that other push buttons are arranged so as to permit a place correction, relative to the pre-stored and selected location, without destroying any pre-storage of a particular location.

5 7. Watch according to one of the claims 2 to 6, characterised in that it comprises means arranged for permitting, in each said table state, the selection either of the current time and date or of another time and/or another date, to serve as a basis for the correlative calculation of the variables of time, solar height and solar azimuth, without affecting the counting or the keeping of the current time.

5 8. Watch according to one of the claims 2 to 7, characterised in that it comprises registers of magnitudes of solar height and of solar azimuth which are capable of being put in position in alignment with the result of calculations effected by the said processing means, receiving for that purpose data of time, geographical position and date, these registers being likewise capable of undergoing step-by-step corrections by the manipulation of certain said push buttons, the register of solar heights being in addition capable of being put into position as a whole, by particular manipulations of push buttons, so that its contents correspond to predetermined situations of solar height and that on this basis the processing means calculate the corresponding time and solar azimuth, taking into account the place and the date, so that a display of the time and the azimuth at which these particular solar heights present

10



(39)

themselves may be furnished.

5 9. Watch according to claim 8, characterised in that the said particular solar heights comprise at least the height (00.0°, sun ascending) of sunrise, a height of the passage of the sun at the meridian, determined only as being maximum, and the height (00.0°) of sunset.

5 10. Watch according to claim 9, characterised in that the said particular solar heights further comprise a height (- 18.0° to 12.0°, sun ascending) of dawn, the height (+ 26.4°, sun descending) of the sun sinking at a tangential angle of 1/2 and a height (- 12.0° to - 18.0°, sun descending) of dusk.

