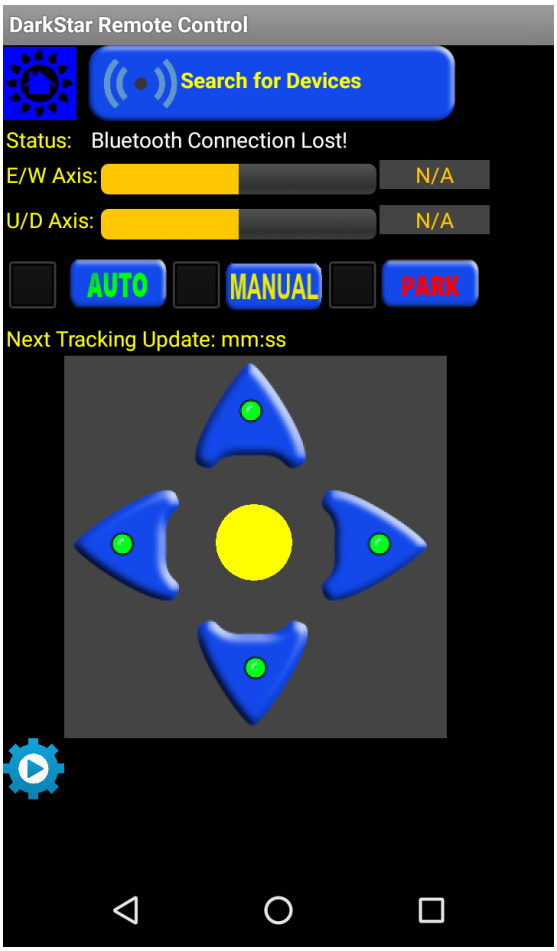
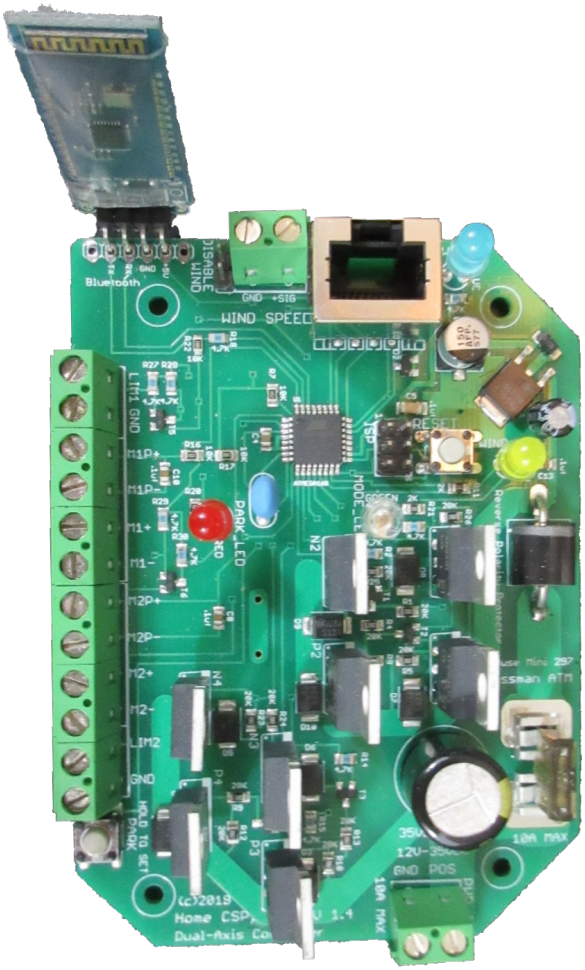
Home CSP, Inc.

Trackers and electronics for home solar energy

www.homecsp.com





DARK STaR v2.1

Dual-Axis Solar Tracker with Bluetooth Control

Home CSP, Inc.
www.homecsp.com

Dark Star – dual axis controller version 2.1a

Thanks for purchasing your **Dark Star** controller from Home CSP Inc. The **Dark Star** provides the most advanced yet simple and effective solution for dual-axis solar tracking with common satellite linear actuators and other various small DC motors.

Important: Adjust actuator limit switches prior to connecting the controller!

Specifications

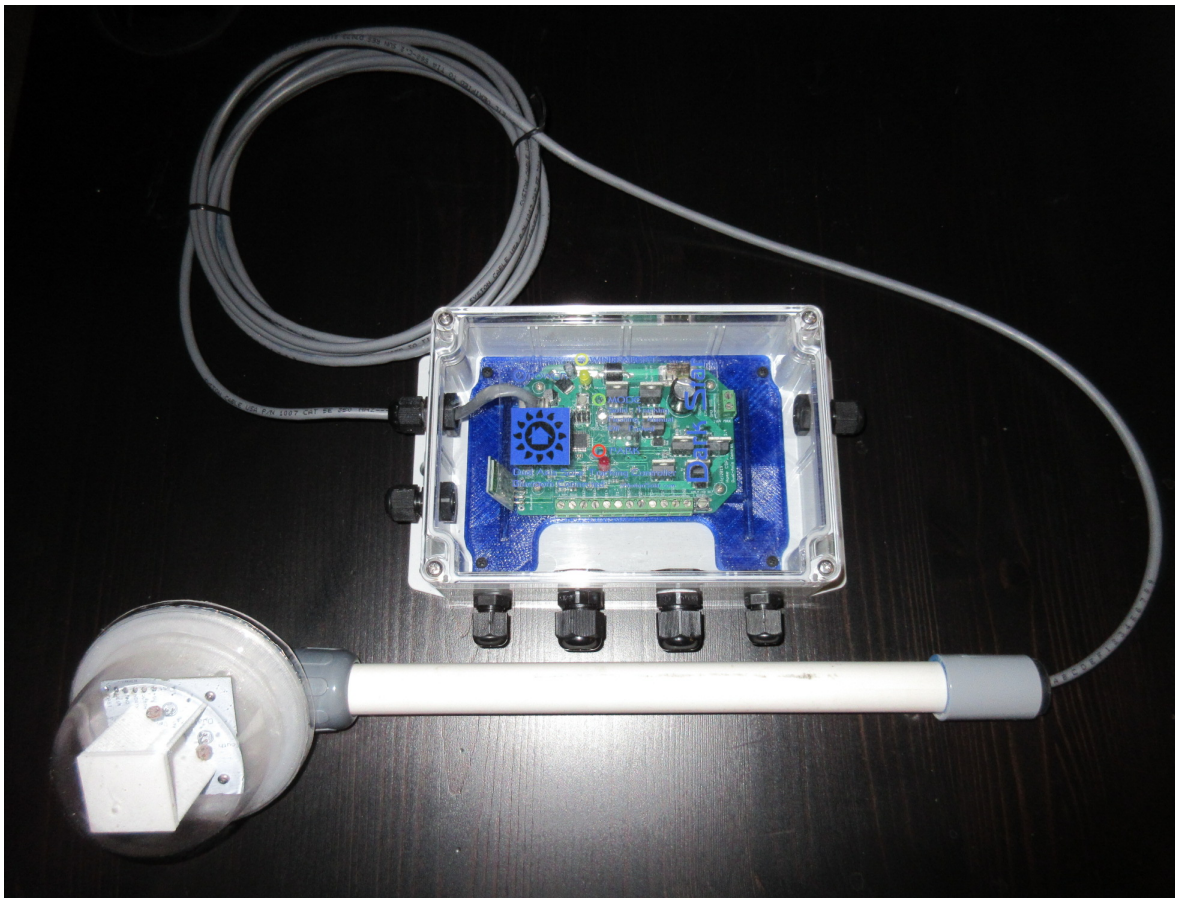
Voltage:	30v dc max, 12-24 recommended
Max Current:	10A, fuse protected, reverse polarity protected
Tracking Period:	1-60 minutes
Motor Stall Period:	0.1 – 2.0 seconds
Max Motor Run:	10 minutes
Motor Driver:	2 H-Bridge drivers for DC Brushed type motors
Max Motor Current::	10A @12v, 7A @24V
Max Motor Wattage:	175W, <150 watts recommended
Park Delay:	5-120 minutes
R/C:	Bluetooth V2.0, Android Application

Before You Get Started!

- **Take a couple minutes to read this manual and familiarize yourself with the concepts.**
- **Low Voltage DC won't kill you but you always need to be safe with electricity. Use a voltmeter to verify proper voltage and polarity before making connections and always make sure power is off while making all wiring connections.**
- **Watch out for any issues associated with motor movement on your mount. Verify safe limit switch operation. Actuator motors are very strong and damage or destruction of your mount may result from improper mounting or limit adjustment!**
- **Be safe when working on a ladder and have an assistant whenever possible.**

- **Consult a licensed and qualified electrician if you have any questions about performing your electrical installation.**
- **Water can damage the controller electronics and void the warranty. Make sure the unit is appropriately protected from the weather! Our boards are sprayed with a special acrylic conformal coating which minimizes corrosion and increases moisture resistance, but does not make the board water proof.**

Dark Star Components



You're DarkStar Controller comes with the following items:

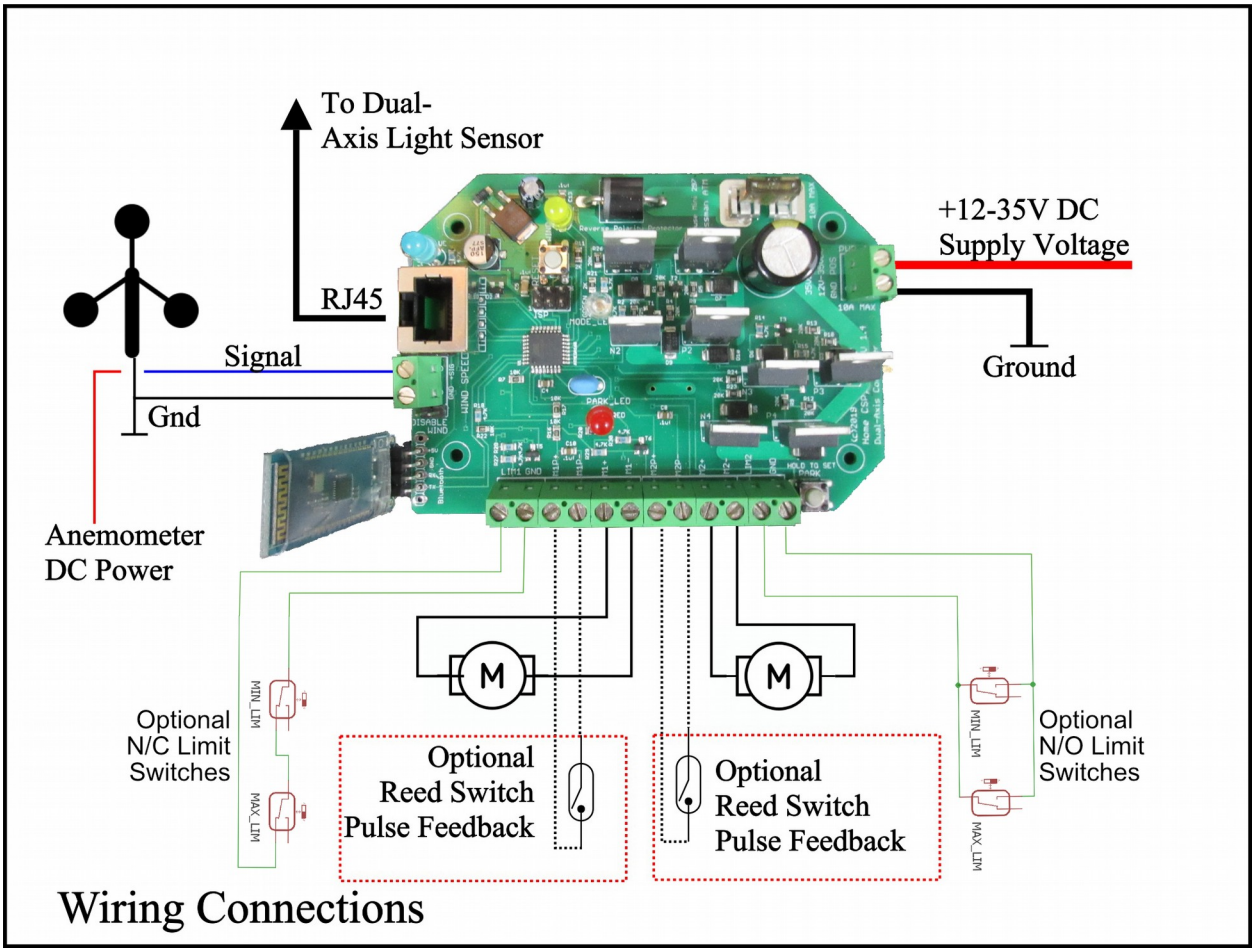
- Dark Star controller board
- Enclosure with 7 cable glands for sensor, motor, and power wires
- Dual Axis Sensor Module with 4m (13') cable

Tools You'll Need

- Wirestrippers/cutters
- Multimeter/Voltmeter
- #0 (~2.5mm) Small Flat Screw Driver

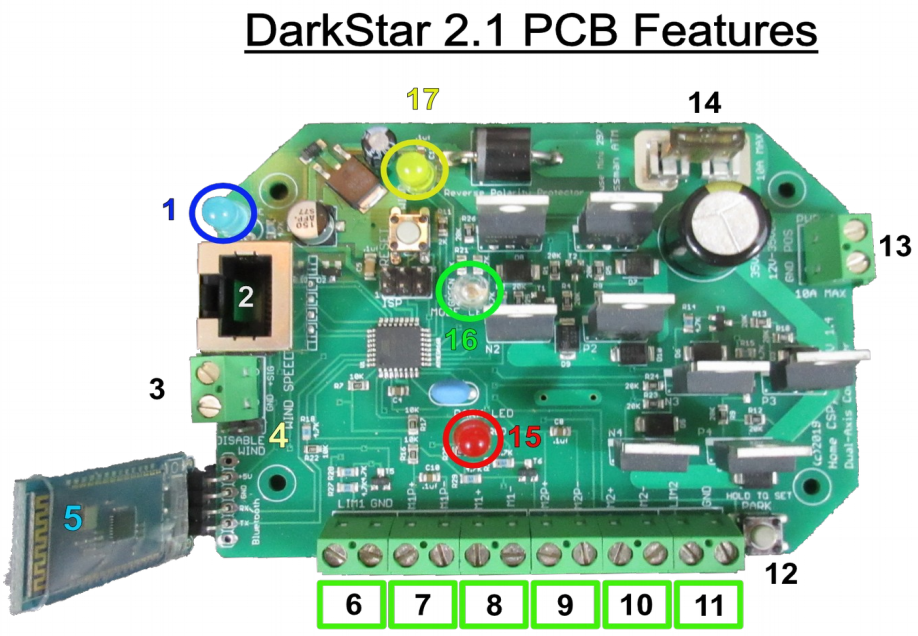
Depending on your installation requirements you may need other screws/tools to mount the controller/enclosure.

Sample Wiring Diagram



Connections should be made as per the illustrations for your system. Note that an additional fuse and/or power switch may be desirable or required in many applications. Please consult a qualified professional for advice on your specific application when in doubt.

PCB Features



1. **Power LED –** blue, indicates DC power to the unit
2. **Ext. Sensor Connector –** standard RJ45 8-wire connector used with Cat-5 cable
3. **Wind Sensor –** GND, and Signal terminals provide hookup to common analog output anemometers (0-4.7V max)
4. **East Inhib –** when jumper is enabled no eastward motor operations will be allowed during the day. The start of day east-return is the only exception
5. **Bluetooth Module –** receives signals for remote control
6. **Primary Axis Limit Switches –** N/C or N/O switches (series or parallel wired)
7. **Primary Axis Pulse Signal –** reed-switch or similar pulse-feedback signal
8. **Motor Terminals –** two screw terminals for each motor provide motor power output connections. #14 max to #20 wire minimum recommended.
9. **Secondary Axis Pulse Signal –** reed-switch or similar pulse-feedback signl

10. **Secondary Axis Motor Terminals –** provide power for elevation motor
11. **Secondary Axis Limit Switches**
12. **Park Button –** can be used both to control automatic/parked operation as well as for configuring the parking position.
13. **PWR Terminal –** DC input power to the controller and connected motors.
14. **Fuse –** a 10A max ATM type automotive fuse provides basic meltdown protection from short circuits.
15. **Park LED –** red LED indicates Park mode
16. **Mode LED –** green LED indicates system Auto (on), Manual (flashing), or Park status (off)
17. **Wind LED –** yellow LED indicates wind sensor high wind condition

Dual Axis Remote Sensor

The DarkStar comes with an external dual axis Cadmium sulfide based photo sensor. Resistance varies based on light. Voltage divider circuit provides a strong signal for longer wire runs, with less noise, and optimum ADC.

Custom PET plastic dome provides long lasting, light weight, weather protection as well as optimal optic presentation.

Clear enclosure minimizes operating temperature

3d printed light vane for optimum isolation of each sensor axis and accurate solar angle

1/2” 90 deg conduit connector facilitates easy mounting to array with zip tie or conduit clamp.

Standard Cat5 cable carries signal from 4 pairs of LEDs

Pin	Signal	T568B
1	+5V	W/Or
2	East	Or

Pin	Signal	T568B
3	Gnd	W/Gr
4	West	Blu
5	Gnd	W/Blu
6	North	Gr
7	Gnd	W/Brn
8	South	Brn

Two sensors at a 90 degree angle to each other for each axis form the core of the light sensor. A microprocessor compares the voltage difference between sides, and then controls a MOSFET based H-Bridge motor driver circuit. This allows the microprocessor to control the direction of the current through the motor, as the controller attempts to achieve a position where the voltage produced by the East/West and North/South sensors are balanced, and the solar array is optimally oriented.

Location: For a south facing panel in the northern hemisphere, the north-east corner of the array is the generally preferred location to mount the sensor. In the southern hemisphere, this becomes the south-east corner.

Tracking operation may be affected by various environmental factors such as trees, clouds, ground color, reflections, and other extraneous light factors. The voltage from the LEDs and the 10bit resolution of the ADCs limit the theoretical resolution to slightly better than 0.5 degrees. The **Dark Star** is primarily intended for PV tracking, and due to the factors mentioned, no minimum accuracy is appropriate.

Once light levels have fallen to “nighttime” levels, the **Dark Star** will wait about 10 minutes (to make sure it’s not a dark cloud, animal, solar eclipse or something else transitory), and then move to the park position. When light levels again return above the daylight tracking threshold, the **Dark Star** performs an East-return and resumes normal tracking operation again.

Enclosure Mounting Location

The **Dark Star** controller's enclosure should be typically mounted under the array on or near the main support pole – within reach of the supplied remote sensor cable.

A large industrial control panel type box is ideal for housing the tracking controller and power supply components.

Use of grommets for all thru-holes is recommended.

Zip tie wires and make sure enough slack is allowed where needed for full range of motor motion.

Extending the external sensor cable past 50' is not recommended due to signal loss with longer lengths as well as possible voltage drop with long motor wiring lengths.

First Time Operation

- **When first turned on, the controller will momentarily run each motor both ways – this is a very important test to show that everything works, and is also used to detect and enable appropriate motor functions.**
- **The primary axis motor (M1) should move West, then East, one second each way**
- **The secondary motor (M2) should move Down then Up.**
- **Turn off power and reverse motor leads if necessary to obtain proper behavior before proceeding!**
- **If pulse-feedback is detected, then:**
- **Primary axis will reset to east-return**
- **Secondary axis will reset to zenith position**
- **Jump a Pulse signal (M1P or M2P, + to -) for singe-axis mode**
- **The unit will pause for about 10 seconds before beginning automatic solar tracking**

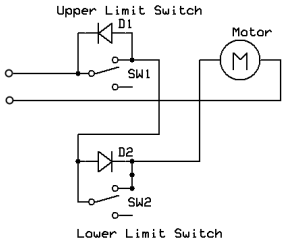
Note: When connecting with Dark Blue Android application during start-up, configuration data may be delayed till the motor reset procedure is complete. Status messages will still be provided during the start-up and initialization process.

Before Allowing Unattended Tracking:

- **It is highly recommended to either hold the Park button down for at least two seconds to engage the auto-scan process, or utilize the Dark Blue Android application to scan each axis**
- This verifies limit switch positions and mechanical limits
- This allows the controller to know the maximum pulse count at limit so that relative extension/position is known

Tracking Mount & Motor Selection

- Compatible with any dual-axis mount based on an Altitude-Azimuth, Equatorial, or Polar geometry.
- Compatible with most linear actuators and slew drives that are equipped with DC brushed permanent magnet motors.
- Typical primary axis rotation rates for solar trackers are less than 0.25rpm. Automotive actuators and other re-purposed motors may not be geared for ideal operation.
- **Limit Switches**: Most linear actuators come with built in limit switches. These prevent the motor from destroying itself or the mechanical components by moving the actuator too far. Rocker switches are normally used and are configured in a Normally Closed manner. They are also used in conjunction in blocking diodes to allow the motor to reverse direction while the limit switch is open. **If you are not using a motor with built-in limit switches it is essential that you use "soft" limit switches connected to the Dark Star limit switch inputs.**
- A standard **hard limit** switch schematic is shown below for reference purposes

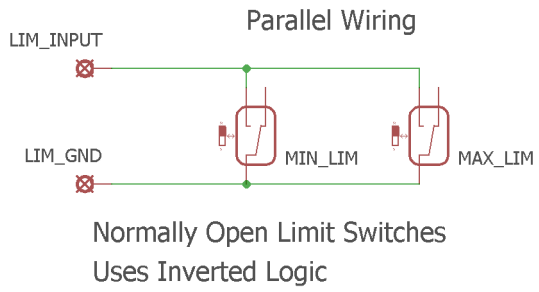


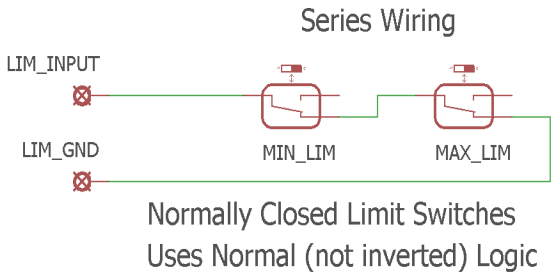
- .

Limit Switch Inputs – New feature for v2.1!

These allow the Dark Star to sense when a motor has moved the array to the minimum or maximum tracking position, and are also called **soft limits** (because software has to read the signal and stop the motor output).

Typically magnetic reed switches are utilized due to their sealed contacts, but any momentary contact weatherproof switch may in principle be utilized.





The **Dark Star** allows for either Normally Open (N/O) switches, or Normally Closed (N/C) to be used. This is done by selecting Normal or Inverted logic for each input.

Position Feedback

A unique feature of the **Dark Star** is that it automatically utilizes pulse-feedback for positioning on both primary and secondary axis when it is present. If pulses are detected during the start-up motor test, then the controller will enable features which require pulse-feedback, such as stall protection and customizable park position.

- Pulse feedback is compatible with both reed-switch, and Hall-effect type sensors. For Hall sensors separate 5v power is required.
- Only one of the two Hall-effect sensors for brushless motors (BLDC) should be used.
- Pulse frequency must be less than 100Hz (a 3000rpm motor should have a 50Hz pulse signal)
- Pulse counts are stored as long data types with a maximum value of 2 billion

Park Functions

PARK Button – depressing the park button on the PCB for one second will cause the Wind LED to turn on. Releasing the button at this moment will cause the Wind LED to run off and the unit to move to the currently configured park position and put the unit in PARK mode (Mode LED turns off).

PARK mode – Automatic tracking not resume till the following day.

Pressing the PARK button for one second in PARK mode will resume AUTO mode for solar tracking.

Park Configuration

Holding the program button down for more than 2 seconds will cause the Park Configuration routine to be executed. This is only applicable when pulse feedback is present on at least one of the two motors.

Primary Axis

- No pulse-feedback:
    - East-return function is performed (4 minute run-time). Nothing else to do.
- Pulse-feedback:
    - East-return function is performed, limit switch stop is detected
    - The configuration sweep is started, and the motor is engaged in a westward direction
    - At any point before the westward limit switch is engaged, pushing the Park button will cause the current position to become the future park position.
    - If the Park button is not pushed, and the westward limit switch is reached, then the **Dark Star** will calculate, and go to, the middle position of the sweep and store that as the park position.

Secondary Axis

- No Secondary Axis:
    - To use the DarkStar for single-axis tracking, you can disable the M2 motor outputs by connecting a jumper wire between the M2 pulse signal terminals. Without doing this the DarkStar will assume there is no pulse-feedback which will cause unwanted delays during parking and tracking operations (equal to the maximum motor run time).
- No pulse-feedback:
    - Zenith-return function is performed (4 minute run-time). Nothing else to do.
- Pulse-feedback:
    - Zenith-return function is performed, limit switch stop is detected
    - The configuration sweep is started, and the motor is engaged in a downward direction
    - At any point before the downward limit switch is engaged, pushing the Park button will cause the current position to become the future park position.

- If the Park button is not pushed, and the downward limit is reached, then the **Dark Star** will calculate, and go to, the 25% position of the sweep and store that as the park position.

Park Position Considerations

- Orient your array to minimize wind loads
- An angled slope may help prevent snow accumulation or minimize hail risk.

Remote Control Configuration

The **Dark Blue** Solar Tracking Ctrl Application is available for free in the **Google Play** store and is compatible with all Android 4.0 and later smart phones/tablets with Bluetooth capability.

You may install the application first, but before running the **Dark Blue** application you'll need to "pair' your Bluetooth device with the **Dark Star** controller.

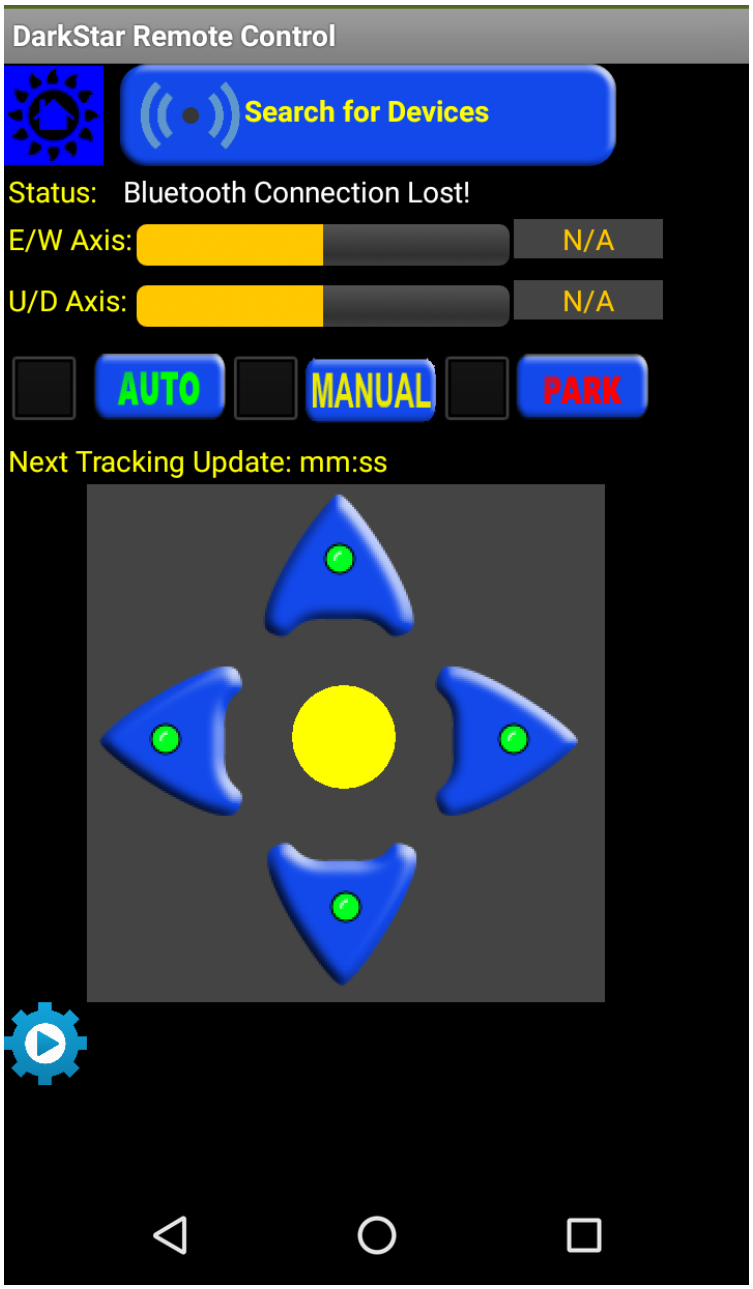
Make sure the **Dark Star** is powered on and you are standing nearby. The red led on the **Dark Star** Bluetooth module should be flashing red.

Pull down your Android System configuration menu from the top of the screen, and hold the Bluetooth icon to open the Bluetooth configuration screen.

Make sure Bluetooth is Enabled and allow the system to search for available Bluetooth devices. The **Dark Star** Bluetooth device will show up as "**HC-06" or "HC-05". You may need to do this several times before successful.** Once detected, select the device to pair it with your phone/tablet.

Enter the code "1234" for the PIN when prompted

About Screen - Pressing the blue Home CSP icon on the top left of the screen opens the **About Screen.** In addition to displaying the software version, the **About screen** has two buttons:



Dark Star Controller Features Button – opens the Controller Features screen which displays a picture of the circuit board with descriptions of all the relevant connections and features. Wiring information for the Cat-5 sensor cable is also provided.

Website – opens a browser window for the Home CSP, Dark Star product page

Configuration Tabs – press the gear icon on the lower left side of the main screen to toggle the display of the configuration tabs, which appear below, and are explained in the following sections.

Remote Control Operation

After starting the **Dark Blue** application, press the Search for Devices button at the top to open a connection to the **Dark Star** controller. Select the **HC-06/05** device that you paired with previously from the available Bluetooth devices (you're standing out by your tracker, there shouldn't be any others!). Once successfully connected it will take a couple seconds for the application to download the **Dark Star** configuration and status information and fully update the displayed values.

In addition to informative status messages displayed at the top, slider bars will appear for pulse-feedback enabled motors. Once a full scan has been performed to calibrate the max pulse counts, these will display relative actuator position. These slider bars cannot be used to move the axis (Manual control is for that)

Displayed to the right of the Actuator sliders is the current photo-sensor values: E/W, and N/S respectively. This is very useful for fine tuning Daylight and Sunlight thresholds as well as diagnosing possible wiring issues.

The **Dark Star** controller has 3 primary operating modes which are the first three codes, and affect tracking and remote control operations:

PARK	No tracking till next day
AUTO	Normal tracking operation
MANUAL	Manual motor control enabled, tracking suspended

When the unit is in AUTO mode, a countdown timer will display the time till the next tracking event.

When a High Wind event has triggered Park mode, a countdown timer will display the time till the end of the Park Period. Note that this will continue to reset to the Park Period if additional High Wind events occur before the Park period is over.

Manual Operation of Tracker Motors

- Only one motor may be active at a time
- Dragging the yellow navigation ball over the arrows, or touching them will cause the corresponding motor to run in the specified direction
- The motor will automatically stop after 10 seconds with no touching.
- The motor will run for the duration defined by the MAX_TRACK parameter if touch is maintained.
- **Tapping the navigation ball, or any empty area of the navigation control will send a STOP command regardless of the operating mode.**

***** IMPORTANT SAFETY FEATURE *****

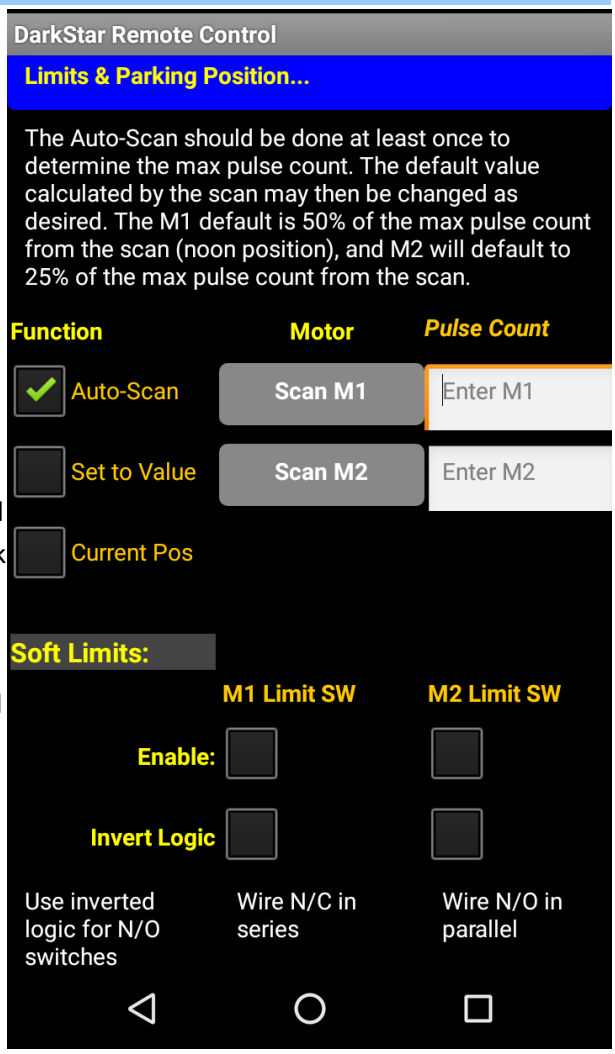
The STOP gesture may be used at any time while a motor is running (and the app is connected) to stop the motor. This applies to tracking movements, parking, park configuration, and east-return motor operations.

Parking Configuration

There are three check boxes which control the effect of the M1 and M2 parking configuration buttons.

As mentioned on the application screen, it is recommended to perform a scan on each axis when using pulse feedback. Manually slewing the motors throughout the entire range of motion will also calculated the maximum pulse count, which is also stored when the park position is set by value or position.

Auto-Scan	Resets the motor to the starting limit switch, runs to the opposite limit, and then automatically calculates the park position. M1 default position is 50% and M2 default position is 25%.
Set to Value	Sets the park position to the specified pulse count
Current Pos	Polls the controller for the current position, and then sets the park position to that value



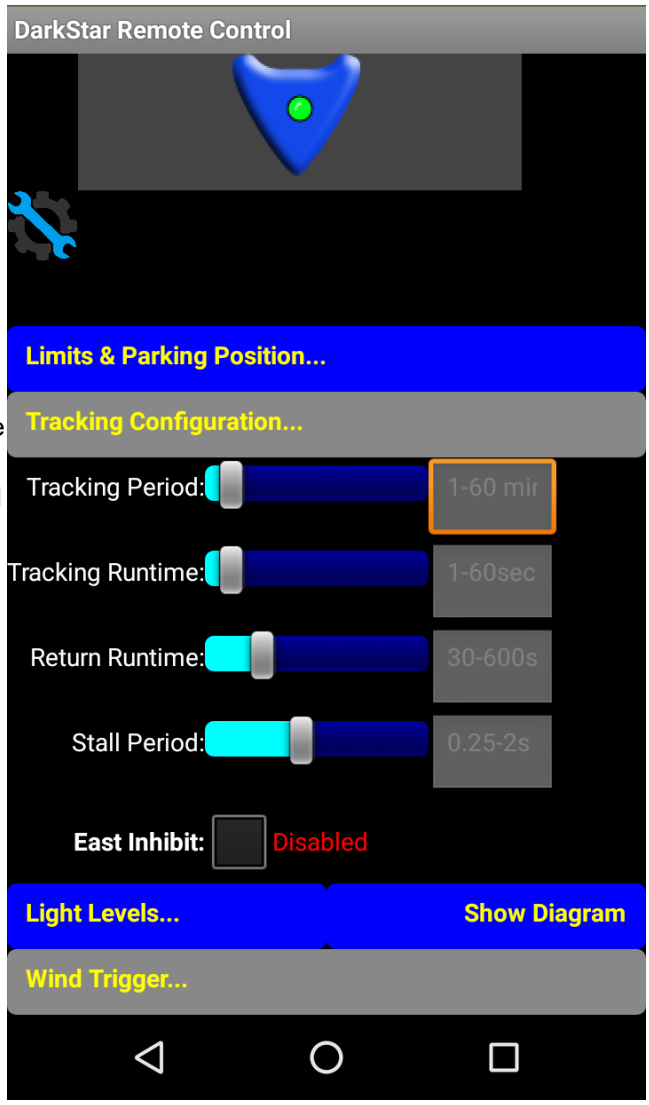
Soft Limit Configuration

This applies when limit switches are connected to the Limit terminals on the **Dark Star** circuit board.

Enable	Turns soft limits on or off
Invert Logic	Triggers limit when circuit opened instead of closed

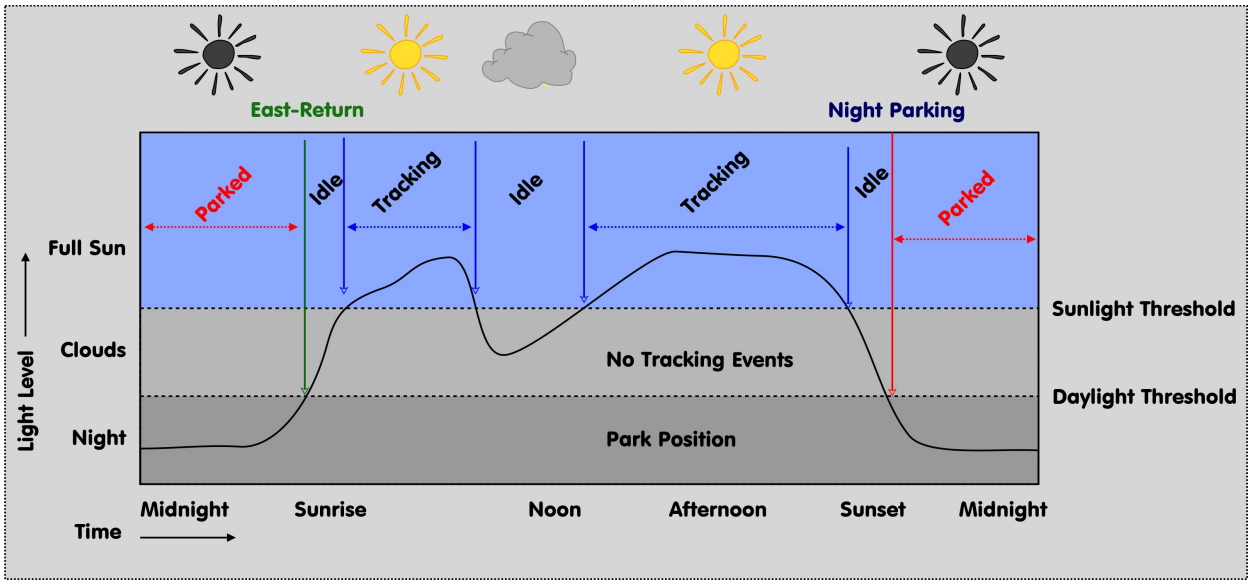
Refer to the section on **Limit Switch Inputs** for more information about using limit switches.

Tracking Configuration

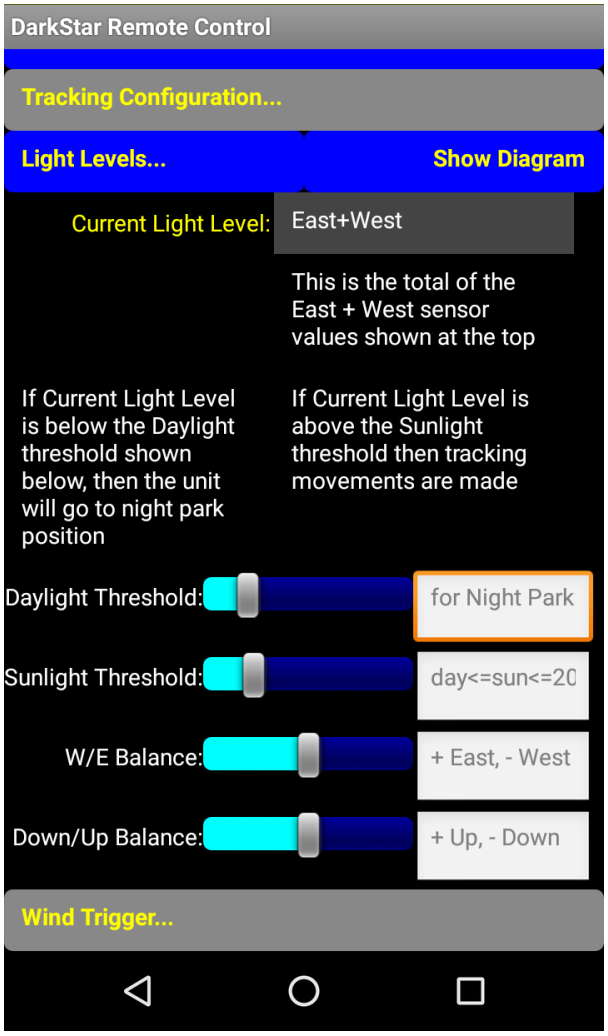


Tracking Period	Duration between tracking events. Adjustable from 1-60 minutes
Tracking Runtime	Normal motor run time during tracking events. Adjustable from 1-60 seconds. Keeping this short as necessary will minimize seeking
Return Runtime	Maximum motor run time for parking and east-return movements. Used to minimize motor energization period with non-pulse feed back motors as well as general overrun safety.
Stall Period	Only applies to pulse-feedback motors. Safety feature shuts down motor driver if pulse signal is not received within the Stall Period. 2 seconds maximum.
Park Period	Park duration for high wind events Adjustable in 5 minute increments from 10 to 120 minutes.
East-Inhibit	Checkbox to soft-enable East-Inhibit tracking. Cannot be used to turn off East-Inhibit if the jumper on the control board has been used

Light Sensor Configuration



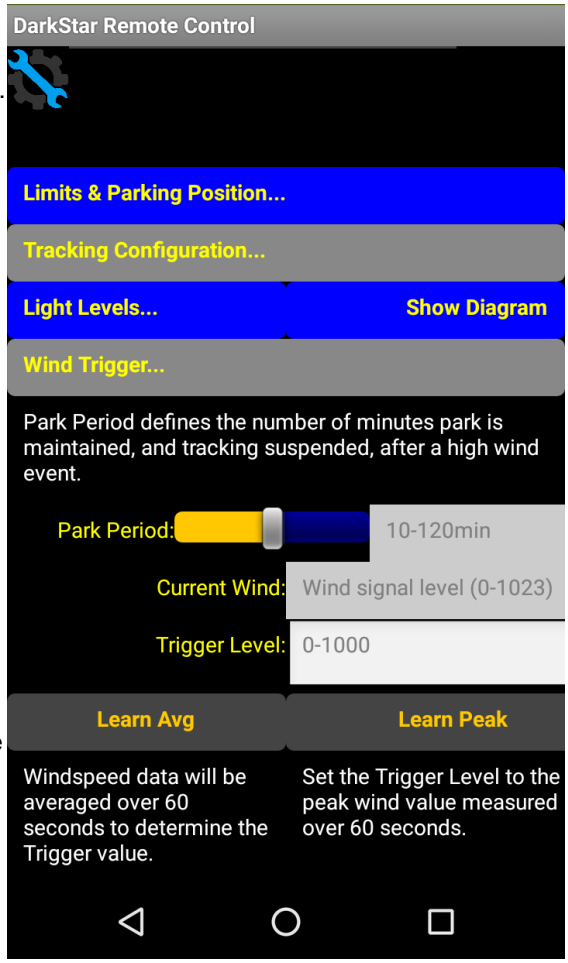
Daylight	Threshold for non-auto-parked night operation. East and West sensor values are added together for this comparison. Must be less than or equal to Sunlight value
Sunlight	Threshold for tracking events. Used to reduce seeking in cloudy conditions. Must be greater than or equal to Sunlight value.
W/E balance	May be used to adjust primary axis aim if sensors are misaligned/out of balance
S/N balance	May be used to adjust secondary axis if sensors are misaligned or out of balance



Wind Sensor Features

Wind Sensor

- Intended for analog output anemometers
- Any momentary 0-5V signal may also be used
- The Wind LED turns on when a “high-wind” condition is present
- This triggers the Wind Park function and puts the unit in the configured Park position
- After the configured Park Period if no further high-wind conditions have been detected, then automatic tracking updates resume.
- Wind trigger may be calibrated from on-board potentiometer, learned wind speed average, or learned peak wind speed.



Park Period Sets the number of minutes before normal tracking will be resumed after a wind event.

Current Wind Displays the current wind value. **This is not calibrated in any units** and is simply a display of the raw ADC value from the wind signal voltage.

Trigger Level Wind events are triggered when ever the **Current Wind** value exceeds the **Trigger Level**

Learned Wind Speed Average

- Press the Learn Avg button on bottom of the Dark Blue Android application screen
- The WIND LED will flash slowly for approximately 60 seconds during the learning period
- The average sampled value during this period will be displayed, and saved to EEPROM for future use as the wind speed reference value for the Park Trigger function.

Learned Peak Wind Speed

- Press the Learn Peak button on bottom of the Dark Blue Android application screen
- The WIND LED will flash rapidly for approximately 60 seconds during the learning period
- The peak sampled value during this period will be displayed, and saved to EEPROM for future use as the wind speed reference value for the Park Trigger function

Appendix

I.Software Updates

Software updates may be released from time to time by Home CSP Inc. These binary releases will be available to registered owners for free upon request, and may be installed through the 6 pin ISP header. An AVR ISP programmer and AVRDude software is required to upload the new firmware. AVRDude is freely available, and is part of the Arduino development environment. AVR ISP programmers are commonly available from Home CSP, on eBay, and from other sources such as www.adafruit.com. Firmware upload instructions are available on the HomeCSP.com website.