

Arduino Due (Programing Port) program to command azimuth and elevation antenna motors to track space objects. Works with any type of motors.

INTRODUCTIONS-

This is a CT4BB program that uses ARDUINO's open-source libraries to read SD cards, RTC Watch, I2C, SPI, etc. The system is designed to track DSN spacecraft probes and celestial objects using Horizons NASA's Ephemeris @ <https://ssd.jpl.nasa.gov/horizons.cgi#top> The data from this site is in txt and are printed in files with the name of the space objects. Ex: Copy Sun data and paste it in the SD card as SUN.txt, and Mars Reconnaissance Orbiter (MRO) data and save it in the SD card as MRO.txt.

The angle position are mapped in voltages(0->5V) to 0-> 4095 bytes using 12 bits resolution of ARDUINO DUE so, in must put on the Setup the instruction `analogReadResolution(12)`.

The model of the (ARDUINO DUE Programming Port) used does not AutoStart when the voltage is applied. To fix this, you must solder a surface mount resistor (0603 size) or 1/4W tubular onto the board: solder a 10k resistor between the ERASE line and + 3.3V, close to Fet T3.

In practice, solder it across the 2 upper pins of T3.

<https://forum.arduino.cc/index.php?topic=256771.60>

Arduino due is 3.3 V logic. To connect with I2C LCD or RTC1307 with Logic 5V, a bidirectional voltage converter is required. The SD Card reader is 3,3V Logic but feed with 5V DC

External Pullup resistors of 5K must be placed to stabilize the digital inputs of pins 3,5,6,7 and 13, because the internal Pullup resistors of ARDUINO DUE are 50K and this high value causes instability and errors in the readings caused by induced noise, namely alternating current.

SYSTEM WORKING –

1 - The tracking system will only work when RTC date equals the recorded Ephemeris, because it will compare the actual date with the date of the Object Ephemeris in the SD card.

If the dates are equal, it will read all file in the SD. Next, operator must choose an object on the Menu with a single Button click, wait for object and select it. After selecting object all data of time and azimuth/Elevation will be read.

Now, the LCD will show alternately two frames: First frame- the name of the object, antenna offset the azimuth and the elevation in Second frame: Date and UTC time.

2 – Every minute the system reads the data file of the object and checks if the time is equal to RTC time. If time it is equal it reads the azimuth and the elevation. Then, compares these values with the previous Azimuth and Elevation to decide to go on CCW or CW exciting respective motor. Motors will run driving a multiturn potentiometer, with pre-calibrate voltages that are mapped to the angles. Motors will stop @ that precise Voltage/angle.

3 – A calibration must be made if you change mechanical hardware.

Normally it is only necessary to do it once. Calibration will make the motors of the Az and El to run from the minimum angle/voltage (0 °) where the microswitch is activated (on to off) to stop and after, motors will travel to the maximum angle/voltage (90° or 360°) to switch (on to off) the end microswitch to stop movement. (Microswitches are Normally Closed).

The azimuth switches must be placed collinear in the same plane, because the 0° coincides with 360°. The microswitches or reed relays are normally closed contacts. Its opening places 3,3 voltage on pins 3, 5, 6, 7 that are powered by Pullups. This high logic level causes the Rotors to stop.

Note: It is possible to use only two microswitches (one for each motor) but this implies a change in the software due to the existence of a protection instruction intended to stop the motors in case the potentiometer reading fails. Motors will continue in permanent motion! A stop is needed which is done by the end microswitches. With some study and changes in the software it is possible to use only 2 microswitches but we think that the mechanical process is more effective and accurate using 4 microswitches.

HARDWARE-

The pinout used on the Arduino Due is as follows:

Pin 11 digital OUTPUT: CCW control of Elevation motor

Pin 10 digital OUTPUT: Elevation motor CW command

Pin 8 digital OUTPUT: Azimuth engine CW command

Pin 9 digital OUTPUT: Azimuth motor CCW command

Digital pin 7 INPUT_PULLUP: Elevation end limit switch sensor 90°

Digital pin 6 INPUT_PULLUP: Elevation start switch sensor 0°

Digital pin 5 INPUT_PULLUP: Azimuth end limit switch of 360°

Digital pin 3 INPUT_PULLUP: Azimuth start switch sensor of 0°

Digital Pin 13 INPUT_PULLUP: Clicks of the Menu Button (single click, double click or long press).

Connections of 6 Pin IDC for SPI located in the middle of ARDUINO DUE to communicate with SD Card

IDC SPI-Pin 1 pin (dot or number 1) is digital MISO .

IDC SPI-Pin 2 Not used,

IDC SPI- Pin 3 SCK Clock communication with SD CARD.

IDC SPI- Pin 4 MOSI.

IDC SPI- Pin 5 RESET Not used

IDC SPI- Pin 6 GND Not used

Digital pin 4 CS (Chip select) for SPI communication with SD CARD

Analog A4 pin SDA for I2C communications RTC Watch DS1307 and I2C LCD

Analog A5 SCL pin for I2C communications RTC Watch DS1307 and I2C LCD

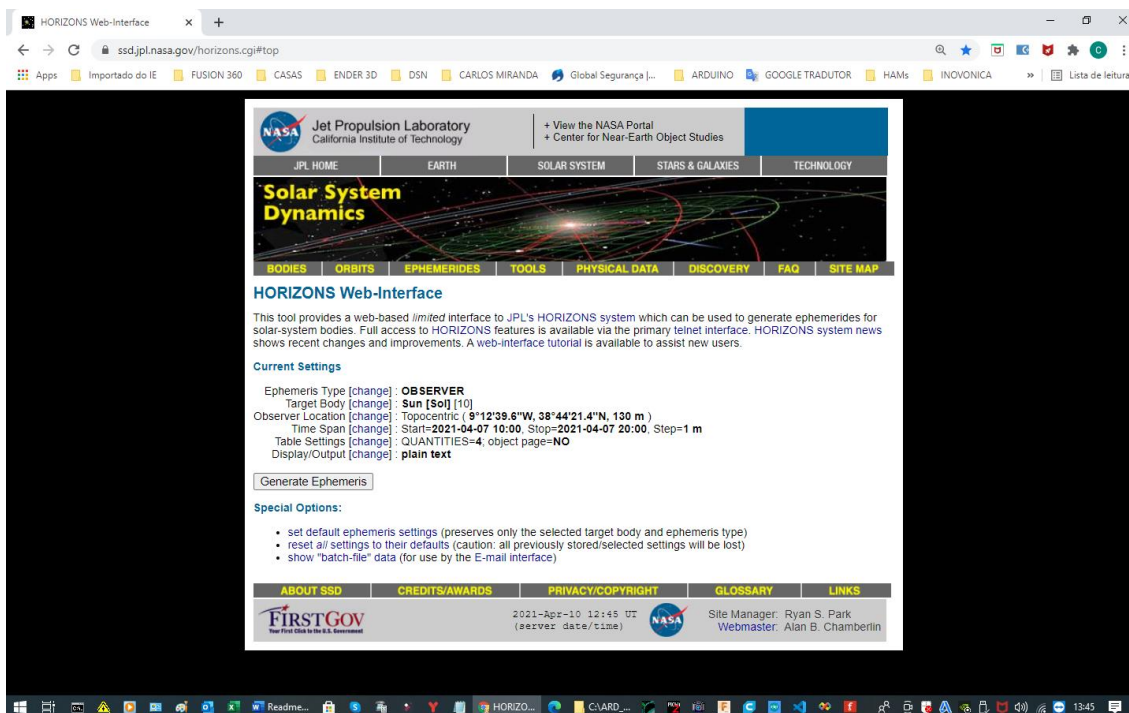
Analog A0 pin INPUT for analyzing the voltage of the azimuth potentiometer

Analog A1 pin INPUT for analyzing the voltage of the elevation potentiometer

How get and format data from NASA Horizons Ephemeris to put in the SD Card:

1 – Go to the site <https://ssd.jpl.nasa.gov/horizons.cgi#top>

2 - Fill the Page with your requirements



3 - Open the Table Settings and check as shown

Table Settings

Select observer quantities from table below:
[switch to manual-entry list-of-numbers form]

Use Settings Below Cancel

Optionally preset observer quantities selection using one of the following:
planets satellites small-bodies default all none

1. ☐ Astrometric RA & DEC
2. ☐ Apparent RA & DEC
3. ☐ Rates; RA & DEC
4. ☒ Apparent AZ & EL
5. ☐ Rates; AZ & EL
6. ☐ Satellite X & Y, pos. angle
7. ☐ Local apparent sidereal time
8. ☐ Airmass & extinction
9. ☐ Visual mag. & Surface Bright
10. ☐ Illuminated fraction
11. ☐ Defect of illumination
12. ☐ Satellite angular separ./vis.
13. ☐ Target angular diameter
14. ☐ Observer sub-lon & sub-lat
15. ☐ Sun sub-longitude & sub-latitude
16. ☐ Sub-Sun position angle & distance
17. ☐ North Pole position angle & distance
18. ☐ Heliocentric ecliptic lon. & lat.
19. ☐ Heliocentric range & range-rate
20. ☐ Observer range & range-rate
21. ☐ One-way (down-leg) light-time
22. ☐ Speed wrt Sun & observer
23. ☐ Sun-Observer-Target ELONG angle
24. ☐ Sun-Target-Observer ~PHASE angle
25. ☐ Target-Observer-Moon angle/ Illum%
26. ☐ Observer-Primary-Target angle
27. ☐ Sun-Target radial & -vel pos. angle
28. ☐ Orbit plane angle
29. ☐ Constellation ID
30. ☐ Delta-T (TDB - UT)
31. ☐ Observer ecliptic lon. & lat.
32. ☐ North pole RA & DEC
33. ☐ Galactic longitude & latitude
34. ☐ Local apparent SOLAR time
35. ☐ Earth->obs. site light-time
36. ☐ RA & DEC uncertainty
37. ☐ Plane-of-sky error ellipse
38. ☐ POS uncertainty (RSS)
39. ☐ Range & range-rate 3-sigmas
40. ☐ Doppler & delay 3-sigmas
41. ☐ True anomaly angle
42. ☐ Local apparent hour angle
43. ☐ PHASE angle & bisector
44. ☐ Apparent longitude Sun (L_s)
45. ☐ Inertial apparent RA & DEC
46. ☐ Rate: Inertial RA & DEC

Notes:
* affected by optional atmospheric refraction setting (below)
> statistical value that uses orbit covariance if available

Observer quantities are described in the [HORIZONS documentation](#).

Use Selected Settings Cancel

Optional observer-table settings:

date/time format: calendar date/time -- display date/time in year-month-day and/or Julian-day format

> statistical value that uses orbit covariance if available

Observer quantities are described in the [HORIZONS documentation](#).

Use Selected Settings Cancel

Optional observer-table settings:

date/time format:	calendar date/time	-- display date/time in year-month-day and/or Julian-day format
time digits:	minutes (HH.MM)	-- controls output precision of time
angle format:	hours/degrees minutes seconds	-- select RA/Dec output format
output units:	km & km/s	-- units for most output quantities
range units:	astronomical units	-- units for range-type quantities
refraction model:	airless model (no refraction)	-- select atmospheric refraction model
airmass cut-off:		-- suppress output when airmass is greater than limit [1 to 38]
elevation cutoff:		(deg) -- suppress output when object elevation is less than limit [-90 to 90]
solar elong. cut-off:		(deg) -- suppress output when solar elongation is outside (min,max) range [0 to 180, min to 180]
hour angle cutoff:		(h) -- suppress output when the local hour angle (LHA) exceeds value [0 to 12]
angular rate cutoff:		(arcsec/h) -- suppress output when the RA/Dec angular rate exceeds this value [0 to 100000]
suppress range-rate:	<input type="checkbox"/>	-- suppress range-rate for range/range-rate output
skip daylight:	<input type="checkbox"/>	-- suppress output during daylight
extra precision:	<input type="checkbox"/>	-- output additional digits for RA/Dec quantities
RTS flag:	disable	-- output data only at target rise/transit/set (RTS)
reference system:	ICRF/J2000.0	-- reference frame for geometric and astrometric quantities
CSV format:	<input type="checkbox"/>	-- output data in Comma-Separated-Values (CSV) format
object page:	<input type="checkbox"/>	-- include object information/data page on output

Use Settings Above Default Optional Settings Cancel

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FIRSTGOV 2021-Apr-10 13:08 UT (server date/time) Site Manager: Ryan S. Park Webmaster: Alan B. Chamberlin

4 - Click Use Selected Settings

5 - Select Target Body (Sun, Moon, MRO, Perseverance, Parker Solar Probe, etc)

6 - Click Generate Ephemeris

7 – You get:

```
https://ssd.jpl.nasa.gov/horizons: X +
ssd.jpl.nasa.gov/horizons.cgi#results

*****
Ephemeris / MMW_USER Sat Apr 10 05:53:55 2021 Pasadena, USA / Horizons
*****
Target body name: Sun (10) {source: DE431mx}
Center body name: Earth (399) {source: DE431mx}
Center-site name: (user defined site below)
*****
Start time : A.D. 2021-Apr-07 10:00:00.0000 UT
Stop time : A.D. 2021-Apr-07 20:00:00.0000 UT
Step-size : 1 minutes
*****
Target pole/equ : IAU_SUN {East-longitude positive}
Target radii : 696000.0 x 696000.0 x 696000.0 k {Equator, meridian, pole}
Center geodetic : 350.780000,38.7392780,0.1300000 {E-lon(deg),Lat(deg),Alt(km)}
Center cylindric : 350.780000,4901.59225,3969.8637 {E-lon(deg),Dxy(km),Dz(km)}
Center pole/equ : High-precision EOP model {East-longitude positive}
Center radii : 6378.1 x 6378.1 x 6356.8 km {Equator, meridian, pole}
Target primary : Sun
Vis. InterFerra : HDQM (R_eq= 1737.400) km {source: DE431mx}
Rel. light bend : Sun, EARTH {source: DE431mx}
Rel. light bnd GH: 1.3271E+11, 3.9806E+05 km^3/s^2
Atmos refraction: NO (AIRLESS)
RA format : HMS
Time format : CAL
RTS-only print : NO
EOP file : eop.210409.p210701
EOP coverage : DATA-BASED 1962-JAN-20 TO 2021-APR-09. PREDICTS-> 2021-JUN-30
Units conversion: 1 au= 149597870.700 km, c= 299792.458 km/s, 1 day= 86400.0 s
Table cut-offs 1: Elevation (-90.0deg=NO ),Airmass (>38.000=NO), Daylight (NO )
Table cut-offs 2: Solar elongation ( 0.0,180.0=NO ),Local Hour Angle( 0.0=NO )
Table cut-offs 3: RA/DEC angular rate ( 0.0=NO )
*****
Date_(UT)_HR:MM Azl(a-appr) Elev
*****
$$$$$
2021-Apr-07 10:00 *m 121.1037 42.1810
2021-Apr-07 10:01 *m 121.3518 42.3480
2021-Apr-07 10:02 *m 121.6011 42.5145
2021-Apr-07 10:03 *m 121.8517 42.6806
2021-Apr-07 10:04 *m 122.1034 42.8463
2021-Apr-07 10:05 *m 122.3564 43.0115
2021-Apr-07 10:06 *m 122.6107 43.1762
2021-Apr-07 10:07 *m 122.8662 43.3404
2021-Apr-07 10:08 *m 123.1229 43.5042
```

8- Select data columns with Date Azimuth and Elevation o object like this

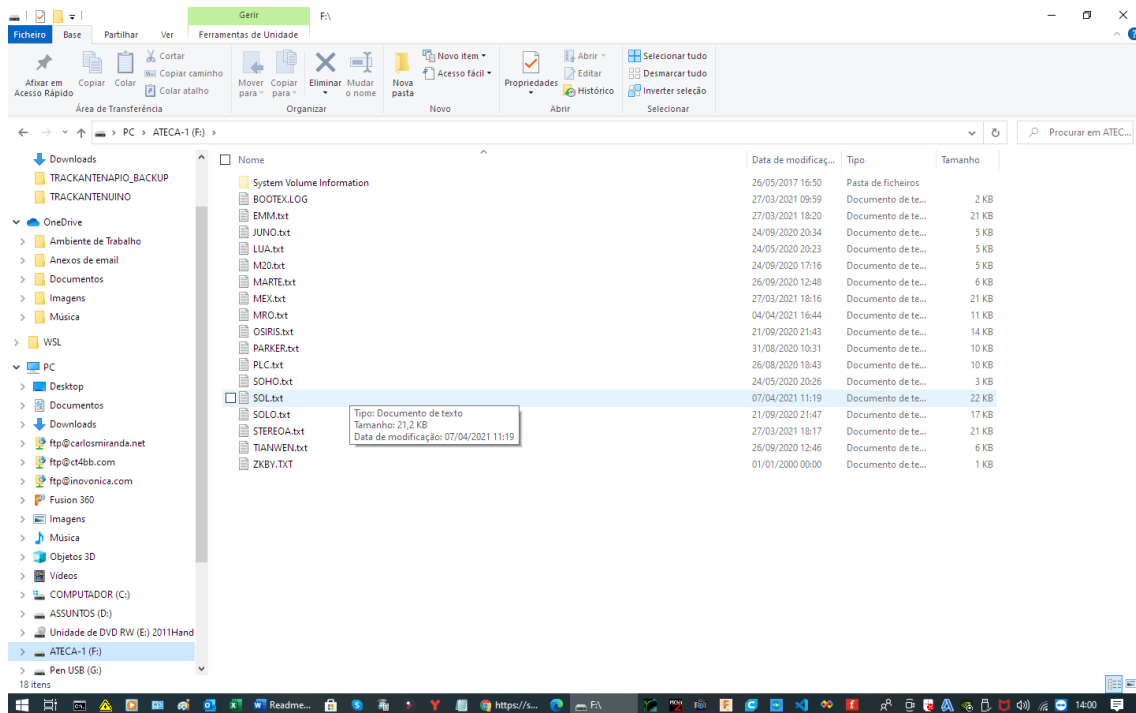
```
https://ssd.jpl.nasa.gov/horizons: X +
ssd.jpl.nasa.gov/horizons.cgi#results

RTS-only print : NO
EOP file : eop.210409.p210701
EOP coverage : DATA-BASED 1962-JAN-20 TO 2021-APR-09. PREDICTS-> 2021-JUN-30
Units conversion: 1 au= 149597870.700 km, c= 299792.458 km/s, 1 day= 86400.0 s
Table cut-offs 1: Elevation (-90.0deg=NO ),Airmass (>38.000=NO), Daylight (NO )
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*****
$$$$$
2021-Apr-07 10:00 *m 121.1037 42.1810
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2021-Apr-07 10:02 *m 121.6011 42.5145
2021-Apr-07 10:03 *m 121.8517 42.6806
2021-Apr-07 10:04 *m 122.1034 42.8463
2021-Apr-07 10:05 *m 122.3564 43.0115
2021-Apr-07 10:06 *m 122.6107 43.1762
2021-Apr-07 10:07 *m 122.8662 43.3404
2021-Apr-07 10:08 *m 123.1229 43.5042
2021-Apr-07 10:09 *m 123.3818 43.6675
2021-Apr-07 10:10 *m 123.6403 43.8303
2021-Apr-07 10:11 *m 123.9009 43.9927
2021-Apr-07 10:12 *m 124.1628 44.1545
2021-Apr-07 10:13 *m 124.4261 44.3158
2021-Apr-07 10:14 *m 124.6907 44.4767
2021-Apr-07 10:15 *m 124.9566 44.6370
2021-Apr-07 10:16 *m 125.2238 44.7968
2021-Apr-07 10:17 *m 125.4925 44.9560
2021-Apr-07 10:18 *m 125.7625 45.1148
2021-Apr-07 10:19 *m 126.0338 45.2730
2021-Apr-07 10:20 *m 126.3066 45.4306
2021-Apr-07 10:21 *m 126.5808 45.5877
2021-Apr-07 10:22 *m 126.8564 45.7443
2021-Apr-07 10:23 *m 127.1334 45.9003
2021-Apr-07 10:24 *m 127.4119 46.0557
2021-Apr-07 10:25 *m 127.6918 46.2105
2021-Apr-07 10:26 *m 127.9732 46.3648
2021-Apr-07 10:27 *m 128.2560 46.5184
2021-Apr-07 10:28 *m 128.5404 46.6715
2021-Apr-07 10:29 *m 128.8262 46.8240
2021-Apr-07 10:30 *m 129.1135 46.9758
2021-Apr-07 10:31 *m 129.4024 47.1270
2021-Apr-07 10:32 *m 129.6927 47.2776
2021-Apr-07 10:33 *m 129.9846 47.4276
```

This will track the object between 10:00 and 10:30 AM UTC @ 21 Apr 07

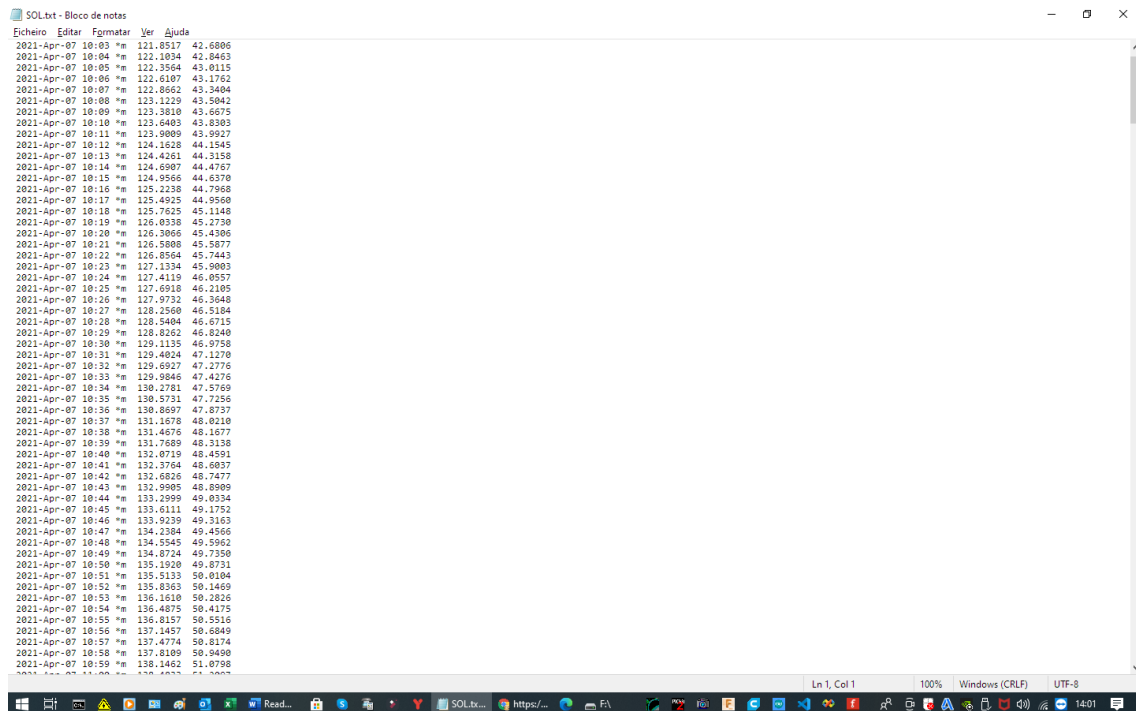
Copy this and put on the SD Card inside a folder with the object name.

Like this SD Card shows some txt files where to paste the data:



Data is from SOL (Sun), so, open the folder SOL.txt (Sun.txt) and paste inside.

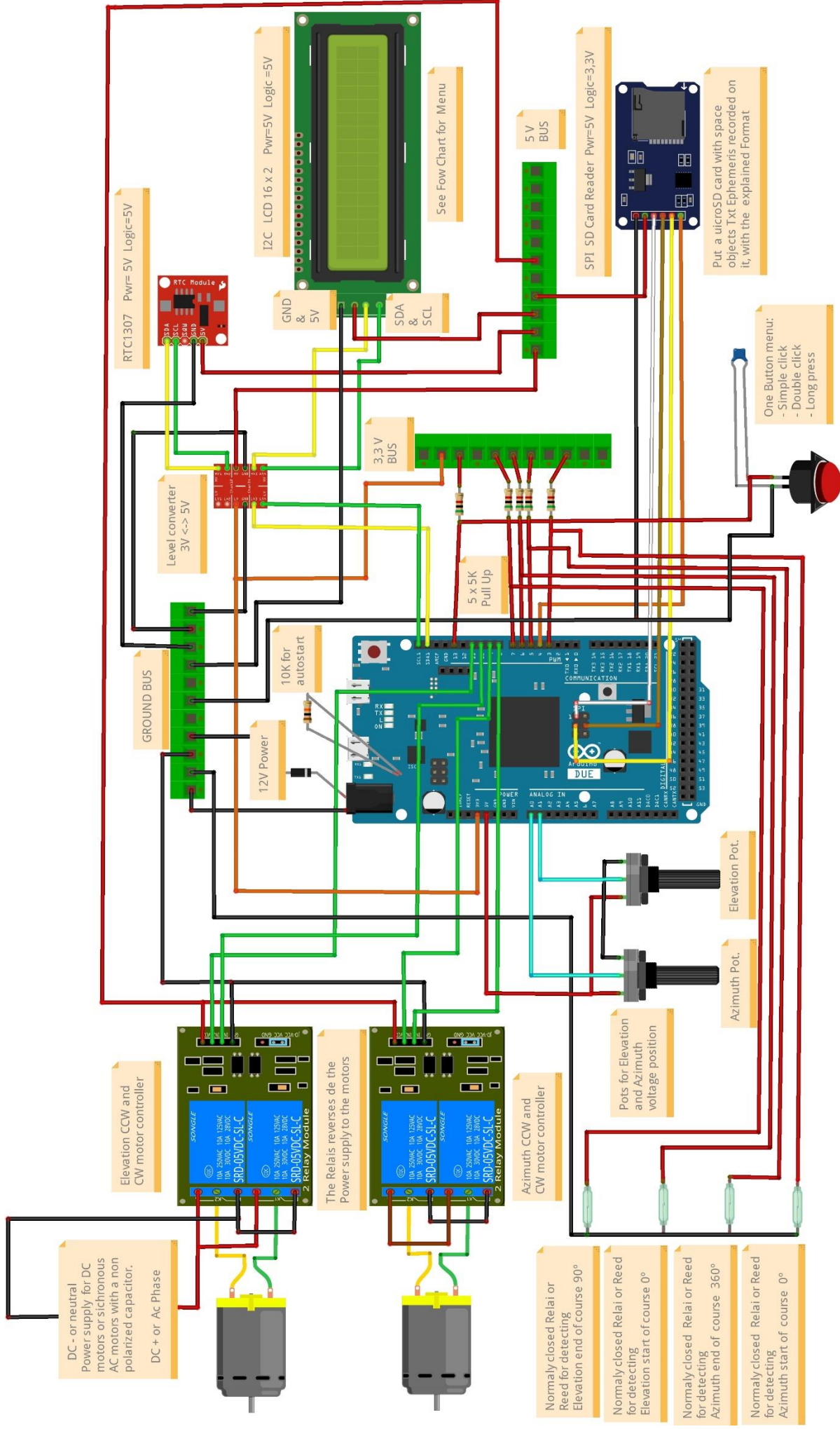
Remember the first column must be a space!

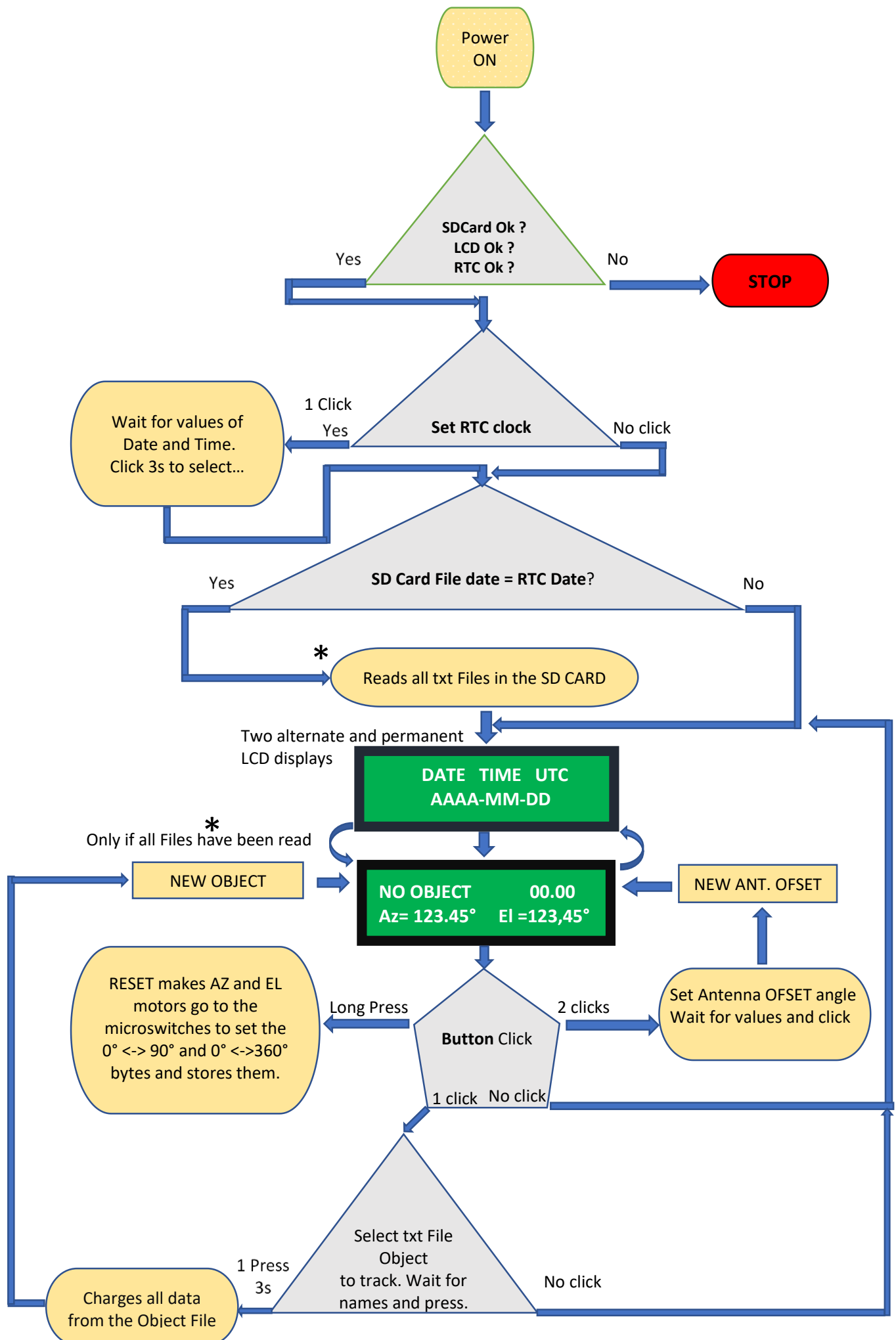


Save.

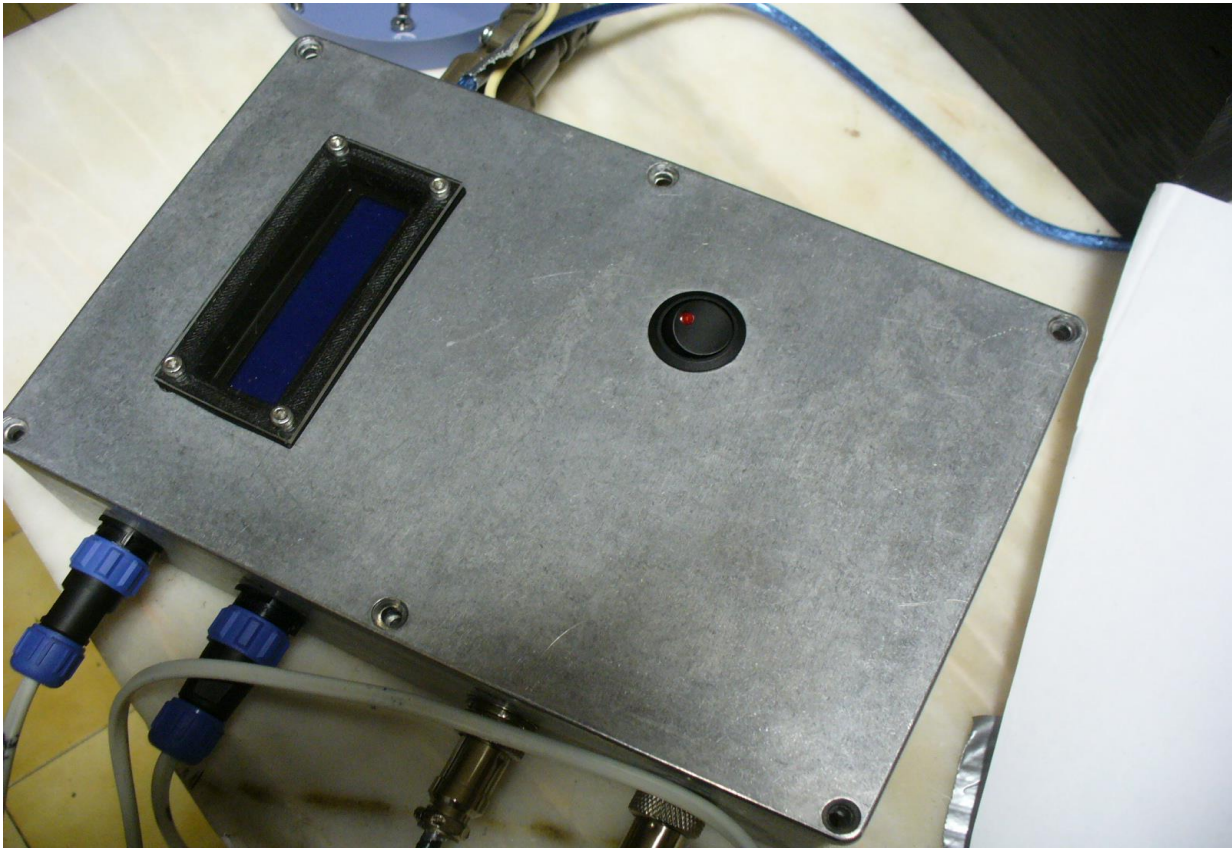
Do the same for all the objects you want to track on a specific day

Put the card in the Tracker and follow the menu to set the clock if needed, to select the object, and antenna offset. Wait for the automatic commands...

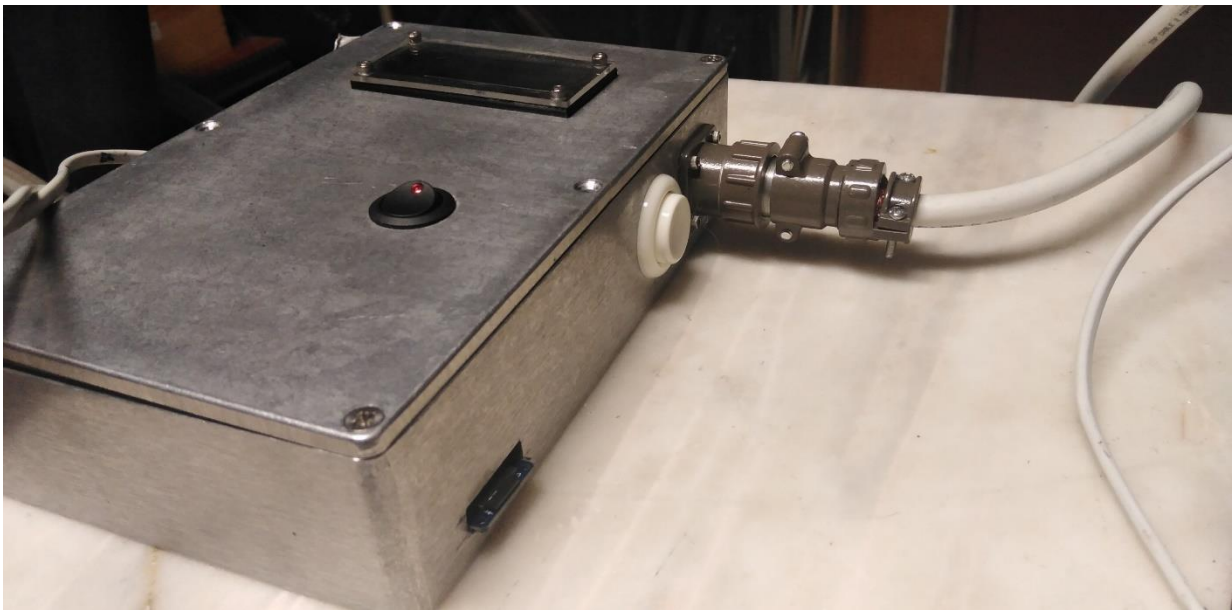




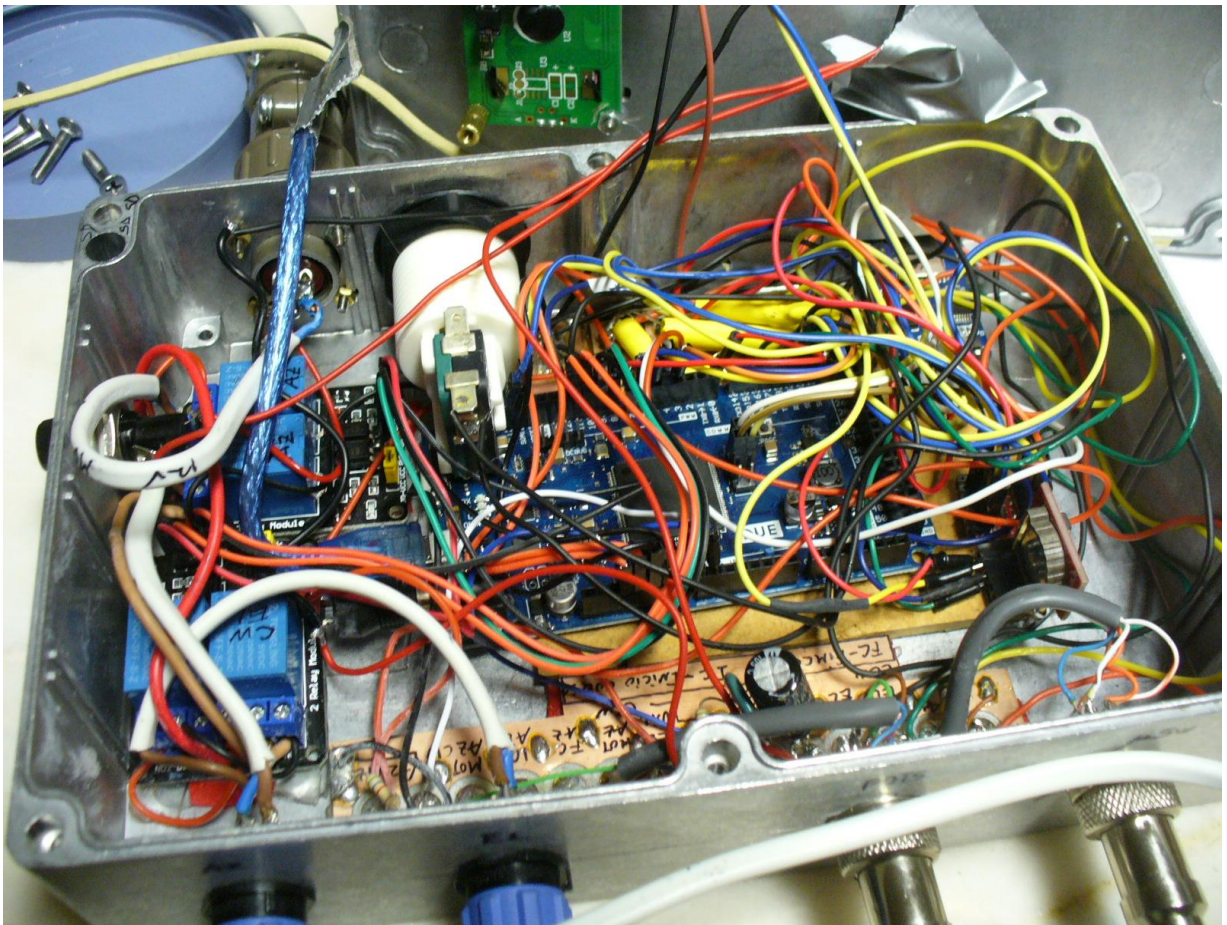
Flow chart Menu



Panel, ON/Off switch AZ/EL and micro-switches connectors



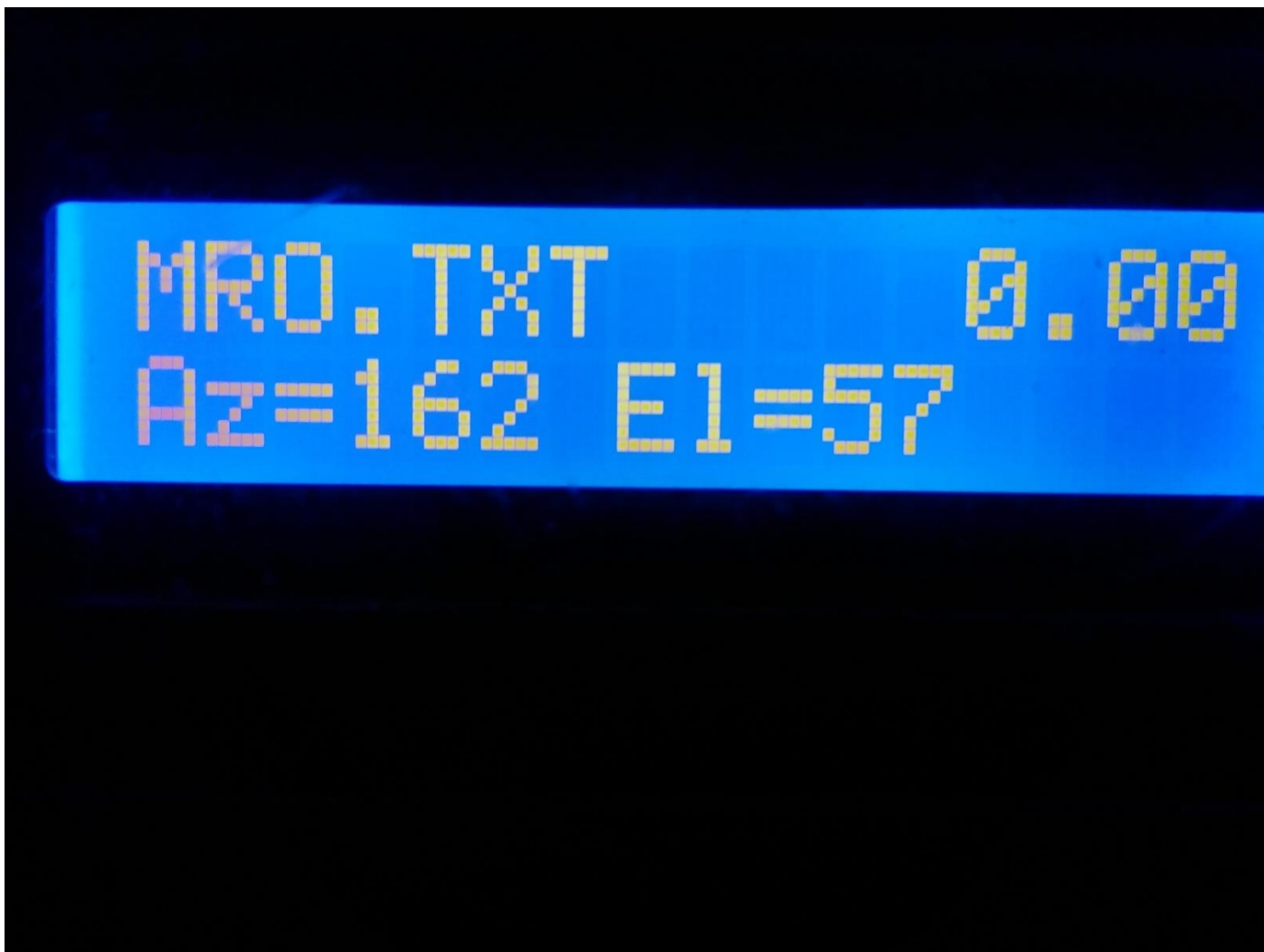
- Connector for ARDUINO 12 V and AC or DC Power for motors
- One robust button for Menu
- Micro-SD Card Slot



Inside the Mule Prototype



Date Time screen



OBJECT Name, OFFSET, Azimuth and Elevation @ the Time of previous screen



3D printing Elevation and Azimuth rotators to test the Tracker.

With this white plate and the rod shadow, it got a zero shadow in one hour of tracking the Sun.

More tests are now underway with a set of two-rotor type CDR Master Rotors @ 24 V AC and a 200 uF condenser without polarity to reverse the moving direction of the synchronous motors.

Good work and 73

CT4BB

Carlos