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Sensorik & messtechnische Entwicklungen

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INTRA
Reference Manual

INTRA/DOC/207-BRU

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1. Introduction

This Reference Manual contains deeper information about INTRA, its principles of operation, technical information for the user and full reference on its firmware. It may also be a help in case of trouble.

2. Connections of the Controller Board

The drawer with the controller board carries different sockets and a fuse holder. The fuse should be a type EU Ø 5 x 20 mm, 3.15 A, slow. The location of these parts are shown in the corresponding figure in the Installation Manual. There, you also will find the pin-assignments of the socket for power supply, serial link, heater option and the sun-monitor.

The tracker comes with the sun-monitor and its cabling already in place.

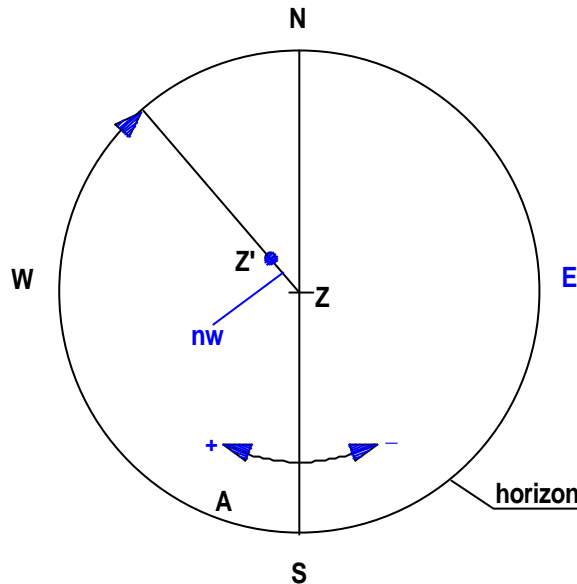
3. Characterization and Measurement of the Misalignment

The tracker has been characterized at factory such that if you command the primary axis to a value of zero, the pointing direction is indeed in a plane perpendicular to the secondary axis (and vice versa). What we cannot characterize is the installation of the tracker by you, our customers. In other words, there will always be some misalignment (due to installation errors) between the astronomical system and the system of the tracker. In general, this is the end of the story: Your tracking will be as good as your installation is accurate - **but not with INTRA**. Using its built in solar sensor, it will learn from its pointing errors and after a few days with good weather conditions, its pointing will be within the specified maximum error of $\pm 0.25^\circ$

INTRA may be installed and configured to operate in the "altitude over azimuth" or in the so called "azimuth over altitude" mode. In the first case, its primary axis is (nominally) vertical, in the second case, its primary axis is (nominally) horizontal, parallel to the east-west direction (see also in the Installation Manual). In the following, in order to describe the effect of a misalignment during installation, we discuss the "altitude over azimuth" mode only (primary axis vertical). The situation for the "azimuth over altitude" mode is analogous and does not give any new insight.

The tracker might be installed in such a way, that the line of its azimuth axis intersects the celestial sphere in a point Z' that does not coincide with the true zenith Z (Fig. 3.1). Furthermore, the azimuth axis of the tracker may have been fixed in a way, that direction south does not coincide with the zero position of the azimuth axis (see fig. 3.1).

Figure 3.1 Installation Errors
 These can be characterized by 3 numbers: The azimuth axis intersects the celestial sphere at a point Z' (instead of Z) with the co-ordinates (Aw,nw). Furthermore, the tracker may have been installed such that it does not point south for an azimuth setting (instead of at null) of -Ao.



During the start-up procedure, the user must properly set the time and date on the clock (RTC) of the tracker and he also must tell the system the geographical co-ordinates of the site (and of course, the mode of operation). Time and date are specified as universal time (UT). Longitude and latitude of the site are entered in degrees. Longitude is positive for sites west of and negative for sites east of Greenwich. Latitude is positive for sites on the northern and negative for sites on the southern hemisphere.

Based on the time and the co-ordinates of the site, the controller computes the position of the sun. Initially it "knows" nothing about installation errors and hence assumes that its system of co-ordinates is the alti-azimuth system.. INTRA is equipped with a sun monitor that allows it to measure the resulting pointing errors. The sun-monitor is a 4-quadrant silicon diode with a diameter of the active area of 1.88 mm, installed in a tube with a 0.9 mm aperture at a distance of (nominally) 5 mm from the surface of the diode. The four quadrants are numbered as shown in fig. 3.2. The maximum useful range of the sun-monitor is app. ± 5°. Note however, that the monitor will "saturate" at this angle and yield 5° deviations for angles up to app. ±15°.

The deviation in azimuth is approximated according to the following formula:

$$\Delta A = c [((Q1 + Q2) - (Q3 + Q4)) / \sum Qi - A0] \tag{1}$$

where

c factor to convert dimensionless quantity to app. degrees

Qi signal from quadrant i (i = [1..4]) measured in arbitrary units.

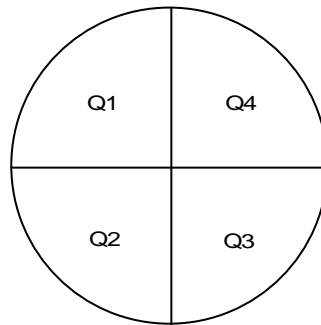
A0: An offset to correct for non-homogeneity of the quadrants or alignment errors during assembly of the sun-monitor.

Similarly, the deviation in altitude is according to:

$$\Delta a = c [((Q1 + Q4) - (Q2 + Q3)) / \sum Qi - a0] \tag{2}$$

Both expressions are of course only approximations. But this is good enough for our purpose, because these results will be used in an iterating procedure, that converges towards $\Delta A = \Delta a = 0$. In other words: If a reading is e. g. 4.5° , it could be that 4.1° would be closer to the real situation, but if a reading is zero, it is indeed very close to zero.

Figure 3.2 Sun-Monitor naming convention for quadrants
 The picture is as seen when looking (from the sun) onto the monitor. If the tracker leads the sun in azimuth, Q1 and Q2 will receive more radiation and hence ΔA will be positive. Similarly, a positive Δa means that the tracker points higher than the sun actually is.



4. Firmware Reference

4.1. Commands

The firmware knows of two levels of user interaction: The command-decoder and the monitor. Upon power-up, the program enters the command-decoder. The command-decoder does not show a prompt, but you may get a list of all valid commands by typing H<cr> or ?<cr>.

Input to the command-decoder and the monitor is not case sensitive. During input, you may use the standard editing key <bs>. If input is for a numeric argument and you enter <cr>, the current value of the corresponding parameter is preserved.

We use a notation where control characters are denoted by a two or three-letter symbol enclosed by the less than and greater than operators. The symbols used are according to the definition of the ASCII set of (control-) characters (e. g. <cr>=carriage return = ASCII 15C, <esc>=escape = ASCII 33C).

The "help-menu" of the command-decoder is shown below (optional arguments of commands are shown in square-brackets):

```
T[hmmss]<cr>           time
D[ddmmyy]<cr>          date
R[primary][,secondary]<cr>  remote deg
C<cr>                  clock-mode
S<cr>                  sun-mode
I<cr>                  get info from sun monitor
E[n]<cr>              if n=even echo off else on
P<cr>                  show status
V<cr>                  s/w version
MON<cr>                monitor
```

4.1.1. Time and Date

Entering T<cr> or D<cr> displays the current time or date of the RTC. You may redefine these parameters by entering e g. T12000<cr> which would set the RTC to 12:00:00 or e. g. D310393<cr> which would set the date of the RTC to 31-Mar-1993. Note that the T-command does not affect the date setting and vice versa.

INTRA uses universal time (UT, roughly equivalent to Greenwich Mean Time), hence time and date of the RTC should always be set accordingly.

4.1.2. Mode-setting Commands

The tracker has four modes of operation: clock-mode, active-mode, monitor-mode and remote-mode. By sending a C-, S-, MON- or R-command, you may enter the corresponding mode.

clock-mode C-command

The position of the sun is computed from the date and time as read from the RTC. Then INTRA points to these co-ordinates, taking into account its current "knowledge" about installation errors. The sun monitor is sampled and pointing information is stored in RAM for later analysis. An automatic rewind to the morning position is done, if the sun goes below the western horizon. The analysis of the data of the sun-monitor is performed just after midnight. The result of this analysis will be a new, more accurate set of parameters that characterize the installation errors. A new set is only computed, if the data are of sufficient quality, that is, if the weather conditions during the day were sufficiently good to allow for the computation of a valid new set of parameters.

active-mode S-command

If the intensity on the sun monitor is high enough (see note below), INTRA uses these data to control pointing. The date/time read from the RTC is used to compute a target position and comparing the current target position with its current position yields data that are comparable (in its contents of information) to the sun-monitor data gathered in the clock-mode. Night-time operation is as described under clock-mode.

monitor-mode MON-command

The mon-command enters the monitor or manual mode. The monitor is a collection of menus (with possible sub-menus) that allows to inspect or modify system variables/parameters of INTRA. For a detailed description of the monitor please refer to the paragraph on the monitor. An overview of the monitor-commands is shown in the appendix A4.

remote-mode R-command

The R-command forces INTRA into the remote mode and sets target-angles for the primary- and the secondary-axis. The arguments you specify in the R-command are assumed to be "astronomical" co-ordinates. In other words: INTRA takes into account its current knowledge on installation errors to control its position. When the tracker is not yet in remote-mode, both

arguments for the R-command are mandatory (e. g. R15.0,45.0<cr>). Otherwise, the R command will be ignored. Once you have successfully entered remote-mode, you may omit one of the two arguments. In order to define a new target-value for the primary-axis, you would e. g. enter R0.5<cr> In order to define a new target-value for the secondary-axis you would e. g. type R,47.8<cr>. Note that the target-value for the other angle remains as before.

In addition to the 4 main modes mentioned above, there are 4 sub-modes: `init`, `rewind`, `update` and `normal`. The `init`-mode is entered upon the `I`-command in the "installation menu" of the monitor. The other 3 sub-modes are controlled exclusively by the program. The logic behind these conventions now becomes transparent:

After a "first-power-up" (this means: INTRA has been without power for more than 24 hours and therefore has lost it's RAM-information or there has been loaded a new program) the positions of the axis of INTRA are undefined. The attempt to enter these modes will lead to the following error-message: "position is undefined - run init first". In this case the user should follow the "start up procedure" described in the Installation Manual. After the successful installation (or if not first power-up, INTRA sends message: "first power up not seen") it continues with the mode currently in effect, but changes its sub-mode to `normal`. At the end of the day and assuming its mode is not "remote", the sub-mode is set to `rewind`. At (local) midnight, the `update` sub-mode is temporarily entered. During this time, no commands are accepted. With all computations for the update sub-mode done, the program then again returns to sub-mode `rewind`, until `normal` is entered again at sunrise.

Below you find a sample session-log that uses commands of the command-decoder. Comments have been added to the log in order to help you understand the meaning of the commands.

```

H                                     'normal mode, help

T[h:mm:ss]<cr>                        time (UT)
D[ddmmyy]<cr>                          date (UT)
R[primary][,secondary]<cr>            remote deg
C<cr>                                  clock-mode
S<cr>                                  sun-mode
I<cr>                                  get info from sun monitor
E[n]<cr>                                if n=even echo off else on
P<cr>                                  show status
V<cr>                                  s/w version
MON<cr>                                monitor

T                                     'what`s the Universal Time?
124738
T130427                               'change Universal Time
130427
D                                     'what's the date (UT) ?
060191
D050593                               'change date (UT)
050593
R0,0                                  'go to position 0.0, 0.0
REMOTE
R25,40                               'go to position 25.0, 40.0
REMOTE
R,25                                  'go to position "same", 25.0
REMOTE
R30                                  'go to position 30.0, "same"
REMOTE
C                                     'enter clock-mode
CLOCK
S                                     'enter sun-mode

```

```

SUN
I                               'show sun-monitor-info
Q1:0.00000 Q2:0.00000 Q3:0.00000 Q4:0.00000 Az:0.00000 Al:0.00000
E0                               'echo off
E1                               'echo on
P                               'show status
Primary : 44.67 Secondary : 51.70 Mode: SUN 'in astron. co-ordinates
V                               'software-info
S/W Version x.xx

```

4.2. Monitor

For an overview of the monitor commands see also appendix A4. Some of the monitor commands are password-protected. These commands are critical and should only be used by a qualified user.

The initial password set at factory is: "CORONA". Please change it to your private password in order to protect INTRA from manipulations by unqualified persons. And do not forget your password!

Following the MON-command, the main menu of the monitor is displayed. It includes the date and time of the creation of the firmware in the format ddmmyy.hhmm. The version of the software shown in this manual may be older than the one installed on your tracker. Do not worry, the commands are still the same - with possible minor changes. If some new features should have been included in the version you have installed on your tracker, you should have received a corresponding Update-Sheet(s) to this manual.

MON

```

INTRA-Monitor main menu: 300493.1055
L cLock menu          T Temperature
C Communication      S Sun monitor
I Installation        P tracker Parameter
D Driver menu         N load New program **
O Outputs             A show lAst events
E Eeprom              W passWord
H Help                V saVe all to EEPROM
X eXit

```

Typing one of the command letters shown above will execute the corresponding command or invoke the menu of a next higher level. Menu items signed with ** are password-protected. Note that in any level.

- typing the X-command will bring you back one level.
- typing the H-command will display the menu of the current level.

In the following, we go through a sample session that uses all commands¹. Many commands are explained by just giving an example. Others need some words of explanation and we will therefore interrupt the session-log by these additional explanations. We also have structured the session log by interspersing appropriate headings.

¹ Note that some of the menus will change with the status of INTRA.

Menus that allow you to enter a numeric argument prompt you by displaying the actual value. You may enter a new value or <cr>. The later will leave the previous value in effect. During input you may use standard editing keys.

4.2.1. Password Menu

Some menu items of the monitor are protected against unintentional and malicious access. The protected items are flagged with two small stars "**". A user who wants to access a protected cmd has to prove his identity by typing a password. This will give full access to all password-protected commands until the monitor is quit.

Typing the W-command will show the following menu:

```

Password Menu
I prove Identity    C Change Password**
V saVe password**  H Help
X eXit

```

After typing the I-command you will be asked for the password. It's also possible to change the password. After changing the password it has to be saved.

WARNING: If you forget the password, you lose the ability to access the protected commands. Contact BRUSAG, but be aware, that we will help you only after you have provided sufficient evidence, that you are indeed entitled to know the password. This can't be done by a simple telephone call. You will lose time.

4.2.2. Clock Menu

typing the L-command on the main menu advances you to the clock menu. Although it is possible to set time and date of the clock from the level of the command-decoder, these commands have been included here for completeness as well.

```

Clock Menu
T set Time (UT)      D set Date (UT)
R Read clock        P set Parameter**
S Show parameter    V saVe
H Help              X eXit

T                                                    'set time
type time as h:mm:ss 131055
05-05-93 13:10:55

D                                                    'set date
type date as DDMMYY 060593
06-05-93 13:11:04
R 06-05-93 13:11:08

P                                                    'set parameter **
crystal adj. [seconds per year] : -3274.61
T0 : 21.92
a : -3.09404000E-008

```

The frequency of the quartz the RTC is running on may systematically deviate from its nominal value of 2¹⁵ Hz. With the P-command, you may enter a correction in the units "seconds per year". You enter the correction as an integer number terminated by a blank (ASCII 40C) or a <cr>. The firmware will then keep track of the time elapsed. Each time the systematic error has added up to a full second (\pm), the RTC is corrected accordingly.

Similarly, the parameters T0 and a are used by the firmware to correct for temperature-induced changes of the quartz of the RTC. Do not edit these values.

Note: Positive values for crystal adjust are chosen, if the real time clock is too slow.

Warning: The P-command parameters have been determined at factory, hence without being sure, that you know better, do not edit these parameters. Also be aware, that these values are stored only in the EEPROM of your tracker. If you force a return to factory settings of the EEPROM, you will loose these important parameters. Take a note and keep it carefully.

```

S                                     'show parameter
show clock parameters
crystal adj.: -3274.6059
T0: 21.9203
a: -3.09404000E-008

X                                     'exit
  exiting clock menu

```

The V-command saves the value entered with the Y-command (Crystal adjustment) into the EEPROM.

4.2.3. Communication Menu

Typing the Gcommand from the main menu displays the communication menu. This menu is intended to configure INTRA's communications settings according to your requirements. In order to enter this menu, the settings of your terminal must match the current settings of INTRA. If you have forgotten which settings you have, matching your terminal to INTRA can be rather tricky. In such a case, it may be simpler to wait for the back-up power of INTRA to run down. Upon power-up, it will then revert to its default settings: 9600 Baud, 8 data- , 1 stop-bit, no parity.

INTRA has two serial interfaces termed S0 and S1. **Only serial I/F 0 is available for the user.** The serial I/F 1 is reserved for special use. It is only accessible on a socket on the INTRA - controller-board. Its levels are TTL compatible. With the S-command you may toggle between S0 and S1 making one of the two the current one. Subsequent modifications of the serial parameters will affect only the current I/F and the saVe command will save only the parameters of the current I/F to the EEPROM.

```

C
  Communication Menu
S elect Serial          B Bit rate
F data Format           P Parity
O shOW settings       V saVe
H Help                 X eXit

S                                     'select serial
actual serial 0
select one of the following:
0 for serial 0
1 for serial 1
X eXit
X
F                                     'set data format
select one of the following:
6 for 7 databits, 1 stopbit
7 for 7 databits, 2 stopbits
8 for 8 databits, 1 stopbit
X
data- stopbits: 8 1
O                                     'show settings
Bit rate:          9600

```

data- stopbits: 8 1

```

Parity:          none
B                                                         'set bps rate
select one of the following:
0  300 bps      1  1200 bps
2  2400 bps     3  4800 bps
4  9600 bps     5 19200 bps
6 38400 bps
X                                                         'exit selection
no change
P                                                         'set parity
select one of the following:
N none
E even
O odd
X                                                         'exit selection
Parity:          none
V                                                         'save serial parameters
Serialparamters null
saved
X                                                         'exit
exiting Com-Menu

```

Exiting the Com-Menu will put the current settings into effect. If you have changed e. g. the baud-rate, you should now adjust your terminal accordingly.

4.2.4. Installation Menu

In this menu, you will find those parameters, that are specific for your site, the way of mounting INTRA and the correction strategy. Also included in this menu is the Init-command, because you will need it after installation following power-up. See also the Installation Manual for further details.

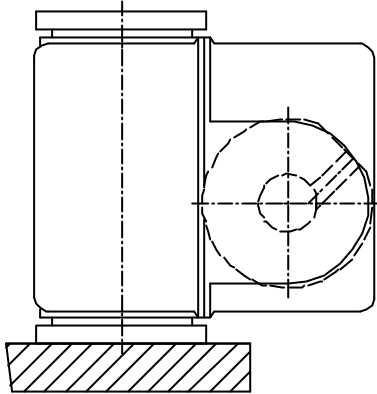
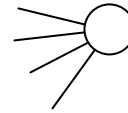
```

I
Installation Menu
S Site parameter      O shOw parameter
A Alignment parameter I Init-mode
R axisRange **       C Correction mode
M Mounting           H Help
V saVe               X eXit

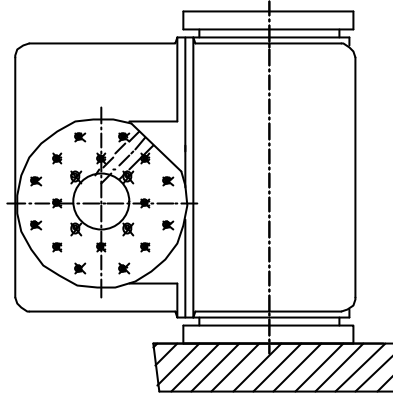
M                                                         'select mounting
Primary axis vertical
select one of the following:
V primary axis Vertical
T primary axis vertical, 180 degrees Turned
H primary axis Horizontal

```

This gives INTRA the information how it is installed on the installation-pod. How you install INTRA is up to you, it depends mostly on the device you want to point at the sun. The axis which is connected to the pod is called "primary axis".



primary axis vertical



primary axis vertical, 180° degrees turned

A change of the mounting-mode will automatically lead to the change of two other parameters:

- axis ranges: primary axis Vertical: primary axis: [-200,200]
secondary axis: [-5, 90]
- 180 degrees Turned: primary axis [-5,350]
[-5,185]
- primary axis Horizontal: primary axis: [-90, 90]
secondary axis: [-200,200]

- alignment parameters: primary axis Vertical: [0.0, 0.0, 0.0]
- 180 degrees Turned: [0.0, 0.0,180.0]
- primary axis Horizontal: [90.0, 90.0, 0.0]

These changes are saved automatically to the EEPROM.

Warning: Selecting the wrong mounting-mode may lead to critical situations, e. g. a collision of the tracker or the instruments with surrounding obstacles. The "M"-command is password protected.

```

C                                     'select correction mode
angle and time correction             'current correction mode
alignment errors not corrected        'current correction status
select one of the following:
N No correction
T Time correction
A Angle correction
C angle and time Correction

```

A great feature of INTRA is its easy installation. Easy installation means, that you don't need to mount INTRA with a precision of a fraction of a degree in order to obtain accurate pointing. INTRA accepts an installation error of up to 5 degrees in each axis. This makes it possible to align INTRA with a simple compass and spirit-level in a short time, even under poor weather-conditions and INTRA will do the rest. You may leave INTRA without supervision, even its mounted on a

lonesome mountain. It will learn where it has to look in order to accurately track the sun. This may require a few days of good weather, but you need not wait for it - INTRA will do it for you.

In order to use all capabilities of INTRA, you should choose the correction mode "angle and time correction". Assuming you have given correct time-information INTRA figures out its misalignment by examining the movement of the sun. After INTRA has determined its misalignment with a precision of 0.05 degrees in every degree of freedom, further computations of the misalignment-parameters are no longer computed. The correction-status changes to 'alignment errors corrected'. From now on, INTRA uses its knowledge on astronomy to correct time-errors of the internal real-time-clock.

In the case you want to take care of the accuracy of the time by yourself - once in a month should be sufficient - you may choose "angle correction".

If you have installed INTRA with a negligible misalignment, you may choose "time correction" or even "no correction". In this case you are responsible for the accuracy of INTRA's pointing.

```
R                                     'set axis ranges**
low range primary <0..-450: -190 -200
high range primary >0..450: 190 200
low range secondary <0..-200: -90 -5
high range secondary >0..200: 90 90
```

Warning: INTRA and all devices installed on INTRA have to be mounted in such a way that both axis can rotate freely - within specified ranges - without causing a collision with any surrounding obstacle. People standing close to INTRA have to keep in mind, that getting in between the moving INTRA and any solid obstacle will be harmful - to the person and/or the equipment. The 'range of the secondary axis' has to be smaller than [-200..200] degree. Exceeding this range will destroy the cabling of the sun-monitor and other components.

We recommend the following settings:

for primary-axis-vertical-mounting

lrp: -200 hrp: +200 lrs: -5 hrs: +90

for primary-axis-vertical-mounting and 180° turned

lrp: -5 hrp: +350 lrs: -5 hrs: +185

for primary-axis-horizontal-mounting

lrp: -90 hrp: +90 lrs: -200 hrs: +200

Note: When INTRA reaches an axis-boundary it will not stop immediately - but depending on its current speed - produces an overshoot of up to several degrees. The range-conditions are checked every two seconds. If INTRA is moving with its highest speed the axis-boundary may be overstepped by app. 4 degrees.

```
S                                     'set site parameters
longitude : -8.73 -8.75
latitude : 47.24
altitude a.s.l. : 420
```

Longitude and latitude are measured in degrees. Latitude is positive west of Greenwich and negative east of Greenwich. Latitude is counted positive on the northern hemisphere and counted negative on the southern hemisphere. Altitude is measured in meters above sea-level.

```
A                                     'alignment parameters
vert. axis azimuth : 0.000
Z-distance. vert. axis : 0.000
misalignment azimuth : 0.000
```

The parameters vert. axis azimuth, Z-distance. vert. axis and misalignment azimuth are the parameters (Aw,nw,A0w) discussed in paragraph 3. Prior to entering the "init-mode" (menu "installation") these values should be checked and possibly reset to zero.

```
O show installation parameters 'show installation
longitude :-8.75
latitude :47.24
altitude a.s.l.: 420
vert. axis azimuth : 0.00
Z-distance. vert. axis : 0.00
misalignment azimuth : 0.00
```

```
I Check and redefine position and ranges. '); 'init mode
R Run init
X eXit
```

Attention: Never enter 'init-mode' while the shading mechanism is installed. Otherwise several mechanical components may be destroyed. This is also valid for the reinitialisation after a long term power fail.

```
R entering init mode 'init tracker
primary init done
secondary init done
```

Typing the l-command will force INTRA into init-mode. This mode searches for the index pulses (hardware marks) on both axis. A message is displayed after detection of the index pulse of either axis. The init procedure should terminate within app. 5 minutes max. If you are waiting for longer than 5 minutes and there is still one of both or both messages outstanding, this may have two reasons: Either your range setting of the axis (or both axis) is such, that the index pulse is at a position outside the permissible range. See tracker menu on the monitors main level for more information on the range settings. If this is not your problem, then there is obviously same failure of the opto-circuits of the index-pulse detector(s). Contact BRUSAG. Typing any key while INTRA is in the init-mode will stop this procedure.

```
X exiting installation menu
```

4.2.5. Driver Menu

Commands in this menu are largely for troubleshooting and/or debugging/tests at factory.

```
D Driver Menu
E trans. Errors S Set speed **
P show Position F redeFine Pos **
D Drive test M Manual rotate
I Index error R dRive status
O show vOltage G Gain **
H Help X eXit
```

```
E illegal transitions 'transition errors
primary axis : 5
```

secondary axis : 14

select one of the following:

C Clear counters

X eXit

C

'clear counters

error counters are cleared

exiting error counter menu

The quadrature signals of the optical encoder circuit of either axis may change levels only in an orderly fashion. There are transitions that are illegal - as it is illegal, when counting up, that 7 follows 5. It must be 6. With the E command you may inspect the number of such transition errors that occurred on either axis. Note that this information is only meaningful if counters were cleared following the first start-up. Typically you will use this command only in case of problems.

P

'show position

Primary : 47.82 Secondary : 50.78

P

'show position

Primary : 47.82 Secondary : 50.93

D

'drive test

speed mot/hal/angle Pr: 10 190 0.00 Se: 0 0 0.00

speed mot/hal/angle Pr: 10 0 0.00 Se: 0 0 0.00

speed mot/hal/angle Pr: 10 0 0.00 Se: 0 0 0.00

speed mot/hal/angle Pr: 10 0 0.00 Se: 0 0 0.00

The D-command writes out the target speed, current speed (as measured by the signals from the hall sensors) and the position of the primary and secondary axis. It does so until stopped by sending a <cr>.

I

'index errors

date,time, delta-cnts

primary axis : 131712 050593 -1

secondary axis : 131403 050593 0

select one of the following:

R Reset values

X eXit

R

values are reset

exiting index menu

I

'index errors

date,time, delta-cnts

primary axis : 000000 000000 0

secondary axis : 000000 000000 0

select one of the following:

R Reset value

X eXit

exiting index menu

If INTRA detects the hardware-zero (index pulse) of its two axis and this operation has already been done before, it should find the index pulses at the same value of the position counter for each axis. With the I-command, you may inspect date and time of the last successful detection of the index pulses and the difference between its current and previous position (Note: 1 count corresponds. to app. 0.04°).

O 'show voltage
Voltage : 26.7

The O-command gives a reading of the voltage applied to the motors. The resolution of the reading is a little less than 2 V. A voltage below 12 V will lead to an additional error message.

S 'set speed
select one of the following:
A primary axis
E secondary axis
X eXit
X eXit
E
speed -3000..3000 : 29 500
speed -3000..3000 : 500 800
speed -3000..3000 : 800 900
speed -3000..3000 : 900 0
speed -3000..3000 : 0 0

Speed is entered in units rpm with a maximum allowable range of ± 3000 rpm. If you just enter <cr>, the monitor returns to the driver menu.

Warning: This command is intended for service use only and is therefore password-protected.

F redefine position
Primary : new angle : 81.44 82
Secondary : new angle : 54.23 55

The F-command redefines the current position of the axis. It is one method to circumvent the blocking of both axes on a tracker, that has not been initialized. Following an F-command you will be able to operate both axis e. g. using the R-command (This may be very useful to position the axis properly prior to an init-command.)

Warning: The F-command invalidates any previous init-command. This command is intended for service use only and is therefore password-protected.

M 'manual rotate
entering manual rotate

Q1 : 0.00 Q2 : 0.00 Sum 0.000
Q3 : 0.00 Q4 : 0.00
Primary : 0.00 Secondary : 0.00

Q1 : 0.00 Q2 : 0.00 Sum 0.000
Q3 : 0.00 Q4 : 0.00
Primary : 0.00 Secondary : 0.00

The manual rotate allows kind of a cursor control of the tracker: We implemented the J-L-M keys, arranged around the Kkey as kind of "cursor control block". Typing J moves the primary axis clockwise (cw), typing L moves it counter clockwise (ccw). Similarly for the secondary axis: I turns clockwise (cw), M turns counter clockwise (ccw). The monitor returns to the driver menu if you enter <cr>.

R 'drive status
Primary : ok
Secondary : ok

During operation, the program checks on both axis if the speed and position as deduced from the hall-sensors of the motors and the position sensors are consistent. If not, the error status of the corresponding motor is set and the motor is switched off. The purpose of this stop-mode is to prevent an axis from going wild in case of a failure of the position encoders (opto-circuits). Once an axis has been switched off, it may be brought back to operation only by typing the reset command in the drive status menu. The R-command is displayed only if an error occurred. The following status messages may appear:

- ok
- error of hall sensor or encoder
- error of hall sensor or no motor connected
- error motor current too high
- axis out of range
- Motors stopped! EEPROM checksum error
- Motors stopped! INTRA not initialized

The gain menu that follows below allows to modify the characteristics of the control loop. Do not touch these settings.

```
G                                     'gain **
  Gain Menu for qualified user only
S Show gain          G Gain pos. cntr.
A gAin speed cntr.  V saVe gain
H Help              X eXit
A

speed gain = voltage * slope + offset
gain slope :-0.000350
gain offset:0.015500
S

gain pos. cntr.: 30000.00
gain speed cntr. slope :-0.00035000
gain speed cntr. offset :0.01550000
G
gain:30000.00
```

Warning: This command is intended for service use only and is therefore password-protected.

4.2.6. Output Menu

In this menu you can set up to 4 user-defined output messages. You may define:

- the trigger condition upon which this message will be output.
- the parameters it will include by selecting a maximum of 10 from a predefined list of 16 parameters.
- the format (label/identifier and separating character) of the list.

As an example, see the definition of output 1 as shown following the S-command below. In order to further demonstrate what can be done using the outputs-menu, we just walk through all the menus, without modifying any parameters.

```
O                                     'output menu
select one of the following:
number of the output 1..4
1                                     'select output nr. 1
```

```

Menu Output 1
S Show setting      E/D Enable/disable output
P set Parameter    T set Trigger
C set sep. Char    L set Label
H Help   V saVe    X eXit

S                                                    'show settings

setting of output 1

output is enabled
Trigger mode is trigger command "Q"
separating char ",",
label ""
parameter
p1 mode   p2 <cr>   p3 pr.is   p4 pr.tar           'pr is primary
p5 <cr>   p6 se.is  p7 se.tar           'se is secondary
P
set parameter separated by comma
nbr1,nbr2,nbr3,....,nbr10
0 date   1 time   2 label  3 mode           'is: is-value
4 pr tar 5 pr is  6 se tar 7 se is         'tar: target-value
8 quad1  9 quad2 10 quad3 11 quad4
12 pr. delta   13 se. delta
14 <cr>  15 test
16 real 17 cardinal 18 integer 19 byte 20 bitset 21 longint

C                                                    'set separating character
set separating-character ",",
E/D                                                    'enable/disable output

T                                                    'set trigger
select one of the following:
T interval of Time                                     'Choose the trigger interval
                                                       (2 seconds up to 1439 minutes)

M interval of Measurement                             'Chooses the measurement-inter-
                                                       val of INTRA (10 minutes),
                                                       possibly interesting as a
                                                       documentation of an error

C trigger by Command                                  'Choose a string of up to 4
                                                       characters (no INTRA-
                                                       keywords). After leaving the
                                                       monitor output is invoked by
                                                       typing these characters.

X eXit
X

L                                                    'set Label
select one of the following:
D Define label                                         'Defines a string which will
                                                       lead the output-string.

C Clear label
X eXit
X
X
exiting output menu

```

4.2.7. EEPROM Menu

This menu offers several services/utilities with respect to the data stored in EEPROM. You may obtain a dump of all its data, revert to factory settings and more.

Warning: Be aware that the EEPROM contains data that are specific for your tracker. These "private" data have been entered at factory (e. g. characterisation parameters of the quartz of the RTC) or by yourself (e. g. mode of installation, site parameters etc). You will loose these "private" settings, if you revert to factory settings. Factory settings only include a "reasonable" set of data that will allow to start its "personalization".

We recommend that you capture a dump of your EEPROM settings and store this file at a safe place.

```

E
  Eeprom Menu
R Restore eeprom   D Dump eeprom
O shOw serial nbr  S define Serial nbr
U Update checksum  V saVe
H Help             X eXit

R                                                     'restore eeprom
select one of the following:
  1 restore site parameter  2 restore alignment parameter
  3 restore axis offsets    4 restore range
  5 restore outputs         6 restore quadrant parameter
  7 restore gain            8 restore serial number
A restore All

O                                                     'show serial number of software
serial number :      x.xx

D                                                     'dumb eeprom
dump eeprom
  Eeprom Menu
R Restore eeprom   D Dump eeprom
O shOw serial nbr  S define Serial nbr **
U Update checksum  V saVe
H Help             X eXit
D

dump eeprom
serial number :*****
version :160394.1230

setting of installation

longitude :-8.73
latitude :47.24
altitude a.s.l.: 420
vert. axis azimuth : 0.000
Z-distance. vert. axis : 0.000
misalignment azimuth : 0.000
range primary:-200.0..200.0

```

range secondary: -5.0.. 90.0
correction mode: angle and time correction
mounting: Primary axis vertical

setting of tracker

offset primary: 0.00
offset secondary: 0.20
index search flag: TRUE
gain pos. cntr.:30000.00
gain speed cntr. slope :-0.00035
gain speed cntr. offset :0.0155

setting of sunmonitor

offset quadr. primary :0.14000
offset quadr. secondary :0.08000
Factor to arc :0.07550
Irange in percent +/- :15.00
I0 : 7.600
Sigma : 0.318
necessary buffer entries in percent : 75
min. elevation : 15

setting of clock

crystal adj.: -3274.6059
T0: 21.9203
a: -3.09404000E-008

setting of output 1

output is disabled
Trigger mode is trigger command "Q"
separating char " "
label ""
parameter
p1 mode p2 <cr> p3 p.is p4 p.tar
p5 <cr> p6 s.is p7 s.tar

setting of output 2

output is disabled
Trigger mode is time interval 1 seconds
separating char " "
label ""
parameter
p1 <cr> p2 p.is p3 p.tar p4 <cr>
p5 s.is p6 s.tar

setting of output 3

output is disabled
Trigger mode is time interval 1 at 0 minutes
separating char " "
label ""
parameter

```
p1 <cr>    p2 quadr1  p3 quadr2  p4 quadr3
p5 quadr4  p6 p.delta  p7 s.delta
```

setting of output 4

```
output is disabled
Trigger mode is interval of measurement
separating char " "
label ""
parameter
p1 test
```

The serial number of the EEPROM is set to the serial number of the tracker. It is followed by a two digit extension. The incentive to include this number as an EEPROM-parameter is to have the identifier of the tracker on each record of the dump-data of the EEPROM. The firmware nowhere uses this data.

4.2.8. Temperature Menu

```
T                                     'see temperature
temperature : 24.73
```

Displays the temperature of the on-board sensor of INTRA. The sensor is not calibrated - it merely serves to compensate the RTC for temperature induced variations of the frequency of its quartz.

4.2.9. Sun-Monitor Menu

Most of the commands in this menu are reserved for special use at factory. The exception is the S-command which allows you to monitor the signals on the monitor. Note that this information may also be requested from the command-decoder level, using the I-command.

```
S
  Sun Monitor Menu
R Read buffer      F Fill buffer
C Clear buffer    N Number of entries
E clear Entry     S Show sun intensity
P Parameter
H Help           X eXit
```

Commands associated with the terms "buffer" and "entry" are for tests at factory only. These commands are not further explained.

Parameters associated with the sun-monitor do have the following meaning:

I0
Sum of signal on all 4 quadrants of the sun-monitor for air mass zero (Extraterrestrial value).

sigma
atmospheric coefficient of extinction for signals of sun-monitor.

iRange
The sum I of the signals of the sun-monitor should follow app. the expression
 $I = I_0 \exp(p(h) m \sigma / p(0))$,
 where m is the rel. air mass and p the atmospheric pressure as a function of the altitude a. s. l. of the site of the tracker. If a measured result falls outside a tolerance of $\pm iRange$ (in

percent) around I, than the tracker will eventually fall back from active- to clock-mode. Similarly, the program will not use such pointing data for the computation of its installation errors.

Offsets of quadrants of primary- and secondary axis

These two number are determined during the characterization of the tracker at factory. The numbers compensate for the effect of small assembly errors or for non-homogeneities of the four-quadrant detector used in the sun-monitor.

Factor

Sensitivity of sun-monitor to angular displacements. Computation of the pointing errors in primary Δ_{pr} and secondary Δ_{se} are as follows:

$$\Delta_{pr} = \text{Factor} ((Q1+Q2)-(Q3+Q4)) / \sum Q_i - pr_0$$

$$\Delta_{se} = \text{Factor} ((Q1+Q4)-(Q2+Q3)) / \sum Q_i - se_0$$

where pr_0 and se_0 are the offsets defined above. The factor is entered to obtain Δ_{pr} , Δ_{se} in arc-units (The program uses arc-units during its computations, but to the user all angles are presented in degrees).

```

S                                                    'show sun intensity
Q1 : 0.00 Q2 : 0.00 Sum 0.000
Q3 : 0.00 Q4 : 0.00
Primary : 0.00 Secondary : 0.00

```

```

P                                                    'see parameter menu
Sun monitor parameter Menu
P show Parameter  O Offsets quadr.**
R iRange**       I I0**
S Sigma**        F Factor**
C Criterion**    V saVe
H Help           X eXit

```

Most of this menu-items are only for service-use (labeled with "**"). They are password-protected and mustn't be changed.

```

P                                                    'show parameter
show sun monitor parameters
offset quadr. primary :0.00000
offset quadr. secondary :0.00000
Factor to arc :0.12
Irange in percent +/- :30.000
I0 : 2.00
Sigma : 0.150
necessary buffer entries in percent : 75
min. secondary : 15

```

```

X                                                    'exit
  exiting parameter menu

```

```

O
Offset Quadrant Primary : 0.00
Offset Quadrant Secondary : 0.00

```

```

X                                                    'exit

```

exiting parameter menu

X 'exit
exiting sun monitor

4.2.10. Tracker Parameter Menu

This menu includes entries that allow to enter the results of the characterization of the tracker at factory. Remaining commands modify the behavior of the firmware during night operation.

P
Tracker parameter Menu
O axis Offsets** S Show parameter
F search Flags H Help
V saVe X eXit

O 'axis offsets **
be careful do not change this values
offset azimuth axis : 0.00
offset altitude axis : 0.00

Offsets are the position of the index pulses of the resp. axis. These values are determined at factory, see also fig. 2.5 in the installation manual.)

Primary- and secondary-values are measured in degrees with a resolution of slightly less than 0.04 °. If you enter a number, it will be converted to a corresponding integer. If now you enter O again, the angle displayed will not confirm exactly to the value you entered, because it has been converted back from the nearest integer value.

Warning: This command is intended for service use only and is therefore password-protected.

F 'search flags
Fsearch index flag : TRUE

Typing "T" or "F" will set the value to TRUE or FALSE. A search index flag of TRUE means that the tracker will redetermine the position of the index pulses on both axis during it rewind-mode after sun-set. This setting is recommended.

S 'Show parameter
show tracker parameters
offset primary: 1.23 secondary: 3.21
index search flag: TRUE

X
exiting tracker menu

4.2.11. Load New Program

see the separate chapter "Update of Firmware".

4.3. Update of Firmware

The software of INTRA is stored in a flashROM and it includes a utility that allows to down-load (and hence replace) itself. This is your easy path to an upgrade/update of the present INTRA control program. As our customer you are entitled to receive updates free of charge up to three years after the purchase of the tracker. The update will come on a DOS-formatted diskette (3.5"

1.4 MB) together with a down-loader. The down-loader named INTRALO.EXE will run on any AT-compatible (or higher) PC. But prior to performing a down-load of software, let's think for a moment what this means.

INTRA has stored many tracker- user- and site-specific parameters in its EEPROM. Now a new version of the software might use a different organization of the data in the EEPROM. In order to prevent chaos, the new software will firstly check the version of the EEPROM (first 4 bytes in EEPROM) and if it finds a version that differs from its own, it will overwrite all data in the EEPROM with default values. Your site-parameters and other specific information will be lost and you will have to re-enter these data. Therefore, prior to loading any new program, verify that you know what you have stored in the following entries:

- Crystal adj. parameters in clock menu
- Site-parameters in the installation menu
- Communications parameters in the communication menu
- Gains in the driver menu (sub-menu: gain menu)
- User-defined outputs 1 to 4 in the output menu
- Offset-values for sun-monitor in menu "Sun monitor"
- tracker specific data as defined in the tracker parameter menu and installation menu

Your password will also be replaced by a the default password.

In the EEPROM menu of the monitor, there is a command that allows to dump all of the contents of the EEPROM. We recommend, that you enter this command and capture the output to a file for later printout.

Now you are ready to proceed with the update of the firmware. We assume you have copied the contents of the update diskette to a suitable directory on your hard-disk and you are currently in this directory. Then follow the step by step procedure as given below:

- Connect your PC's COM1 port to the serial port (serial interface connector) of INTRA.
- Turn power of INTRA on.
- Using your terminal emulator software on your PC, enter INTRA's monitor and command both axis to an angle of 15.0 °. Wait for INTRA to reach these positions.
- Change - if not already in effect - your communication parameters to 9600 Baud, 8 data-, 1 stopbit, no parity. Adjust settings of emulator accordingly.
- select the monitor-menu "load New program" by typing N on the level of the monitor's main menu.
- repeatedly send - during several seconds and immediately following the N-command - the character * until you receive the character § (some computers will return other characters) as echo.
- Exit emulator.

- Type INTRALO<enter> on your PC. INTRALO should come up with its message as shown below:

```
INTRA Loader V 1.0
```

```
-----
```

```
0   exit
1   erase flashrom
2   download
3   status
4.  go
5   define baudrate
6   find monitor
```

```
status : ready to load
```

Any other status would mean that INTRA is not ready to load. The status: no answer means that there is no communication between INTRA and your PC. Check your cable and the selected baudrate (default 9600 bps) with command 5. You may also try to get the connection by using command 6 (find monitor). If any other errors occur, please start procedure again and if errors persist, contact BRUSAG.

Once you received the status "ready to load" do proceed as follows:

- type 1 (erase flashROM), then 1 again to select ROM-type 28F001 and wait for new status "ready to load".
- type 2 (download) enter the filename of the file to be down-loaded and wait for new status "program loaded". During the loading process, a dot will be echoed on the screen for each record transferred. After the successful download, the loader menu will be displayed again. If this does not happen and no new dots are echoed on the screen, the download has failed. In this case restart INTRA (power off & on) and start again by erasing the flashrom.
- type 4 (go), wait a few seconds, then type 0 (exit) on your PC to exit INTRALO.
- Restart your terminal emulator on your PC. Keep in mind, that INTRA has lost its previous settings of its communication parameters and will come up with default values: 9600 b/s, 8 data-, 1 stop-bit, no parity.
- enter INTRA's monitor again by typing MON<cr>.
- Set date and time of INTRA and re-enter all parameters according to the notes on the sheet you prepared earlier.
- Force INTRA into init-mode by typing the command I on the level of the installation menu. Wait for the init-mode to terminate.
- exit monitor and resume normal operation.

In case something went wrong during the download, you may end up with no program loaded. For this case, there is an alternate path to enter INTRA's down-load-mode. Proceed as follows:

- Connect a terminal (9600,8/1,no parity) to INTRA.

- Switch power of INTRA on, then repeatedly send the character * (* is ASCII 2Ah) to INTRA until you receive the character § as echo. This should happen within a few seconds.
- Connect a PC and run INTRALO as described above.

5. Troubleshooting

5.1. Init-mode failure

Assume you entered init-mode and even after 5 minutes, you are still waiting for either "primary init done" or "secondary init done" or both. There are two possibilities:

If both axis are moving:

- a) The range of the axis on which the index pulse is not found is such, that the index-pulse is outside the current range. Check range settings in "installation menu" and try again.
- b) There is indeed a failure of the index pulse circuit. Contact BRUSAG.

If one or both axis do not move:

Check the drive-status (monitor, driver menu, drive-status). If any drive-error appeared see chapter "3.2.4 Drive Menu".

5.2. Low current consumption after first power-up

INTRA has hardware to allow for a stand-by mode. This stand-by mode may only be put into effect by the processor and it is reset by any character arriving on the serial interface or from an alarm issued by the RTC. However, if the back-up power supply of the board is empty, it may happen, that the controller starts up in power-save-mode. Because now you need to define the clock and other parameters anyway, you must communicate with INTRA (using its serial interface) - and this will bring back the controller to normal mode.

5.3. Tracker doesn't move its axis

If INTRA detects a failure, which could lead to harmful consequences for INTRA or devices mounted on INTRA, both motors are stopped.

In this case you have to connect a terminal to INTRA. Enter the monitor (MON<cr>), select the "driver menu" (D). With the R-command you get the driver status information.

- a) One of the following messages appears:
 - error of hall sensor or encoder
 - error of hall sensor or no motor connected
 - error motor current too high

Control the cabling of the motors and use the R-command to reset the status. Exit the monitor. The motors should work now again. If the same failure appears within the next 30 seconds, you have to contact BRUSAG.

- b) The following message appears:

- axis out of range

One or both axis have exceeded the range defined in the installation-menu. Enter the installation menu and change the range settings. Make sure that these changes do not affect the safety of the tracker and/or your instruments.

c) The following message appears:

- Motors stopped! EEPROM checksum error

INTRA has detected an EEPROM checksum error. Therefore, it assumed, that the installation information stored in the EEPROM are not correct anymore. Enter the EEPROM menu and make a dump of all EEPROM information. If you are sure that the information are correct, update the checksum (U-command in the EEPROM menu). The motors will work again.

In case this failure does occur from time to time, the EEPROM is probably defect. Contact BRUSAG.

d) The following message appears:

- Motors stopped! INTRA not initialized.

INTRA is not initialized. Run init.

6. Specifications

6.1. Electrical

supply voltage: 24 V DC nominal.
minimum: 10 V
maximum: 30 V

current (@24V)
peak: 2 A max.
operating: < 500 mA (typical)
standby: < 50 mA (typical)

fuse: type EU Ø5 x 20 mm, 3.15A, slow

serial interface: RS232-C or RS422 or RS485 (selectable), default settings are:
9600 Baud, 8 data-, 1 stopbit, no parity.

protection: All electrical lines to and from the tracker are filtered and
protected with 1.5 kW Transorb-type diodes.

6.2. Mechanical

mass
INTRA I: 25 kg
INTRA II: 31 kg

configuration: Altitude- over azimuth-axis.
"Azimuth-" over "altitude-axis".

motors: brushless DC-Motor on each axis (Minimotor, Type 2444 S BL1
K315 with attached gear type 30/1S/66:1 MM529

gear: worm-drive, ratio 150:1 Coupled with 1:1 (toothed) belt drive to
66:1 gear which is directly coupled to the motor.

position encoders: Coding disks that are attached directly to primary- and
secondary-axis resp.

resolution: 9380 cnts per 360° corresponding to a resolution of 0.038°.

max. capacity: 30 kg or 90 Nm shared among both flanges or 20 kg/60 Nm total
on single flange.

max. speed: 100 °/minute (either axis)

6.3. Operational

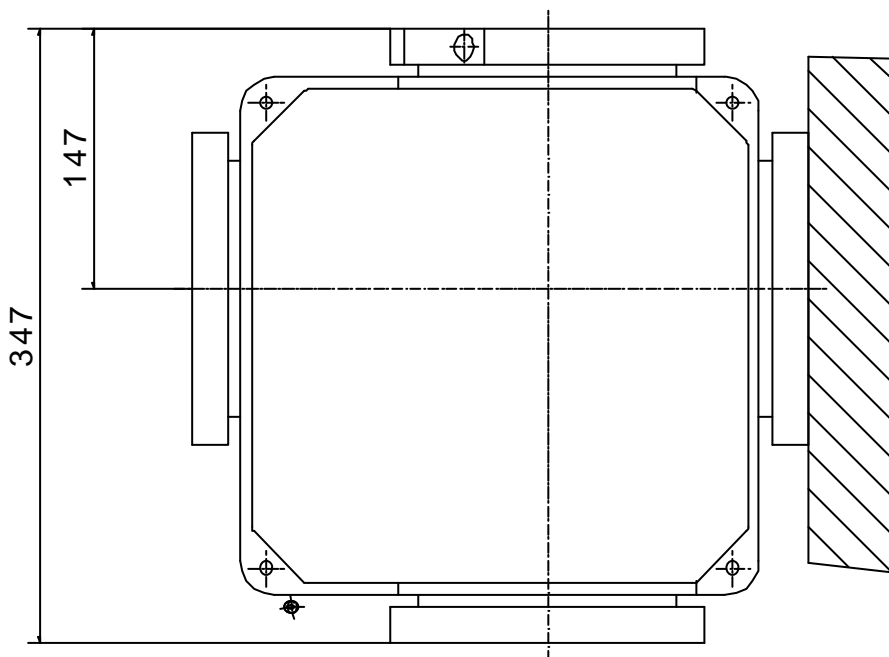
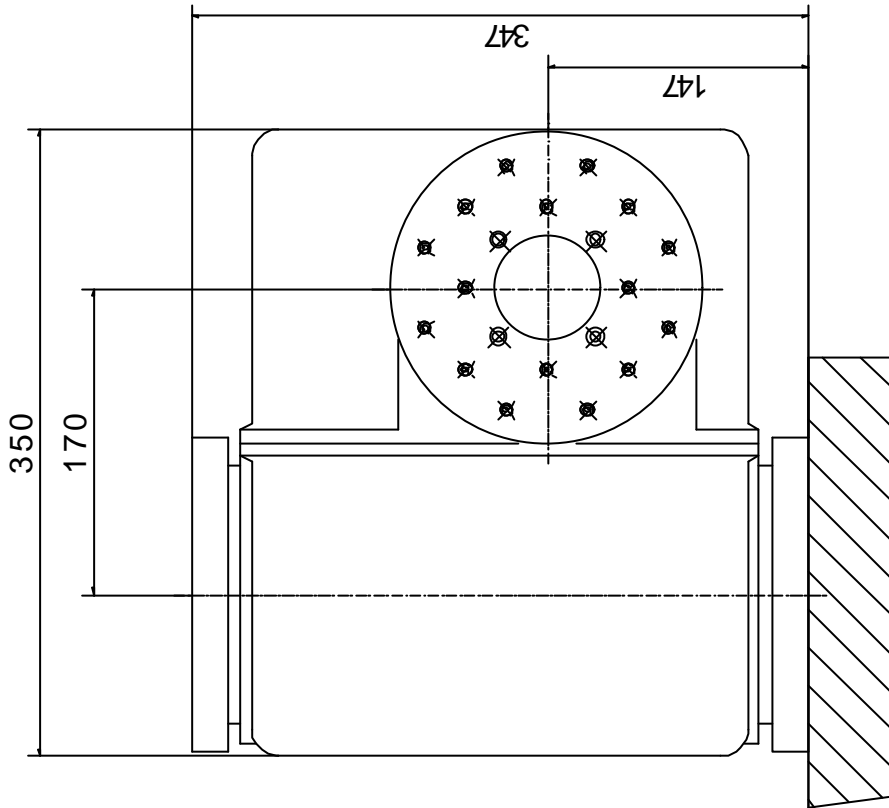
general: built for operational outdoor use.

temperature: -30° C to 50° C
-46° C to 50° C with heater option

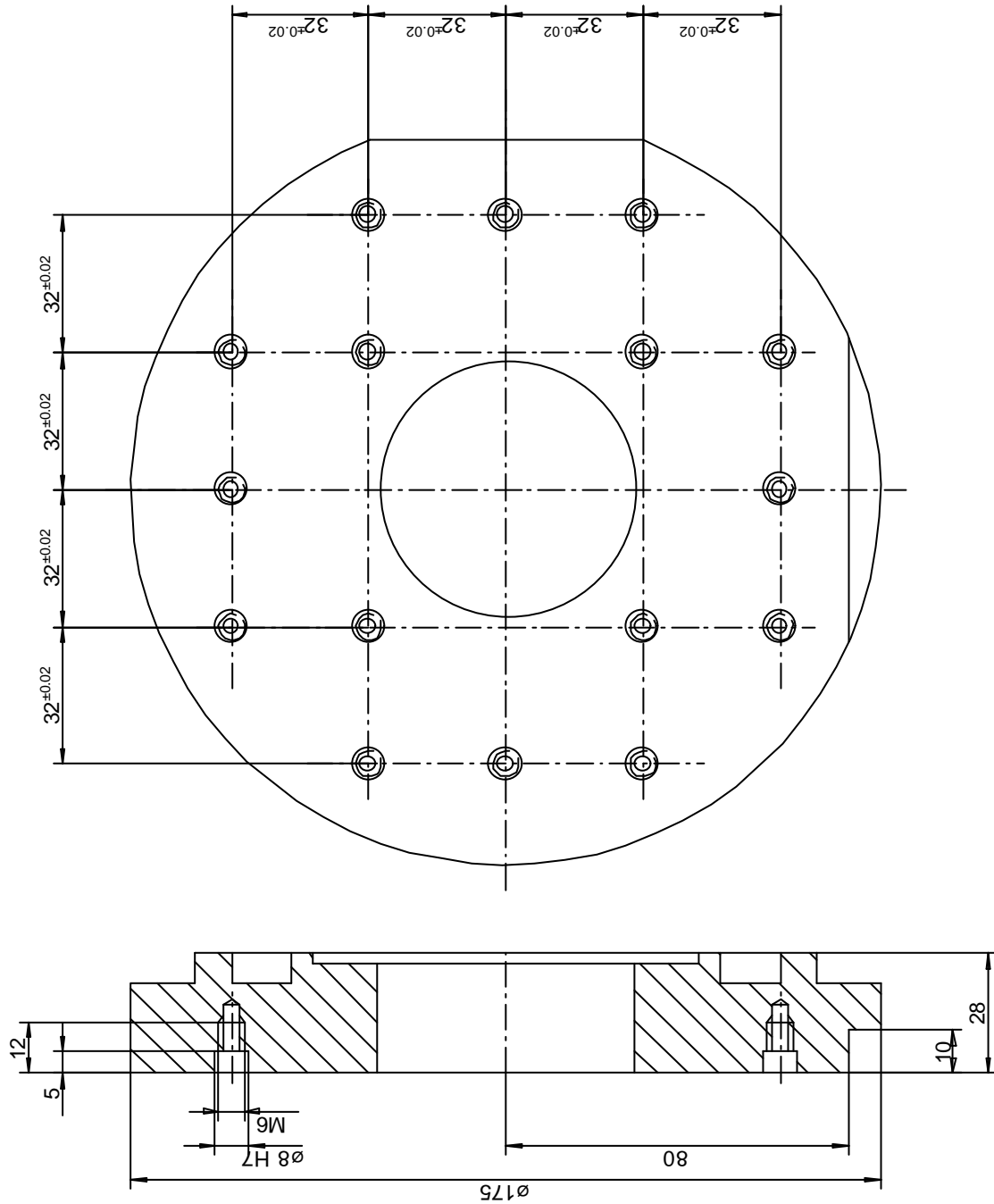
Pointing: ±0.25° maximum pointing error (±0.1° typical, after several days
of operation during good weather conditions)

7. Appendices

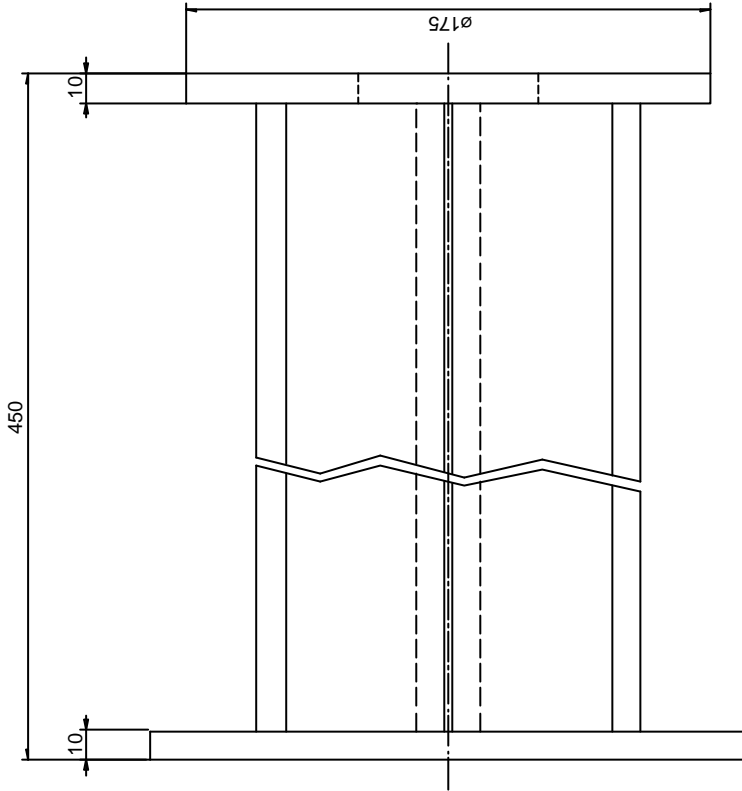
A1. INTRA Mechanical Dimensions



A2. Drawing of Mounting Flange

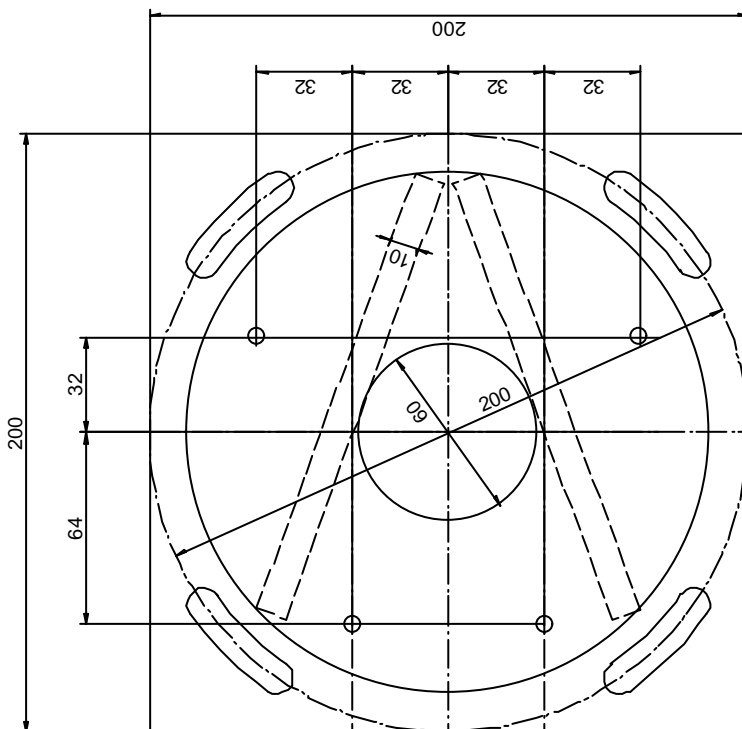


A3. Suggested Mounting Pods for INTRA

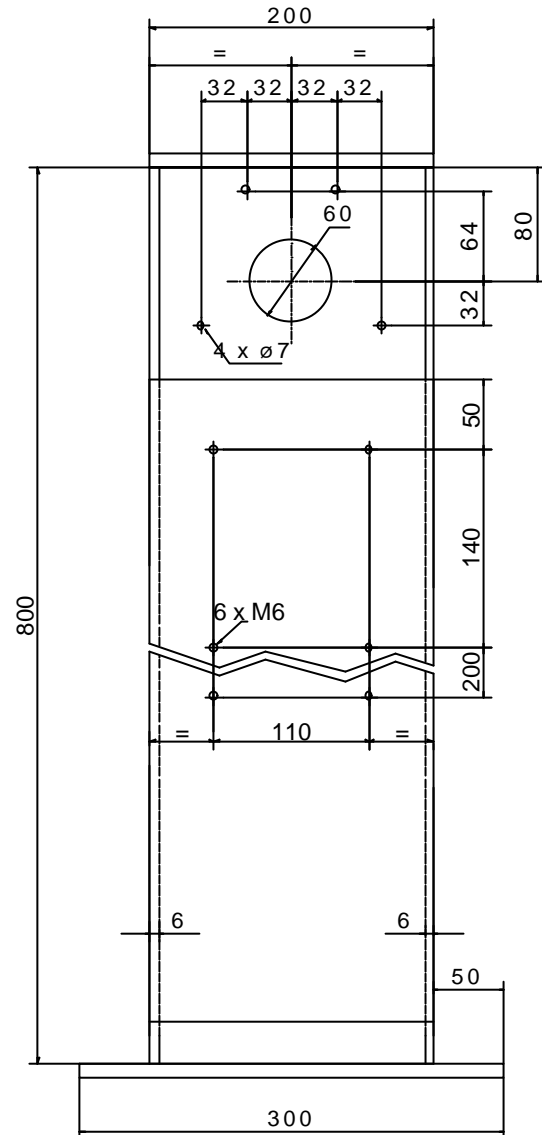
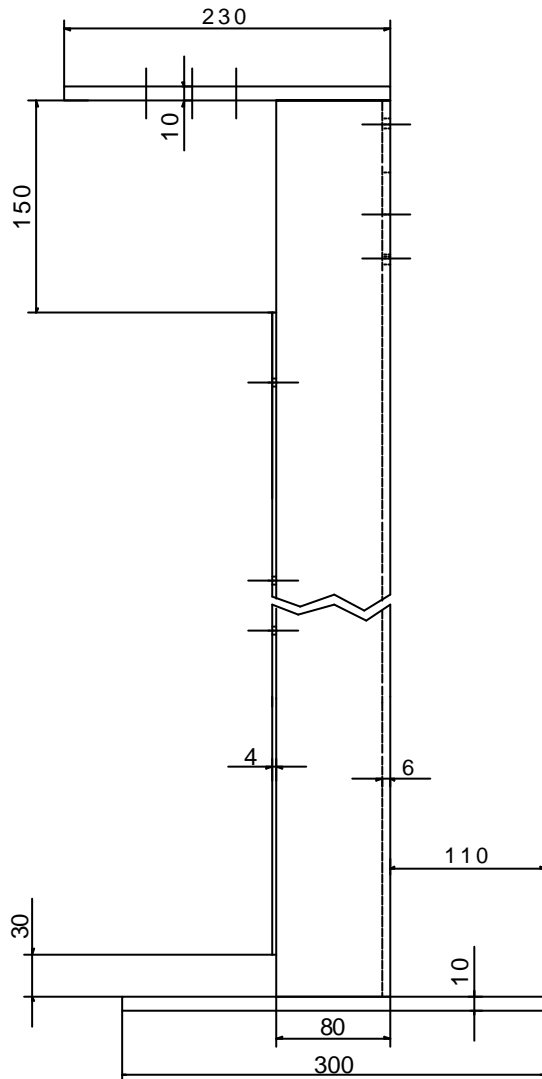


Finish: anodised

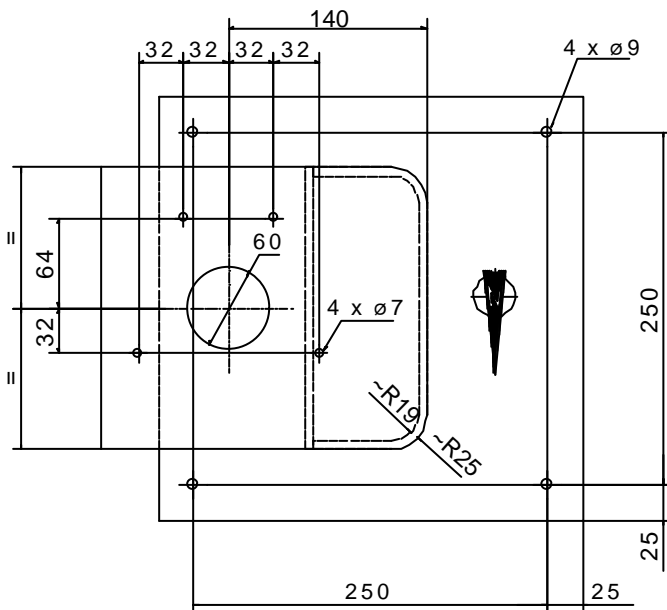
Assembly: Welded or with screws inbus M6x30 (stainless steel)



Mounted on concrete-base. Fixation with 4 threaded bars (M10). Bars molded into base. Provide for proper grounding of Tracker Pod (copper wire 5mm to ground).



Material: Stahl, feuerverzinkt
alle Verbindungen geschweisst



A4. Summary of Monitor - Commands

- L cLock menu----- | T set Time
 | D set Date
 | R Read clock
 | Y crYstal adj. **
 | V saVe
- T Temperature
- C Communication----- | S Select serial
 | B Baudrate
 | F data Format
 | P Parity
 | O shOw settings
 | V saVe
- S Sun monitor----- | R Read buffer
 | F Fill buffer
 | C Clear buffer
 | N Number of entries
 | E clear Entry
 | S Show sun intensity
 | P Parameter----- | P show Parameter
 | O Offsets quadr. **
 | R iRange **
 | I I0 **
 | S Sigma **
 | F Factor **
 | C Criterion **
 | V saVe
- I Installation----- | S Site parameter
 | O shOw parameter
 | A Alignment parameter **
 | I Init-mode
 | R Range **
 | C Correct. mode----- | N No correction
 | T Time correction
 | A Angle correction
 | C angle and time Correction
- | M Mounting **----- | V Primary axis Vertical
 | T Primary axis vertical, 180° turned
 | H Primary axis Horizontal
- | V saVe
- P tracker Parameter----- | O axis Offsets **
 | S Show parameter
 | F search Flags

D Driver menu-----	E trans. Errors-----	C Clear counters
	S Set speed **-----	A primary axis
		E secondary axis
	P show Position	
	F redeFine Pos **	
	D Drive test	
	M Manual rotate-----	I sec. cw
		J prim. cw
		L prim. ccw
		M sec. ccw
	I Index error-----	R Reset values
	R dRive status	
	O show vOltage	
	G Gain **-----	S Show gain
		G Gain pos. cntr.
		A gAin speed cntr.
		V saVe gain

N load New program **

O Outputs-----		S Show setting
	E Enable/disable	
	P set Parameter	
	T set Trigger	
	C set sep. Char	
	L set Label	
	V saVe	

A show lAst event entry

E Eeprom-----	R Restore eeprom
	D Dump eeprom
	O shOw serial nbr
	S define Serial nbr**
	V saVe

V saVe all to EEPROM

W passWord

** means command is password-protected

A5. INTRA Electrical Interface Drawing and Wiring Diagram

A6. INTRA Component Locations on Controller Board