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Introduction to Solar Trackers

There are many useful solar energy applications which can benefit from tracking the motion of the sun across the sky, such as optically focused solar collectors. The daily motion of the sun traces out a simple arc, which can be tracked with a single axis of mechanical motion… usually through some arrangement of electric motor and drive train. This booklet explains the basic principles of tracking the sun and presents several examples of mechanical mounts, you should watch the videos for details on how to build the sun tracking device for your solar panels. This booklet also describes several simple electrical circuits capable of controlling a DC motor or linear actuator for the tracking. The solar tracker circuits are simple and effective, and they resets the tracker to the East at the end of the day.

Basic Solar Tracking Mounts

Tracking an object's motion across the sky has been the basic challenge of astronomy for centuries, and not surprisingly, some clever solutions to the problem have been devised.

A very basic type of tracking system is the Altitude-Azimuth mount. An example of a telescope mounted this way is shown in Figure 1. It consists of a yoke which can rotate around a vertical axis. The telescope is mounted inside the yoke and can be aimed with respect to the horizontal. This mount is mechanically simple to build, but the arrangement is cumbersome to use in practice. That's because tracking the sun requires continuous adjustment in two directions; horizontal and vertical. The frequency of adjustment depends on where the object is in the sky, and the adjustments are not a simple continuous motion.

Astronomers quickly improved on this basic arrangement to create the Equatorial mount. If the vertical axis of the Altitude-Azimuth mount is aimed parallel to the axis of the earth's rotation the tracking motion becomes greatly simplified. With an Equatorial mount the sun will be tracked with only one simple continuous motion. In the Northern hemisphere, pointing the rotational axis at the North Star will align it correctly for tracking the sun. Figure 1 shows how an altitude-azimuth becomes an Equatorial mount. Figure 2 shows how the alignment angle is specified, with some examples.

The Equatorial mount can be motorized to track celestial objects, since the rate of motion is approximately one revolution every 24 hours. A constant RPM AC synchronous motor connected to a mechanical gear train is called a "clock drive". Clock drives have reached a high degree of development for telescopes, but unfortunately they are expensive and require user input to point at the sun.

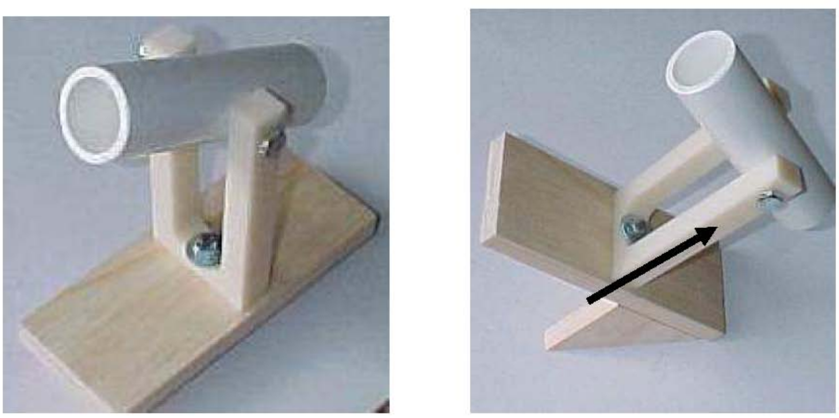
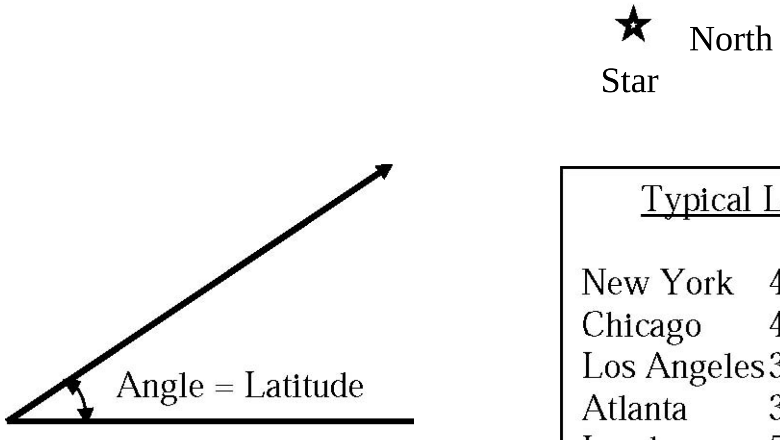


Figure 1. A basic Altitude-Azimuth mount becomes a single axis tracking Equatorial mount by aligning one axis to the North Star.



Typical Latitudes	
New York	40 Degrees
Chicago	41 Degrees
Los Angeles	34 Degrees
Atlanta	33 Degrees
London	51 Degrees
Paris	48 Degrees
Tokyo	35 Degrees

Figure 2. The angle of the single axis solar tracker with respect to the horizontal is equal to the latitude of your location.

The photographs in Figure 3 show two good examples of mechanical hardware for tracking. The first is an Equatorial Telescope mount, and the second is a mount for a large television satellite dish.

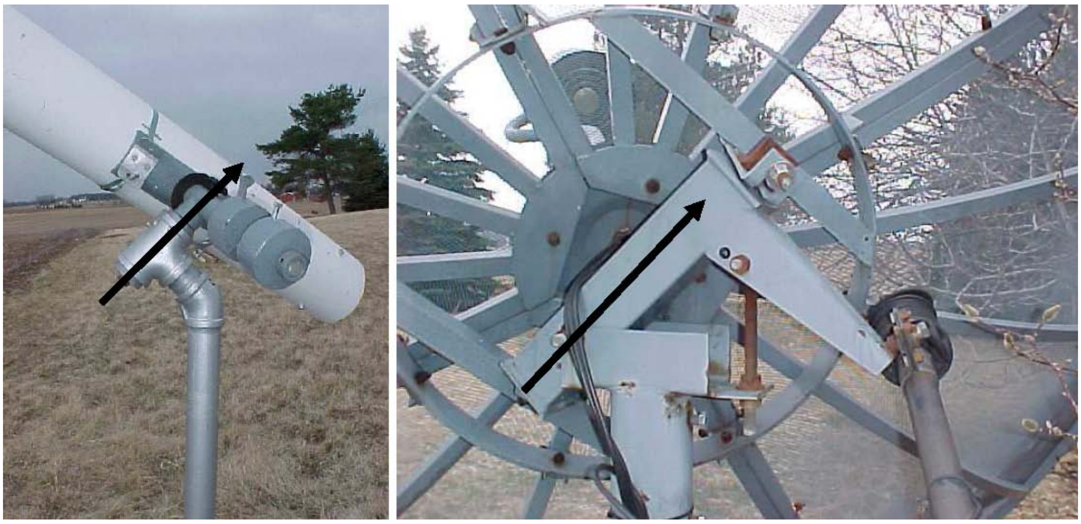


Figure 3. Examples of mechanical mounts aligned to the polar axis.

The benefit of tracking the sun can be calculated directly for a simple example. Consider a flat plate collector located at the equator of the Earth. Everyday is the same at the equator: the sun rises at 6 AM, is directly overhead at noon, and sets at 6 PM. As shown in Figure 4, a stationary flat plate collector receives the full sun at noon, but the fixed collector receives no sun at dawn or sunset because of the angle of approaching light. In comparison, solar tracking of the collector provides full sunlight during all 12 hours of daylight. The amount of sunlight collected for a stationary collector varies as the sine of the angle of the sun position, and the total sunlight received is the integral over the course of the day. The net result is that a tracking flat plate collector will receive approximately 59% more sunlight than a stationary collector. In practice the benefit will be less because the early and late sunlight is less intense, having traveled through more of the Earth's atmosphere before reaching the collector.

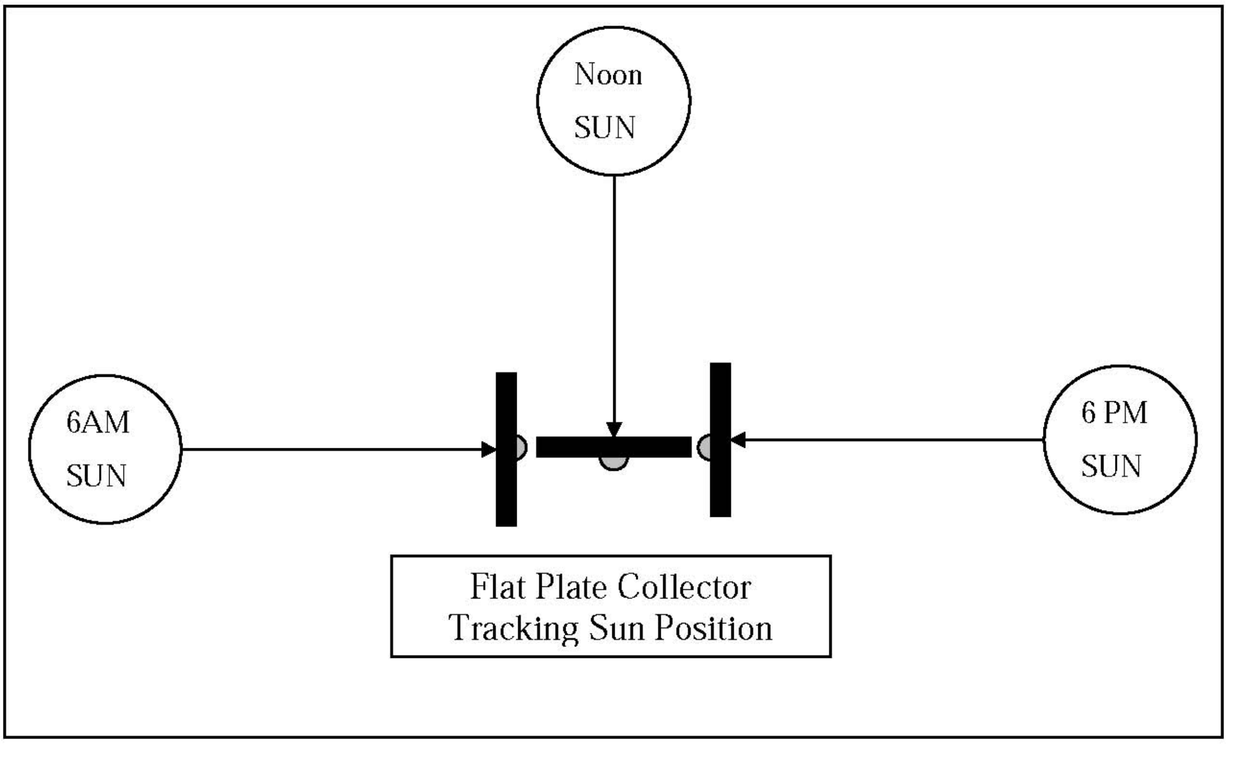


Figure 4. Simple example of Solar Tracking Benefits

Tracking systems for astronomy must be able to follow faint stars. However, the sun is a very bright object and we can use the sunlight to actuate sensors for automatic tracking. This is called feedback control.

An electronic tracking system must sense if bright sunshine exists, and where in the sky the sun is physically located. With that information, the tracking system can send the signal to actuate a motor to move in the proper direction. As it turns out, a relatively simple tracking system circuit is able to accomplish this task.

Figure 5 shows the details of a basic solar tracking system. It consists of two CdS photocell sensors mounted on opposite sides of a central divider. The divider, referred to as a shadow block, is arranged such that it can cast a shadow on the sensors, depending on the position of the sun. With regards to the divider, the sun can only be in one of 3 positions: Position 1: East of Center, Position 2: Centered, or Position 3: West of Center.

Referring again to Figure 4: If the sun is in Position 1 (East of Center), then the East Photocell will be in bright sunlight and the West Photocell will be shadowed. The tracker system sends the signal “Move to the East”. In the same way, if the sun is in Position 3 (West of Center), the West Photocell will be in bright sunlight and the tracker sends the signal “Move to the West”. Finally, if the sun is in Position 2 (Centered), both Photocells will be in bright sunlight and the tracker sends the signal “Don’t Move”.

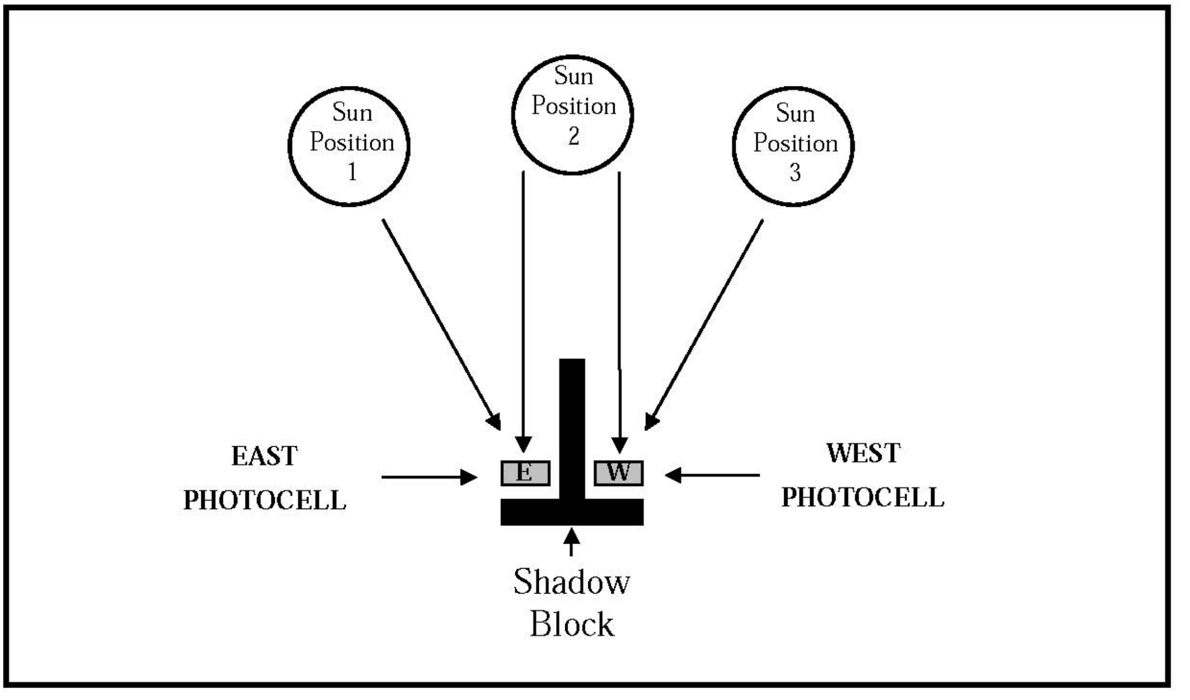


Figure 5. The is the basic layout of a solar tracker with feedback control.

In this type of solar tracker the pointing accuracy is controlled by the height of the shadow block. When the block is made taller, the shadow it casts will move faster and actuate the controller more often, resulting in more precise aiming. A good starting height for a shadow block is about 3 inches (7.6 cm).

The shadow block concept can be implemented on your project using existing hardware. It is only necessary to find a planar part of the tracker structure which points at the sun during alignment. Figure 6 shows an example of the sensors mounted on opposite sides of a mechanical support bar, hence in this case it was not necessary to build an actual shadow block.

Figure 6. Sun sensors mounted on opposite sides of tracker structure.

Circuit Details

The basic circuit for sensing and actuating a DC motor or actuator (usually 12 VDC) to follow the motion of the sun along a single axis is shown in Figure 7. This circuit is built using 9 resistors, 2 photosensors, 5 diodes, 2 limit switches, 1 integrated circuit comparator and 2 miniature relays. Figure 7 shows the circuit diagram. A photograph of the same circuit, assembled on the printed circuit board, is shown in Figure 8.

In the circuit, the East and West photocells are each connected in series with a 1K Ohm resistor to form voltage dividers. When either photocell is exposed to light the resistance is reduced, and consequently the voltage from the divider will also be reduced. The "trigger point" for each comparator is set by the fixed voltage divider, made with the 100K Ohm and 9.1K Ohm resistors. The LM339 IC comparator senses the voltages from the photocells, compares the voltage to the threshold reference and makes a decision about tripping the H-bridge relays to move the tracker.

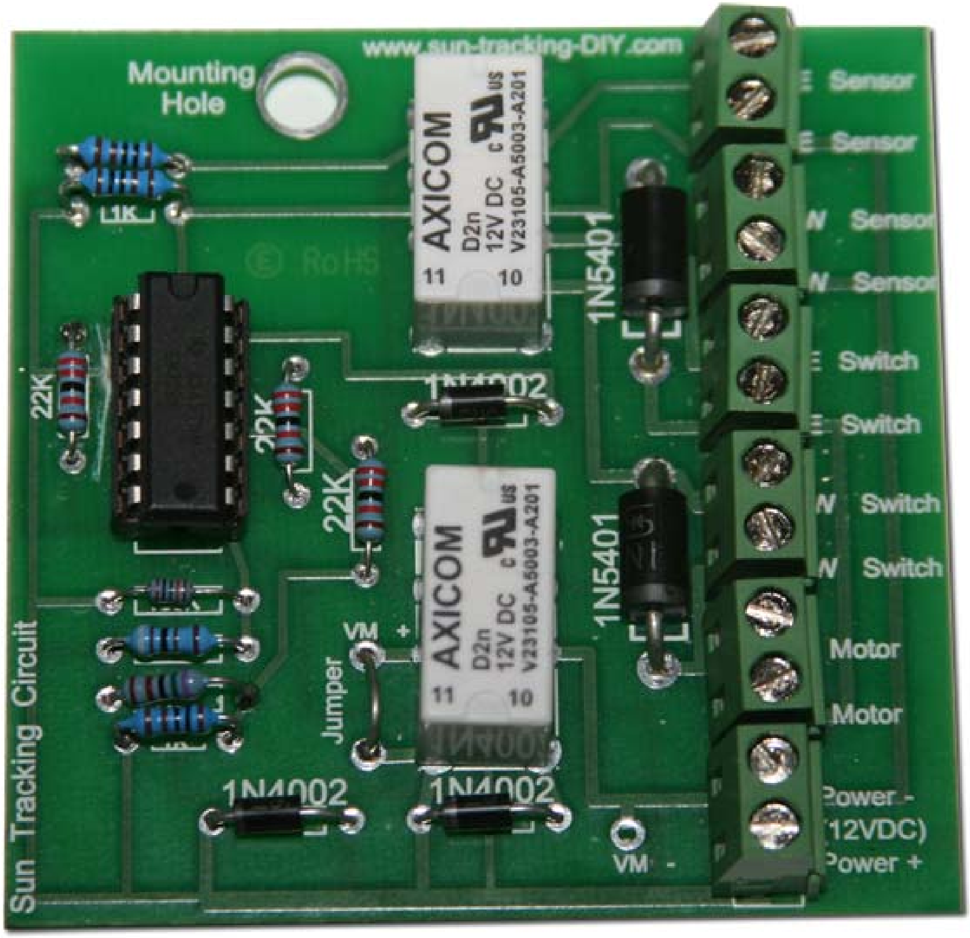


Figure 8. Photograph of the assembled Solar Tracker circuit board kit.

In a control system such as this, undesirable behavior can occur when the system is very close to the trigger point. For example, the motor could erratically switch on-and-off as the sensor voltage dithers near the threshold set point. This potential problem is solved by providing something called positive feedback. The positive feedback in the tracker circuit is provided by the 22K Ohm resistors. These resistors provide a damping action known as hysteresis.

This circuit is designed to operate on 12 VDC, although in practice the voltage can vary by a few volts up or down. The voltage rating of the coil inside the relays is what determines the allowable voltage range. Also, since the relays are rated at 3 amps maximum current, the relays also determine the maximum allowed current draw for the DC motor or actuator.

Most applications using this kit will be with a 12 VDC motor. When using 12 VDC there is a soldered jumper on the circuit that must be installed, as shown in Figure 9. The jumper provides the 12 VDC power to the motor.

Figure 9. Install the jumper on the board if you are using a 12 VDC motor.

The circuit can be used with motors with a voltage different than 12 VDC. In such cases do not install the jumper. Instead, connect the positive (+) lead of the motor power supply to the terminal marked VM+. The negative (-) lead of the motor power supply is connected to the terminal marked VM-(Visible in the lower left hand corner of Figure 9.) The circuit board must always have a 12 VDC power supply for the electronics, regardless of what voltage is being used for the motor.

The circuit board and electronic components of the kit must be assembled. Kit assembly requires using a fine tip soldering iron with electronic rosin core solder. If you are not familiar with electronic soldering there is a helpful tutorial available on the MTM website.

During assembly, all the components are mounted on the top side of the circuit board. Install the IC chip with the notches aligned as shown in Figure 10. Installing the chip upside down will damage the chip permanently. Also note that the green terminal block connectors are designed to slide together to form an assembly, as shown in Figure 11.

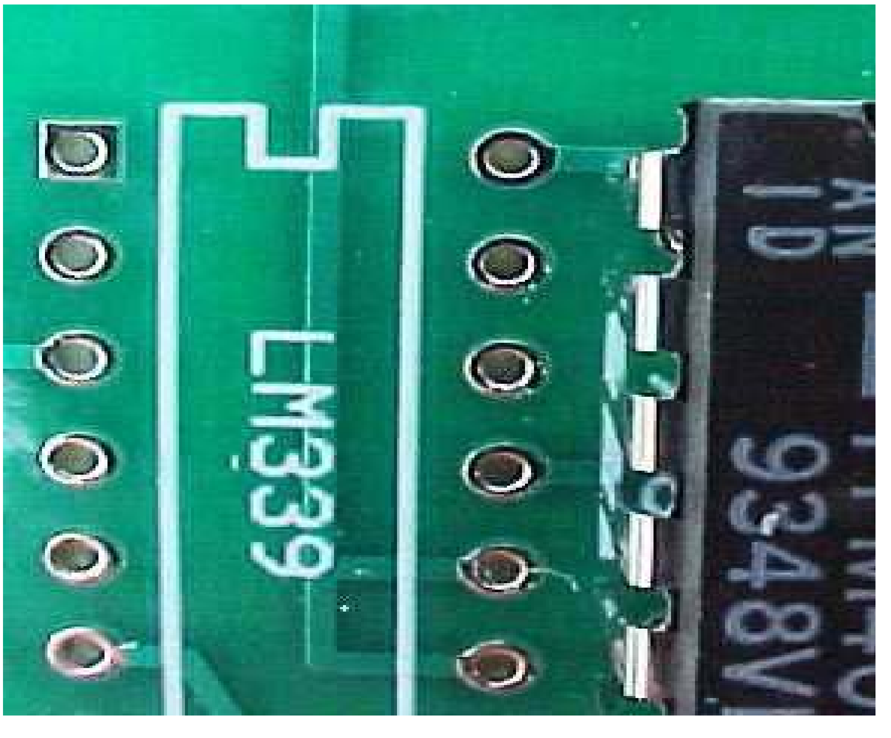


Figure 10. Install the IC chip so the top notch is aligned with the artwork outline.

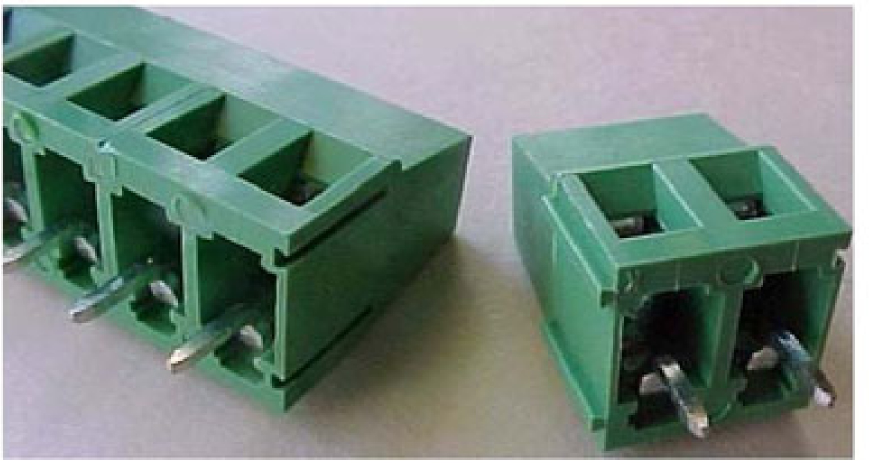


Figure 11. Note that the terminal blocks slide together using the side notches. Assemble the blocks together before soldering them to the board.

The tracker follows the sun all day until sunset. The West limit switch stops the motion. This tracker circuit has been designed with a special feature: The tracker will reset the tracker position to the East at the end of the day, after it becomes dark. The circuit monitors the West sensor and compares the signal to a dark threshold voltage, as shown in the schematic of Figure 7.

The tracking circuit can be assembled on the printed circuit board, but bench testing should be done outdoors in bright sunlight with a shadow block. Do not take shortcuts when testing: Install the limit switches! If you have a multimeter, check the voltage and polarity of the 12 VDC power supply before connecting it to the circuit board. ***Connecting a reversed polarity power supply connection will damage the circuit beyond repair.*** For testing, the output of the circuit can be wired to your motor, or you can use a multimeter to monitor the voltage output to the motor terminals. (Actually, you can hear the relays switching with no load if you listen carefully.) Proceed with the testing by exposing one of the photocells on the shadow block to direct sunlight. Bright sunlight applied to one photocell with the other photocell shaded will actuate the relays and send 12V output to the motor connections. The motor output polarity will switch (+/-) depending on which photocell is in the sunlight.

One of the key challenges to having this circuit work properly is to avoid making the circuit overly sensitive to light. The trip point for the sunlight sensors is set by the 9.1K Ohm resistor in the circuit. A higher resistance value will make the circuit more sensitive to sunlight. If you would like to make the sensitivity adjustable, replace the 9.1K Ohm resistor with a multiple turn potentiometer. Note: If the sensitivity is set too high the circuit will trip on a false signals, such as hazy diffuse sunlight or reflections, and the erratic movements will continue until a limit switch is hit. If the sensitivity is set too low, the tracker will not move at all. The sensors are tested and matched as pairs for the kits and they should perform well in this circuit without any adjustment. Normal resistance in sunlight is about 65 ohms for the sensors.

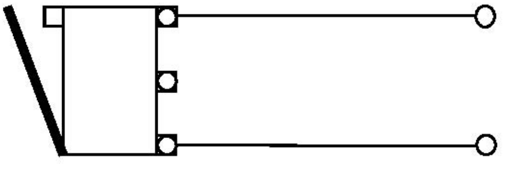
Once you are satisfied with the operation of the circuit, and if you don't plan on making any more changes, it is a good idea to mount the circuit board in a weatherproof enclosure. The circuit board is small enough to be mounted inside a standard watertight outdoor junction box, as shown in Figure 12. Standard applications with a 12 VDC motor will have six pairs of wires attached to the circuit board terminals (East Sensor, West Sensor, East Limit Switch, West Limit Switch, Motor and Power Supply)

The best approach for building your tracker is to mount the circuit board inside a waterproof enclosure and run wires to the photocells, limit switches, motor and power supply. Water tight connections can be made with pure silicone sealant, or you can purchase a special wire feed thru connector such as seen in Figure 13.

Figure 12. The Solar Tracker circuit board fits inside a standard outdoor box. Be sure to insulate the bottom of the board from making metallic contact.

Figure 13. Example of wires exiting the box using a feed thru connector. This NPT feed through connector is McMaster-Carr part number #7807K43.

One very important feature of building the solar tracker is using limit switches, as shown in Figure 14. The purpose of the limit switches is to limit the mechanical motion of the tracker to a safe range. If the tracker moves too far in either direction a limit switch is actuated and stops the motion before damage.



Limit
Switch
Wiring

Figure 14. Limit switch and wiring. Switches are wired NC. (Normally Closed)

Normally, a tracker would need to be reset manually after tripping a limit switch, however the tracker circuit has provision for automatic reset. A diode is wired in parallel with each switch to allow movement *in the opposite direction* after a limit switch is actuated. The limit switch diodes are mounted directly on the circuit board, as shown in the circuit diagram.

The solar tracker circuit will track the sun during the day until the West limit switch is actuated. When it becomes dark the tracker will move to the East position until the other limit switch is actuated and then wait for dawn. Parking the tracker pointing to the East captures the first sunlight in the morning, and also has the advantage of moving the tracker with freshly charged batteries.

NOTE: During your initial trials with the tracker you may find the tracker motor is moving in the wrong direction. (Opposite to what you expect.) In this case you should change the motor polarity by swapping the 2 motor wires at the terminal block on the circuit board. This is why there are no polarity marks on the circuit board connector for the motor connection. The correct wiring connection depends on your motor and mechanical setup.

Motors & Drive Trains

The 12 VDC Motor for operating a single axis tracker should be chosen to have high torque at low RPM. This is most easily accomplished by using a special type motor known as a DC Gearhead Motor. Gearhead motors are built with an integral gear drive reduction mechanism which reduces the RPM and increases the torque. Figure 15 shows an example of a solar tracker mounted directly to the output shaft of a large DC Gearhead motor. Note that the “T” section shadow block for mounting the photocells is made of wood.

An AC power supply and AC motor can not be used with the MTM Solar Tracker Circuit. A DC motor reverses direction when the polarity of the power supply is reversed, but an AC does not reverse direction.

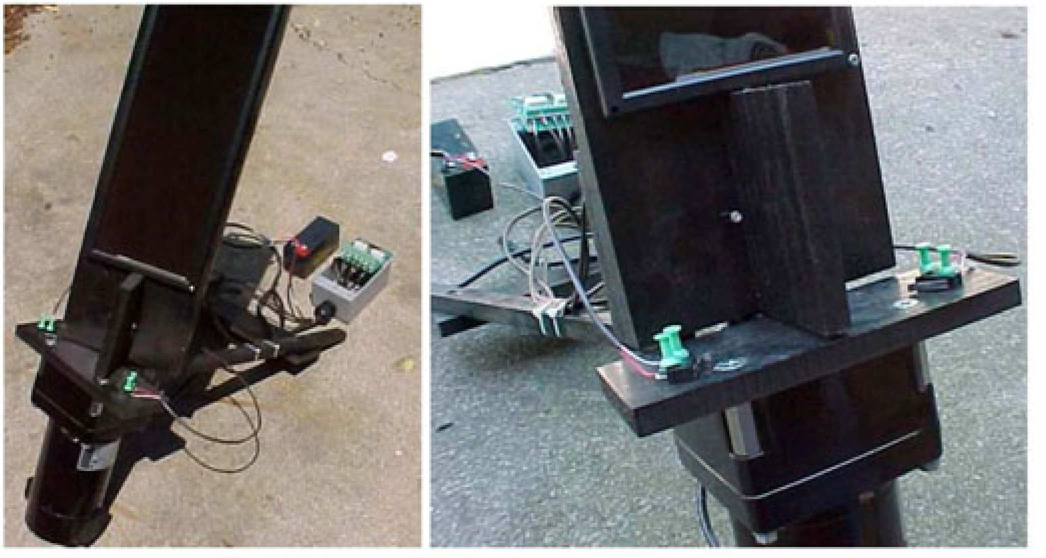


Figure 15. Prototype solar tracker mounted directly to a gear head motor.

In practical terms, it is almost impossible to find a DC motor that is too slow. Recall that the the motion of the sun is effectively one revolution per day. Figure 16 contains a few excerpts from supplier catalog pages with typical examples of motors that would work. A good source of inexpensive low RPM gear motors is Jameco Electronics (www.Jameco.com).

If you happen to already have (or find) a nice gear head motor rated for a voltage higher than 12 VDC, perhaps 24 VDC, chances are it will probably work just fine at the lower voltage… it will simply rotate slower. Actually, the motor shown in the example for Figure 15 was rated for service at 90 VDC, but it works just fine at 12 VDC and provides a very nice extra-slow movement.

A common question when building a Solar Tracker is "What size motor do I need for my tracker?" The answer to that question depends on: 1) The mechanical advantage of your drive train, 2) The amount of friction in the pivot points, and *most importantly* 3) The quality of balance in your mechanical setup.

Mechanical advantage is provided by the gearhead on your motor, and the additional gears and pulleys in the power train. The sun moves slowly and it is almost impossible to create a mechanical drive arrangement which is too slow. Timing belts and V-Belts are great ways to increase the mechanical advantage in your drive system. Mechanical advantage is gained when a small diameter pulley drives a large diameter pulley, as shown in the Figure 18. Increasing the mechanical advantage is less expensive than buying a larger motor.

Reducing the friction in your tracker drive system also has obvious advantages. Less friction means less resistance to motion. A great way to reduce the mechanical friction is by using free running ball bearing pivot points in your design. Nonmetallic plastic sleeve type bearings are another low friction option, especially if you limit the shaft size to the smallest practical diameter.

While mechanical advantage and friction reduction are important, achieving mechanical balance is also important, and the importance of this in your design is easy to overlook. Trackers should be designed to have good weight balance at all positions, as shown in Figure 17. This means the rig is stable and that you can place the rig in ***any position*** and it will not move from that position. A balanced tracker design allows the motor to work only against the friction…the motor is not wasting power by lifting dead weight. Astronomers learned about the importance of balance a long time ago. Large telescopes are easy to move by hand because they are balanced.

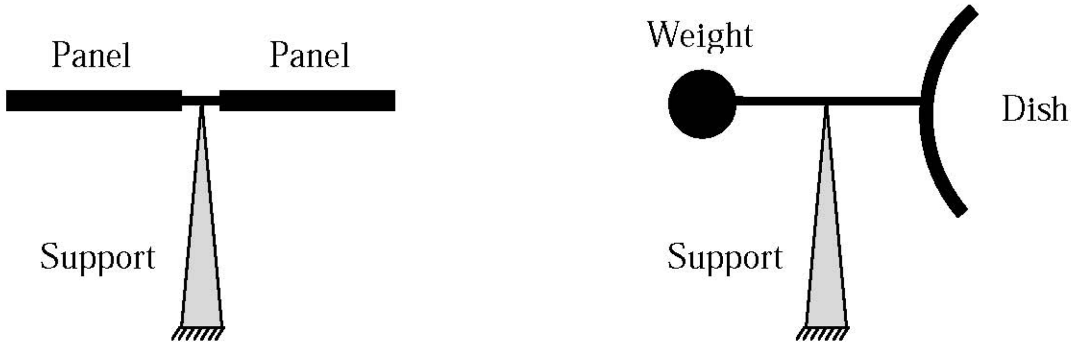


Figure 17. Design symmetry for balance reduces the motor size requirements. Adding weight to achieve balance is a viable design option.

The easiest way to achieve balance is by mounting your solar project's payload symmetrically. If your tracker project is not perfectly balanced, consider adding weight to improve the balance. You might consider this a surprising suggestion, but adding weight will substantially reduce the motor size requirements if the overall payload balance is being improved in the process.

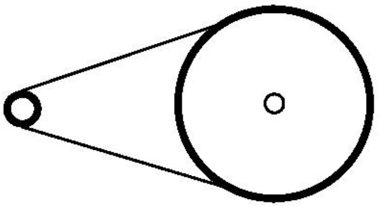
Design Tip: How to maximize the service life of electrical relays.

The output of the solar tracker circuit is provided by dual electrical relays wired in a special configuration known as an H-Bridge. The H-Bridge configuration provides a complete polarity reversal, so the DC motor can move both forward and reverse. The relays can be used for millions of actuations, however their life can be substantially shortened or lengthened according to the way they are used in service.

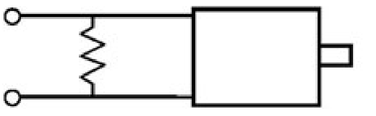
A simple method to increase relay life is to reduce the number of actuations in a typical day. As simple as this sounds, this is an easy thing to overlook. For example, if your payload is a photovoltaic panel it is not necessary to be adjusting position every few minutes. An adjustment every 10 minutes is more than adequate and it will materially extend the relay's lifetime. Reduce the frequency of tracking adjustments in your design by simply making the shadow block shorter, or by using the computer controlled PICAXE version of the solar tracker circuit.

Powering a motor with relays is a challenging application because motors have an inductive component which tends to cause arcing during relay switching. Contact arcing is a major cause of shortened relay lifetime. Fortunately there is a simple technique to minimize arcing, and using the technique provides an additional unexpected benefit in your design. Relay contact arcing can be reduced by placing a small power resistor in parallel with the leads to the motor. The resistor will provide a path for the inductive currents that might otherwise cause contact arcing inside the relays. For a 12 VDC system consider using a 27 ohm power resistor rated for 5 watts, such as Jameco #660480. (A 24 VDC system could use a 100 ohm power resistor rated for 5 watts, such as Jameco #660623)

Adding a power resistor to snub the arcing has another advantage: The resistor will provide a path for the motor current to flow if something should attempt to dislodge your tracker, such as high wind or an imbalance caused by snow accumulation. The snub resistor provides a braking action that makes your tracker much less sensitive to external forces and therefore more stable overall.



Gaining mechanical advantage usi
pulleys.



A motor snub resistor prolongs relay life and adds braking action.

Figure 18. Use pulleys to gain mechanical advantage. Adding a motor snub resistor will prolong the life of the relays and add a modest braking action.

Mechanical Design Considerations

The mechanical drive between the motor and solar tracker can take many forms. As shown in Figure 15, our prototype solar tracker shadow block was directly mounted to the shaft of the DC Motor. This is a viable approach with low RPM motors and small devices, especially if you are want to get a quick start experimenting with the tracker circuit.

Larger devices will require a mechanical drive system between the motor and the tracker. Using a mechanical drive system makes it possible to incorporate a speed reduction feature into the drive system. For example, one effective drive system uses simple timing belt pulleys. The timing belt pulleys are notched, and mate with a cogged timing belt. A speed reduction occurs if the driving pulley is smaller than the driven pulley: The reduction is the ratio of their respective diameters. Figure 19 is a photograph of just such a drive reduction system using 0.20” pitch timing belt, often referred to as the XL series for “Extra Light”. Components for building drives are available from Small Parts Inc (www.smallparts.com) and McMaster-Carr. Figure 20 shows a very simple belt drive system for moving a solar oven on a lazy susan type turntable.

Figure 19. Example of a cogged timing belt mechanical drive syst

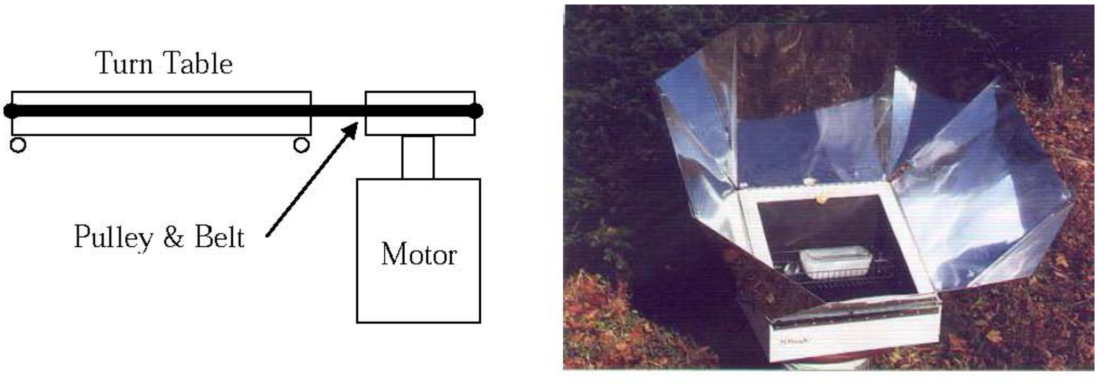


Figure 20. Turntable mounted solar oven for solar tracking

A DC Linear Actuator can be used instead of a DC motor to move the tracker. A simple mechanical arrangement is shown in Figure 21. Linear actuators can sometimes be found surplus on satellite dish movers, and some hobbyists even make their own homemade linear actuators. Figure 22 shows a linear actuator.

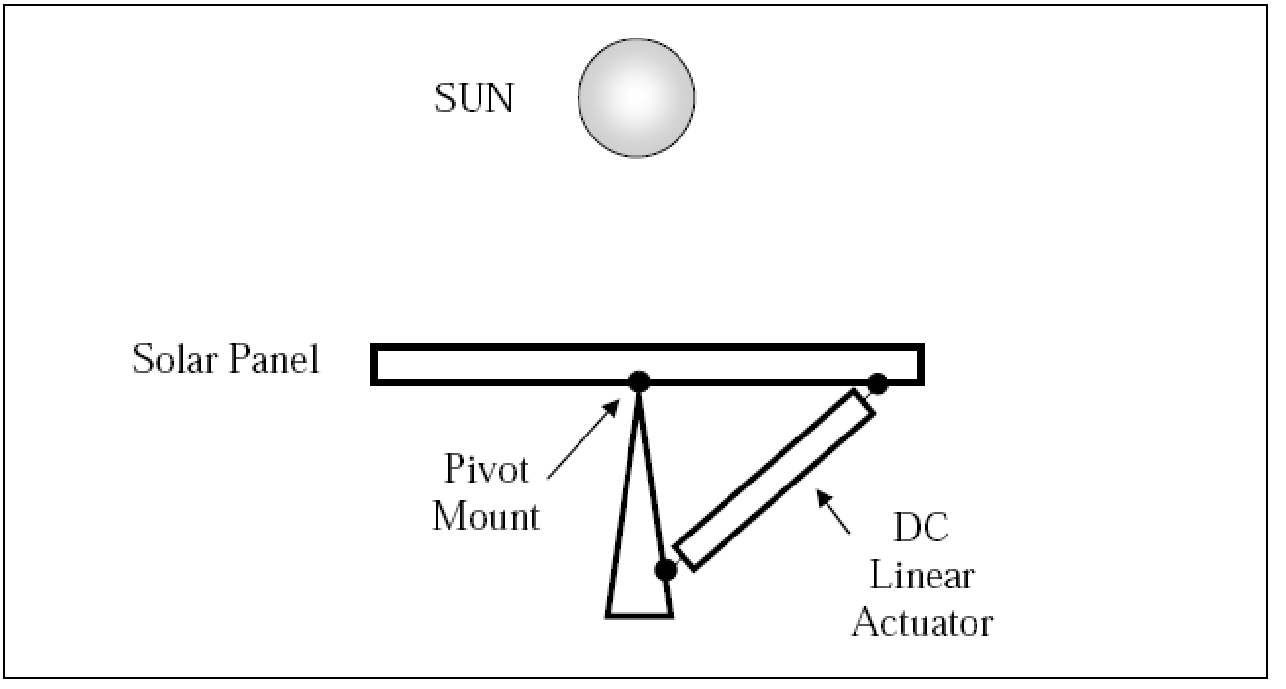


Figure 21. Simple mechanical arrangement for using a linear actuator.

Figure 22. Example of a satellite dish linear DC actuator.

Bearings

Tracking the position of the sun involves moving mechanical hardware. The tracker must be designed to withstand the weather and the elements. The tracker must also be capable of controlled movement with low friction. Bearings are used to accommodate motion with low friction. There are many types and styles of bearings which can be used.

One simple, inexpensive and effective bearing type is the sleeved or flanged bearing, as shown in Figure 23. These simple bearings are useful for solar trackers because the loads and speeds involved for tracking the sun are low. These basic bearings are available in a variety of sizes, and will work with ordinary bolts used for the shafts as shown in the photos. The location of the bolt shafts can be secured by using vibration free nuts with nylon inserts. Typical construction materials for sleeve bearings are metallic (sintered bronze) or plastic (nylon). Both types are generally quite inexpensive.

Figure 23. Flanged sleeve bearings used with a simple Fresnel Lens tracker.

Another common type of bearing is the ball bearing. Ball bearings can handle heavy loads and they provide very low friction. The basic outline of a ball bearing is shown in Figure 24. A simple ball bearing consists of an outer race, inner race, balls and ball spacer. The inner race is able to move with respect to the outer race by virtue of the intermediate balls. The balls "roll' along grooves in the surfaces of the races, hence the reason why this design has low friction.

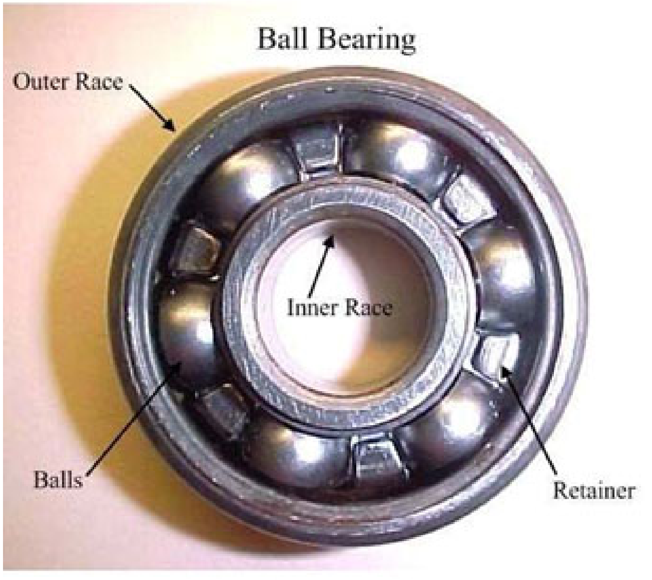


Figure 24. A typical Ball Bearing

Since the balls and bearing races are made of steel, they are subject to rust and corrosion from the weather. A typical solution to this problem is packing the bearings with grease, and sealing them. Fortunately, packed and sealed bearings are readily available, and are the most common type sold at hardware stores.

From a design perspective, the real challenge with using a ball bearing is attaching the mechanical elements of the tracker structure to the inner and outer races of the bearing. Fortunately, there are several design options available.

Probably the simplest method is to use a ball bearing already mounted in a housing called a ‘pillow block” as shown in Figure 25. The pillow block holds the outer race of the bearing, and includes convenient mounting holes as part of the frame. Usually the pillow block also provides for some amount of angular adjustment, with a spherical cup-and-socket type mechanism integral to the assembly.

Figure 25. Ball Bearing mounted in a Pillow Block

Another simple method for using a ball bearing is to use a style known as a 'flanged bearing' as shown in Figure 26. In this case the bearing has been mounted in a flanged bracket, which also has convenient mounting holes as part of the frame. Usually the flanged bearing style also provides for some amount of angular adjustment with a spherical cup-and-socket mechanism.

Ball bearings are design rated for a maximum load and a maximum RPM. Generally the ratings are not a design limit for solar trackers, therefore the most usual case is to use bearings that are conveniently available or fit the existing mechanical hardware (shaft sizes, etc.) Low cost, high capacity bearings mounted in pillow blocks or flanges are available online from such sources as EBAY and McMaster-Carr.

Dual Axis Sun Tracking

The same principle that is used for building a single axis solar tracker can be expanded to include building a two axis tracker. This is possible by building two tracker circuits and having one track East & West while the other circuit tracks North & South. With such a configuration, the tracker will actually find and follow the sun automatically, no matter where it is. In practice the annual variation in the sun's position along the second axis is slow enough that manual adjustment during the year is usually adequate for most applications.

Here we have compiled a list of the most common questions we receive from hobbyists building the Solar Tracker Kits.

I applied power to the Solar Tracker Kit and smoke appeared. What's wrong? Can I fix it? Power was applied to the kit with reversed polarity (+ and -). The circuit cannot be fixed. You must order a new kit.

I'm bench testing my Solar Tracker Kit and the motor only moves one way (EAST)? Your kit is working properly. Remember that the circuit has a feature to reset your tracker to the East at the end of the day. The low light level on your bench has the circuit trying to do the reset to the East. Solution: Do the circuit testing in bright light, preferably OUTDOOR DAYLIGHT.

I'm bench testing my Solar Tracker Kit and I can hear the relay clicks, but the motor does not move? Your kit is working properly. For the motor to move the limit switches must be installed. The motor power path is through the normally closed limit switches. Solution: Install the limit switches, or jumper out the limit switch connections on your board.

I was testing my Solar Tracker kit and the LM339 comparator IC got hot and smoked? The comparator was damaged by either: 1) Static electricity, 2) A voltage surge from your power supply, or 3) Was installed backwards. Solution: Replace the comparator with a LM339 IC that's available at Radio Shack (#276-1712) for about $2. Install the IC correctly, as shown in Figure 10.

I'm testing my Solar Tracker kit, but the motor is moving my tracker the wrong way? Your kit is working properly, but the East and West directions are reversed. Solution: Reverse the wiring of the two leads to the DC motor.

Is there an easy way to increase the current output of the standard kit for a larger motor? No. If there will be more than 10 requirements, I will build a heavy duty circuit rated for up to 8 amps.

My kit was working fine at first, but now I hear a whining sound and there is no movement? Check the voltage output of the battery you are using. It's likely the battery is discharged and needs to replaced or recharged.

Kit Assembly Troubleshooting

We have sold hundreds of these kits for projects without problems. However, if you are having trouble with your project, here is a list of the most common problems we have encountered working with customers:

1) Forgetting to install the power supply jumper on the circuit board. (Refer to Figure 9.)

2) Solder Problems. Typically, incomplete solder joint connections or solder shorting between pins... especially in the critical area around the IC comparator socket. Do not use plumbing solder for electrical circuits… it has a corrosive flux.

3) Resistors placed in the wrong location, or diodes installed backwards. Use the artwork outlines on the circuit board as an assembly guide.

4) The Integrated Circuit Chip is installed backwards. (See Figure 10.) This is lethal to the IC. Purchase a replacement IC at Radio Shack (#276-1712).

5) A wire inserted into one of the screw terminal connectors is not making contact because of the insulation on the wire. *This problem happens surprisingly often, so look close!*

Payloads for Solar Tracking

Sunlight is a powerful but diffuse energy source. Useful applications of solar energy generally make arrangement for collecting sunlight over a large area. Flat panel hot plate collectors for heating domestic hot water and solar photovoltaic panels for generating electricity are two good examples. Flat plate style collectors do benefit from tracking the sun, however the accuracy of the pointing is not critical, and position adjustments made infrequently are often adequate.

Focusing solar collectors use optical methods to concentrate the sunlight. Consequently the accuracy of the pointing is more critical. The two major types of optical solar concentrators are reflective and transmissive.

A typical reflective solar collector is a parabolic dish. A parabola is a special mathematical curve which focuses the light to a single spot called the focal point. A simple circular curve can form a reasonable approximation of a focusing surface, and can be more easily constructed by experimenters. Figure 31 shows an example of a parabolic reflective curve. A parabolic focusing type collector must be aimed accurately in two directions, requiring a dual axis solar tracker. However it is also possible to build a trough type solar reflector collector using the parabolic curve, in which case a single axis tracker will suffice.

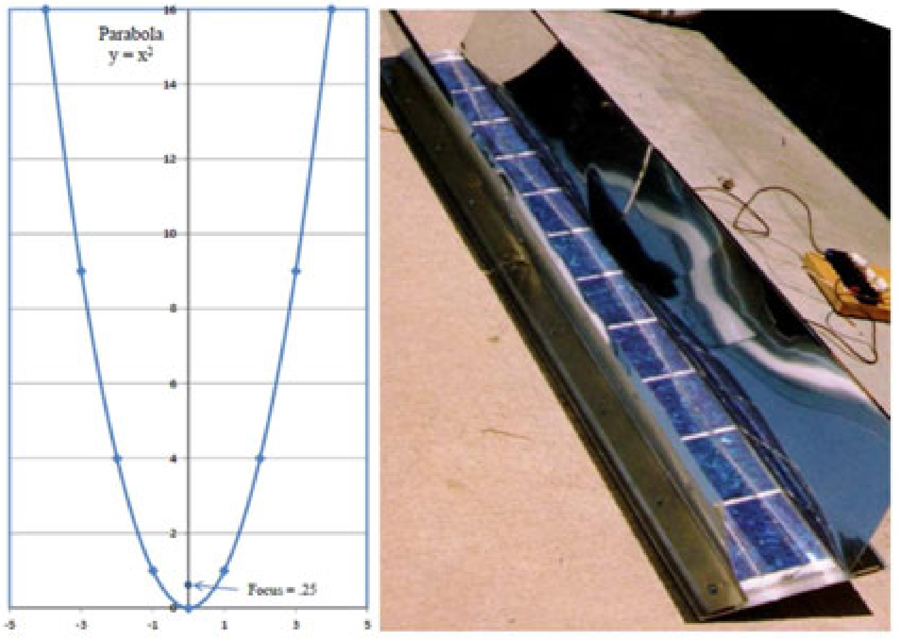


Figure 31. The parabolic curve and a linear trough collector example for photovoltaic cells.

Figure 32. Example of a spherical reflective collector built using cardboard and aluminum foil. A typical example of a transmissive type solar concentrator is a glass lens. The lens focuses the light to a single spot, also called the focal point. Glass lenses tend

to be thick, heavy and expensive. A special type of focusing lens made of plastic is the Fresnel lens. The Fresnel lens is made of concentric grooved rings molded into a sheet of acrylic plastic. The method of manufacture results in a large thin lens that is fairly inexpensive. A normal Fresnel lens focuses to a point and must be aimed accurately in two directions, requiring a dual axis solar tracker. However it is also possible to construct a linear Fresnel lens which focuses the sunlight along a line, instead of a point. With a linear Fresnel lens the sun can be tracked using a single axis solar tracker, and the solar energy subsequently collected with a tube or pipe arrangement.

Figure 33. Fresnel lens powering a small air cycle stirling engine.

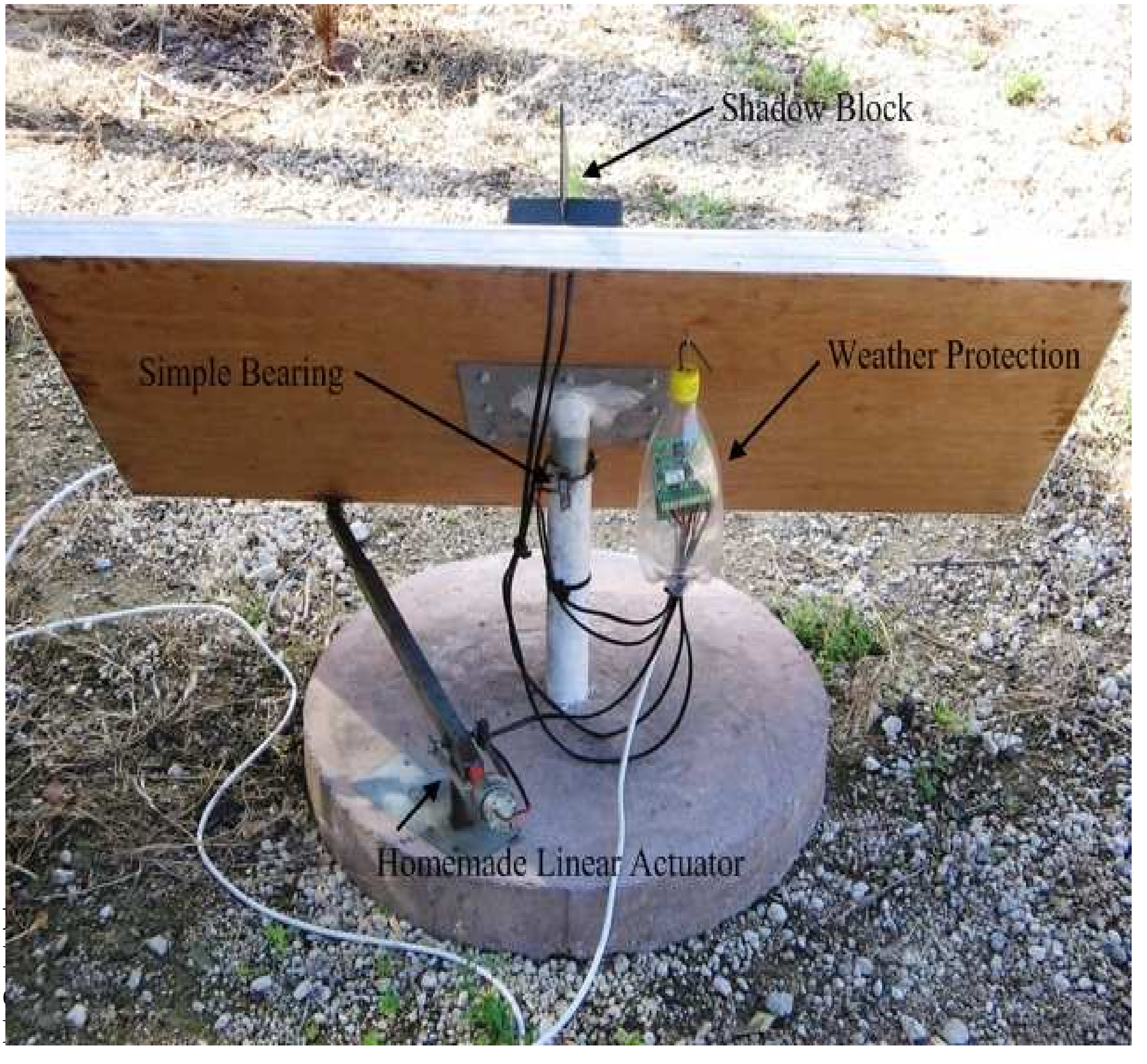


Figure 35. This Solar Tracker Project uses a DC linear actuator to move the panels. The controller is mounted inside a weatherproof electrical enclosure. The photos are courtesy of Bill F.

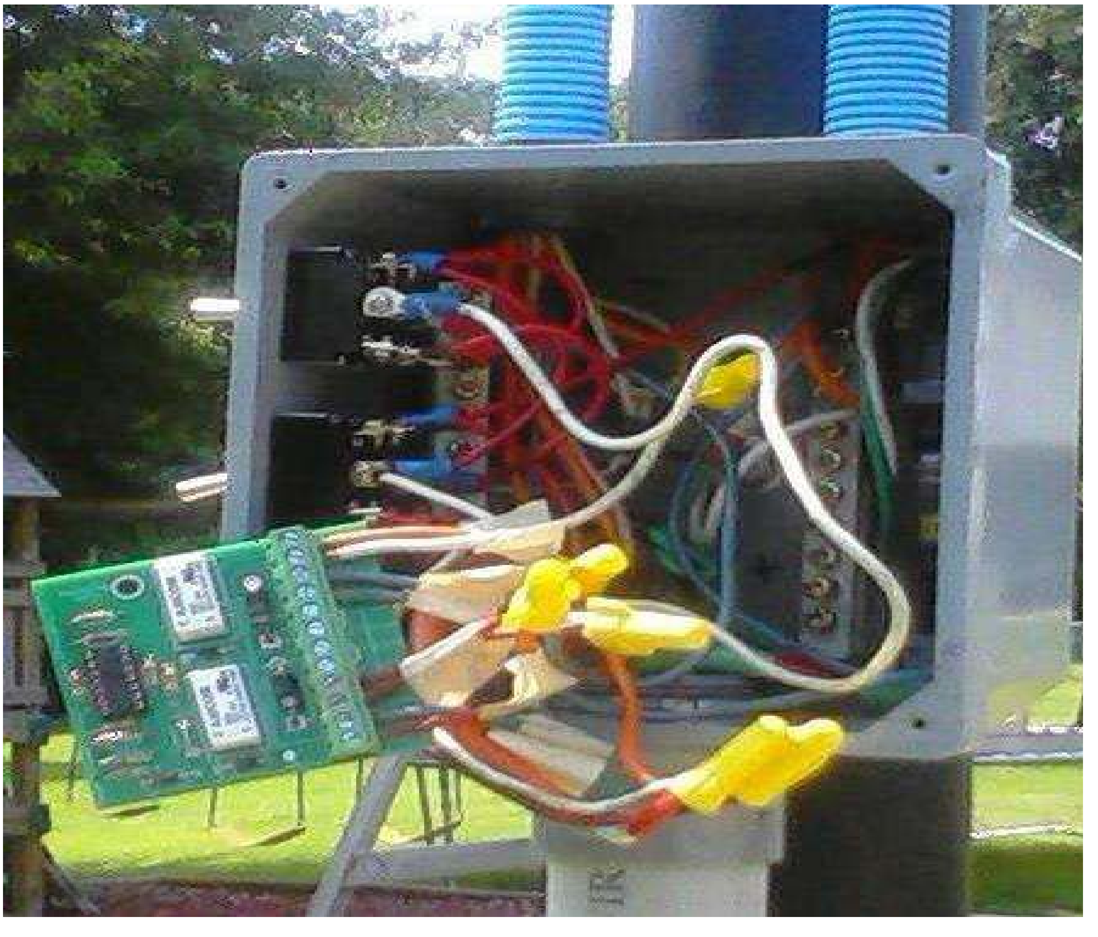
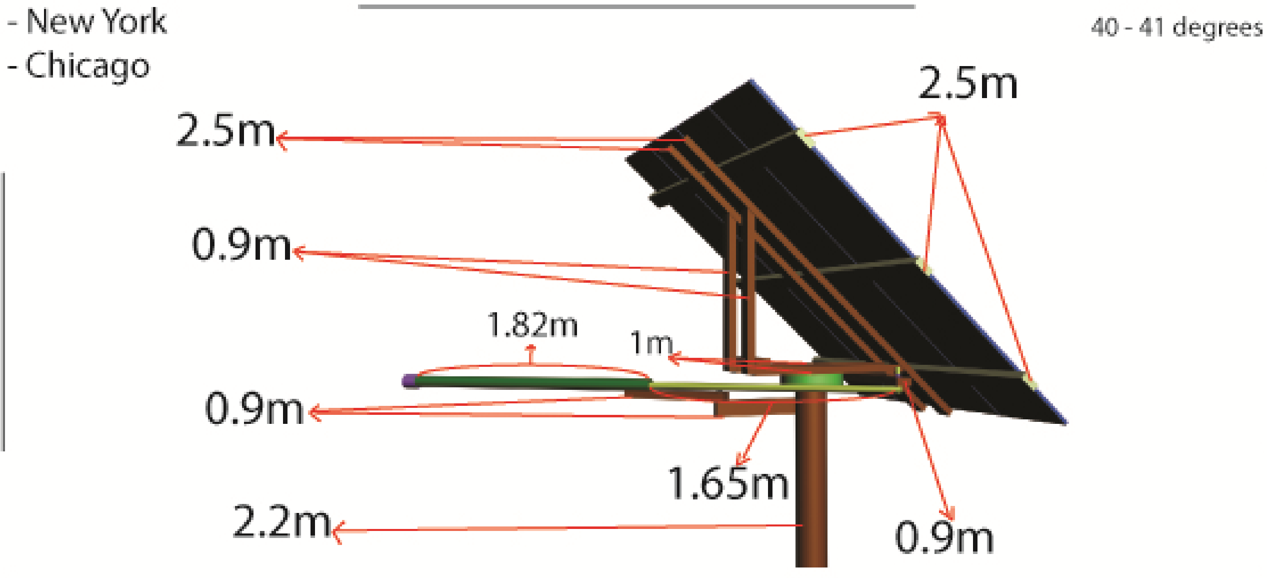


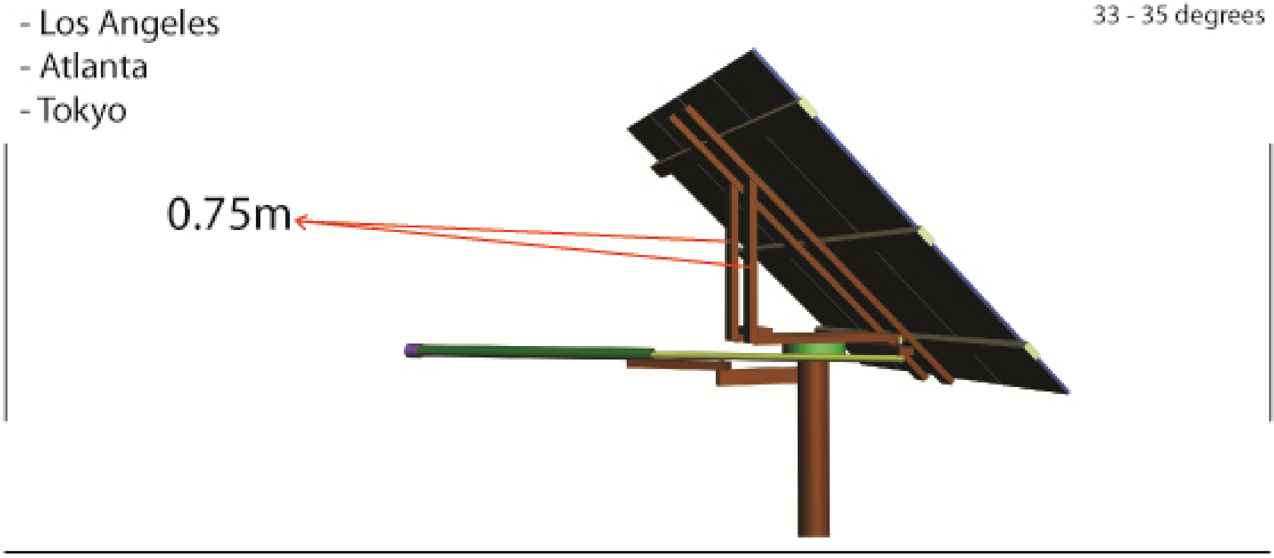
Figure 36. Here is a view of the enclosure for the electronics for the tracker shown in Figure 35.

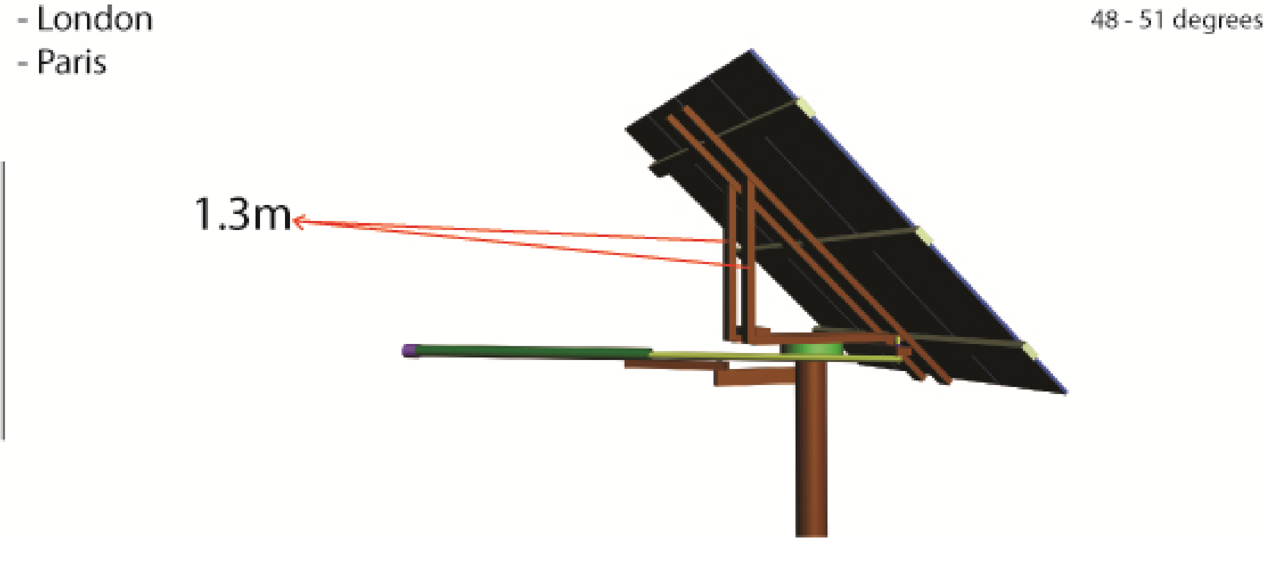
Figure 37. This awesome Solar Tracker project is the work of David. Note the use of a central mirror reflector to increase sunlight on the panels. These panels are moved with a heavy duty linear actuator.

Figure 38. Here is a view of the same tracker from Figure 33. Note the the shadow block assembly. Also, note how the circuit board was ruggedized with a conformal coating and is mounted in a weather tight enclosure.

Sun Tracking Schemes







About Batteries – Bonus

Batteries are very important to the overall project of your System because next to your PV panel, Wind turbine and the electric generator as backup, batteries can be one of the most expensive components in your entire system.
I will talk about the purpose, types, specifications and system sizing as it will
relate to batteries. One of the first question we are going to ask is : why even have batteries ?
On the surface the questions seems self-explanatory, but let's just talk about it for a moment.
If your PV system provide power to your house and you are not connected to the local electrical grid, you absolutely need to have batteries in order to provide 24 hour electrical power for you and your family.

Batteries are used to collect DC electrical energy produced by the PV, Wind Turbine and electric generator system for later use. Therefore, if your System produce during the day time when it's sunny, or the wind blows the batteries will produce power during the night time, when it's cloudy or when the wind will not blow .
Since our System power output can and will fluctuate through the day depending on the clouds and the weather, the batteries are going to provide a relatively constant source for periods of reduced solar energy.

Now, previously we talked about that paying close attention to how much load you want to have on your system but a small motor's across the line start will be supplied for by the battery or the batteries in your battery bank.
Let's talk more about …

PV Batteries

Batteries accumulate excess energy created by your PV system and store it to be used at night or when there is no other energy input. Batteries can discharge rapidly and yield more current that the charging source can produce by itself, so pumps or motors can be run intermittently.

The battery's capacity for holding energy is rated in amp-hours: 1 amp delivered for 1 hour = 1-amp hour

Battery capacity is listed in amp hours at a given voltage, e.g. 220 amp-hours at 6 volts. Manufacturer's typically rate storage batteries at a 20-hour rate:
220 amp-hour battery will deliver 11 amps for 20 hrs
This rating is designed only as a means to compare different batteries to the same standard and is not to be taken as a performance guarantee.

Batteries are electrochemical devices sensitive to climate, charge/discharge cycle history, temperature, and age. The performance of your battery depends on climate, location and usage patterns. For every 1.0 amp-hour you remove from your battery, you will need to pump about 1.25 amp-hours back in to return the battery to the same charge state of charge. This figure also varies with temperature, battery type and age.

Battery Types
Different chemicals can be combined to make batteries. Some combinations are low cost but low power also, others can store huge power at huge prices. Lead-acid batteries offer the best balance of capacity per dollar and it's a common battery used in

stand-alone power systems. In this section we will cover lead-acid batteries, for information on other type of batteries, please visit the FAQ link above.

Lead-Acid Batteries - How They work

The lead-acid battery cell consists of positive and negative lead plates of different composition suspended in a sulfuric acid solution called electrolyte. When cells discharge, sulfur molecules from the electrolyte bond with the lead plates and releases electrons. When the cell recharges, excess electrons go back to the electrolyte. A battery develops voltage from this chemical reaction. Electricity is the flow of electrons.

In a typical lead-acid battery, the voltage is approximately 2 volts per cell regardless of cell size. Electricity flows from the battery as soon as there is a circuit between the positive and negative terminals. This happens when any load (appliance) that needs electricity is connected to the battery.

Good care and caution should be used at all times when handling a battery. Improper battery use can result in explosion. Read all documentation included with your battery in its entirety.

Wattage, Volts, Amps, etc.

Most electrical appliances in the United States are rated with wattage, a measure of energy consumption per unit of time. One watt delivered for one hour equals one watthour. Wattage is the product of current (amps) multiplied by voltage.

watt = amps x volt

One amp delivered at 120 volts is the same amount of wattage as 10 amps delivered 12 volts:

1 amp at 120 volts = 10 amps at 12 volts

Wattage is independent of voltage:

1 watt at 120 volts = 1 watt at 12 volts

To convert a battery's amp-hour capacity to watt-hours, multiply the amp-hours times the voltage. The product is watt-hours.

To figure out how much battery capacity it will require to run an appliance for a given time, multiply the appliance wattage times the number of hours it will run to yield the total watt-hours. Then divide by the battery voltage to get the amp hours.

For example, running a 60-watt lightbulb for one hour uses 60 watt-hours. If a 12-volt battery is running the light it will consume 5 amp-hours (60 watt-hours divided by 12 volts equals 5 amp-hours)

How big a battery do I need for a PV System?

Ideally, a battery bank should be sized to be able to store power for 5 days of autonomy during cloudy weather. If the battery bank is smaller than 3 day capacity, it is going to cycle deeply on a regular basis and the battery will have a shorter life. System size, individual needs and expectations will determine the best battery size for your system.

Please contact us and our engineers and consultants will be happy to assist you.

Battery Cycles

Batteries are rated according to their "cycles". Batteries can have shallow cycles between 10% to 15% of the battery's total capacity, or deep cycles up to 50% to 80%. Shallow-cycle batteries, as those for starting a car, are designed to deliver several hundred amperes for a few seconds, then the alternator takes over and the battery is quickly recharged. Deep-cycle batteries or the other hand, deliver a few amperes for

hundreds of hours between charges.
These two types of batteries are designed for
different applications and should not be interchanged. Deep-cycle batteries are capable of many repeated deep cycles and are best suited for PV power systems.

Lead-Acid Battery Types

Starting Batteries - Shallow cycle automotive battery not suitable for Photovoltaic Systems.

RV or Marine "Deep-Cycle" - 12 volt batteries usually 80 and 160-amp hour capacity. A compromise between shallow and true deep cycle batteries. Life expectancy is about 2 to 3 years.

Lead-Calcium Batteries -Occasionally these shallow-cycle batteries recycled from the telephone company are used in remote power systems. At 400 pounds per 2 volt cell and cycle limited to 15% - 20%, these batteries are not recommended.

Sealed Batteries - These are liquid-tight batteries that can operate in any position without leaking acid. Because of the seal construction, you cannot check cell conditions with a hydrometer. Vents prevent pressure build-up in case of gassing. Recommended only for situations where hydrogen gassing during charging cannot be tolerated, or the battery is going to be moved a great deal, or to be fit in tight spaces. Require lower voltage charge controls. Most AGM batteries (absorbed glass mat) have a life expectancy of 2-5 years, and 5-10 years for higher quality Gel cell batteries. Most sealed batteries are AGM.

True Deep-Cycle Batteries - True deep-cycle batteries are specifically designed for energy storage and deep-cycle service. They tend to have larger and thicker plates as shown in the image above. Ideal for renewable energy systems, deep-cycle batteries withstand having a majority of their capacity used before being recharged and survive hundreds and even thousands of 80% cycles. It is recommended to use 50% as the normal maximum discharge and leave 30% for emergencies. Do not use the bottom 20%, the less deeply you cycle your battery, they longer it will last. Available in many sizes and types.

List of Materials and Tools

Materials:

1. 3 x 5 cm rectangular steel pipe – see the schemes and get the right dimensions.
2. 4 x 6 cm rectangular aluminum pipe – These bars are represented by horizontal bars on the scheme. Only three bars of 2.5m will be used on this project, anything else is made from steel
3. 2m of pipe, around 15cm in diameter.
4. Self Drilling screws. I used 5 cm long self drilling screws to secure the aluminum bars to the steel bars.
5. 8 cm wide steel clamps to fix the actuator in place, watch the videos for more info.
6. 2m of PVC pipe, 4 cm in diameter.
7. 2 bearings, 15 mm interior and 38 mm exterior. You don't need to use the exact dimensions, but they should be in this range.
8. 2 threaded roads 1 m each, 12mm in diameter, (If you can find a 2 m threaded road, this will be great).
9. Plastic exterior box, 30 cm by 17 cm, (or around these values).
10. Plastic box, 10 cm by 10 cm, used to place the tracking circuit inside.
11. Car hub, this can be found on scrap yard, try to get the hub from one of the back wheels.
12. 12 V gearhead motor for the actuator, this should have around 22 RPM.
13. 12 V motorcycle battery, this also can be found on a damaged motorcycle or scooter in the scrap yard.
14. Cable connectors.
15. 12 V Charge controller.
16. Cable to connect the actuator with the tracking circuit.
17. Zip ties
18. Electrical Tape
19. One piece of glass, 6 by 9 cm.
20. Silicone

Tools:

1. Drill and drill bits
2. Welding machine, if you don't have one, you can go on a workshop and do all the welding there.
3. Angle Grinder
4. Level

Video Transcripts

Transcript on how to build the sun tracking device.

I will start by presenting the components that I will use for the sun tracking circuit.

These are the photo resistors, we will call them “sensors” because they will detect the light and will transmit the signal to the motor and move the panels in the right direction.

This is a comparator which will be also soldered to the circuit board.

Here I have a relay and diodes.

These are the terminal blocks which will be used to connect the wires to the circuit board.

This is the main circuit board where all the parts will be soldered together. If you didn’t ordered the “sun tracking kit” with all the parts, including this circuit board, you should click to order the kit now or you can order just the videos on how to print your circuit board at home and buy the rest of parts by yourself (this by the way it will take you a lot of time and I don’t guarantee that you will find all the parts on a local store, so you will need to order them on the internet).

This is a limit switch which will be used to stop the motor if the actuator that we will built will reach one of the ends.

This is a small, but very powerful 12V DC motor, the motor it’s spinning with 7000 rpm but the gear reduces that to 22 rpm, so the torque on this is huge and it’s more than enough to move our solar panels.

You should already have this motor if you ordered the sun tracking kit.

I am going to show you how slow the shaft of this motor is spinning.

If the polarity is changed, it will spin in the opposite way.

These are the resistors that I will use on this circuit, you can download the full list of spec and print it out if you are going to search for the parts by yourself.

Ok, I’ve presented you the parts for this circuit and now I can start soldering them on the circuit board.

I will start soldering the diodes first. You can get the scheme for the circuit assembly from the download section and print that out. For those who ordered the kit, you will find that in the book.

I will stay quiet for a while because there’s not much that I can say on this process, so I will let you enjoy the video. If you already know how to solder parts on a circuit board and you don’t have any questions, you can skip this part and watch the rest of videos.

This is the finished circuit board, all the parts are soldered in place and now I can get outside to start digging the whole for the pipe which will hold the solar tracker.

I will make a whole, 50 cm deep and about 30 cm wide.

After it’s finished, I will weld some pieces of steel to the pipe, this will secure it in the concrete.

Now, I will mix the cement with gravel, sand and water, then fix the pipe in place.

I will add some concrete, then I will add some rocks to secure the pipe in place until the concrete hardness. Using the lever I will make sure that the pipe it’s fixed straight.

I will check again to see if everything is ok.

After this step is completed, I will let the concrete to dry out and I will go on a scrap yard to get a car hub, preferably from one of the back wheels. You will need the part that’s moving and the static one that’s attached to the car.

The best cars for this project are the one used to carry things. Like vans and trucks.

If you don’t have access to any, you can try with the back hub of a small car.

I will start disassembling this hub, it may look different from car to car, but if you go on a back yard, there you may find some people that will help you with your project.

Ok, I’ve got my hub from a truck and I will start cutting the bolts.

I am actually using the small angle grinder to not scare you, but it will take much longer than using the bigger one. I will eventually switch it. If you are not feeling secure using the big angle grinder, you can use the smaller one but you should have 2 disks for this step.

If you are using the big angle grinder, make sure you have a good grip on it and you don’t let go even if it’s vibrating, just get the hand from the “trigger” if you want to stop it.

Ok, it’s done now.

I will start cutting the rectangular pipe that I will weld to the hub. I am using 3 by 5 cm rectangular pipe made of steel for this step.

I will cut 2 pieces of 1 m each.

I am building the 42 degrees version of this sun tracking device, you may want to go on the download page, get the “E-book.pdf” file and look for the scheme with the specifications to build the sun tracking device for your area.

I will measure and mark the center of this steel piece. It will be welded that in place right in the middle.

Now I am welding the second rectangular pipe.

I will weld a piece of 90 cm now. I need to make sure that I have a 90 degrees angle between these pieces.

You may think to other ways which will help you to weld the pieces in a 90 degrees angle, but at that time I’ve found that taping the angle square to both pieces did the job for me.

If you are using the same method, make sure that you are not using a plastic made angle square, because it will be a “one time only use” and you have to weld two pieces in a 90 degrees angle.

Make sure the bars are parallel, perhaps it’s a good idea to weld them together first using a spacer and then weld them to the steel pieces fixed on the hub.

I used a piece of cardboard as a spacer with some electrical tape and that worked well for me.

I will make sure that the distances are equal and the bars are parallel before I start welding them for good.

I will make a mark using the longer rectangular bar which is going to be weld in an angle.

After I've made the marks, I will start cutting using the angle grinder.

I will do the same thing on the other ends as well.

Now, I will weld the two parts together using a spacer. Make sure you look on the printed book or the E-book that can be downloaded from the download page to get the right dimensions for the spacer and the rectangular bars.

Now I will weld everything together. I will measure to make sure that I have the same distance on both ends, so everything will be well balanced.

After I finish welding the pieces together, I will get the part which normally is fixed on the car. It may look different on your hub, but it's the same thing.

Ok, this is the part that I will weld to the pipe.

Right now, I will start the work on the actuator, this will move the tracker back and forth. You can buy an actuator from the internet, but the prices are starting from $120. You can build one for $40 or less. If you bought the "Sun tracking kit" you will find there the 12V Dc motor and the bearings which I will use on this actuator.

I will join two 12mm threaded rods to make one 1.7m threaded rod. I couldn't find a rod long enough, to avoid that. If you know a place where you can get a 2 m threaded rod and cut it to size, that would be great, if not, just buy two 1m rods and join them.

I will weld two nuts on a piece of L steel profile. I will use these nuts to align both pieces together.

I am going to unscrew the rod now and get the other one in place.

I will use some electrical tape to fix both rods in place.

Make sure that they will be well aligned before you start welding them. When you are welding the threaded rods together, make sure that you go deep with the welding, in order to get that passing the nuts when the threaded rod is unscrewed.

You can use the angle grinder and the file to finish up the final piece.

Now I will start working on the moving part of the actuator. I will put two nuts on a bolt in order to get them well aligned and I will weld the nuts on a piece of 10mm steel rod.

I will unscrew the bolt now and see if everything is ok.

Before I mount the motor shaft to the threaded rod, I will insert the bearings and the nuts first. After that I will start making a cut exactly in the middle of the rod. If you bought the kit with all the parts, you will use the joining piece that's coming with the motor.

For those who didn't ordered the kit, I've found that this is an easy way to join the motor to the rod.

The shaft will be inserted in that split. I will insert another nut that I will use to tighten the shaft and fix it in place. Using a screw driver I will make room for the shaft. After the shaft is fully inserted, I will start unscrewing the nut and that will fix the shaft in place.

Try to get that right and make sure that the motor is well aligned with the rod, so it will spin smoothly.

I will unscrew the nut to fix the shaft in place.

Ok, it's mounted now.

I will build the housing for the actuator from a PVC pipe. The pipe has 4.2 cm in diameter. The actual dimensions can be found on the pdf book or the printed book.

In the near future I will try to find a way to make this system work with a smaller actuator, so you don't have to join two threaded rods together.

The inside of the bearing is bigger than the rod, so I will apply some electrical tape to get them centered and then I will tighten the nuts to block the bearings in place.

I will leave about 8cm between each bearing.

Try to get the amount of tape just right, so it will fit well.

Now I will tight the nuts and block the bearing in place.

I will do the same thing for the other one.

I will make a mark to know exactly where the bearings will be when I insert the rod and the motor inside that pipe.

I will use these two clamps to secure the bearings to the PVC pipe.

The clamps will be placed where I've made the marks for each bearing.

Now I can insert the rod inside.

I will make a mark for a small cut in order to get the motor in place.

I won't remove that plastic part, I will use that to secure the motor in place with some tape.

You can also put a clamp on the motor if you want.

Before I start tighten the clamp, I will apply some heat, so the PVC pipe will mold on the bearing securing it in place.

I will do the same thing on the other clamp.

I will add some electrical tape to secure the motor in place, then I will add silicone to make sure that it will stay in place and it will also keep the water out.

I will try to improve this design and make things much simple, so you can check the members page and see if there are any updates on the actuator.

I will drill a hole in the cap and insert the wire through.

Now I will start soldering the wire to the motor. The red lead will be soldered on the positive contact and the red/black lead on the negative contact.

I will put the cap and I will add more water proof electrical tape.

I will add some silicone on the hole to keep the water out.

Now I will cut the cable and do a test to see if everything is working properly.

I will use a 12V DC source to test the motor.

The rod is spinning and I can say that's having enough power to spin the solar tracker.

I will add the moving part of the actuator to see if everything is aligned properly.

Now, I need to weld a piece of steel that will be used to push the limit switches, so when the moving part is close to one end or the other, it will send a message to the circuit board to stop spinning the motor and avoid any damages on the actuator or on the solar tracker.

This piece of steel should be small enough to fit in the PVC pipe.

I will make a slight adjustment to the limit switch trigger.

Now, I will install the limit switch inside the pvc pipe.

On this step you can use some self drilling screws to keep the switch in place. I will use some wire to speed up the process.

Make two holes in the pvc pipe and secure the limit switch in place.

I will connect the wires to the limit switch. I will solder a wire on pin 1 and the other wire on pin 3.

Make sure you look on the E-book or on the handbook to get the right measurements when you are installing the limit switches. In the video I will just show you the easiest way to complete this step.

Using the angle grinder, I will make a hole and install the 2nd switch.

I will solder the wires first and then I will fix it inside the PVC pipe.

If you will use self drilling screws to fix the switches in place, make sure that they will not touch the threaded rod and block it.

To cover the hole I've made, I will cut in half a piece from a PVC pipe and I will fix that in place with silicone. I will add some electrical tape to keep the piece pressed down until the silicone hardness.

Now, I will create a closed tip for the actuator using a smaller piece of PVC pipe which will connect with the bigger one. Because I have the piece of wire holding the switch, I can't insert the PVC pipe, so I will use the blowtorch to heat the pipe and then insert it.

I want to make a closed end on the smaller PVC pipe, this will help to keep the water out.

I will insert a self drilling screw to keep the end closed.

And this is the home built actuator.

I am outside now and I will weld the static part of the hub to the pipe that I've secured in concrete.

I will make sure that's mounted straight. It really depends on how the end of your pipe is cut out, try to have that end as straight as possible to simplify this step.

I will weld that piece 360 degrees, to make sure that's well secured and it will hold the assembly without any problems.

I am using the hammer to remove the welding slag.

After this step is finished, I can mount the solar panels support.

If it's too heavy for you, it's a good idea to have a friend helping you on this step.

Now I will tighten the nut to secure the assembly in place.

I will cut two similar pieces of rectangular pipe for the moving arm where the actuator will be installed.

I am using a 12 mm drill bit to make a whole for the pivot.

A 12 mm bolt as a pivot and I will block that in place with a nut. I will drill a hole in the second piece as well.

Now I will join both pieces.

I will put a washer and I will use two nuts to block them into each other, so they won't move with the arm.

After I tested the assembly, I will weld the piece into place.

I actually did a mistake when I weld the piece in the first place, but I didn't removed that on the montage because I also showed how to mount the actuator on the arm.

I've first installed the arm in the East to West direction and that didn't work. The piece should be welded in the North/West Position. I will show you in a couple of minutes how to get the right direction.

I will install the moving part right now, and then using two clamps, which also come with the sun tracking kit, I will fix the actuator in place.

Now I will weld the other rectangular pipe.

It's time to cut the fixed part of the arm and weld it again in the right place.

Ok, so to find the right place for the fixed part, you should face the assembly to the East and with a long stick or a piece of pipe, try to get both pivot points in line by moving the rectangular pipe that is going to be weld in place.

Ok, so this is how you get the right alignment.

Before I weld the piece for good, I will test again and see if everything is ok.

And … it isn't.. Try to get this as perfect as possible, because if you don't, the solar panels won't spin in the East to West direction and you can lose a lot of sun light.

It’s also a good idea to use a level when you are welding the piece in place, to make sure that everything is aligned properly.

Now that I’ve got the right position for my rectangular pipe, I can weld that for good.

I will put the actuator in place now.

Make sure that’s spinning freely and the nuts are not tighten to block it into place.

I need to move the actuator back to get it leveled with the moving arm.

Now I will drill a hole for the second pivot point.

I will also use a screw on this step. The nut should be not tighten to block the screw in place.

Now I want to test and see if the assembly is spinning. It’s working, the motor’s rpm are very low, but that’s good because the sun is not moving fast at all.

I will measure the distance between rectangular pipes and mark on the aluminum rectangular pipe where the holes should be drilled.

On the aluminum rectangular pipe I will mark the center first and then I will mark the place of the two rectangular steel pipes, so I know where to drill the holes.

I will do the marks on the rest of two aluminum bars and drill the holes in them as well.

I will measure and mark the distance between bars.

I will make the holes bigger in order to get the self drilling screws spinning freely when I try to insert them in the steel pipe.

I will insert the self drilling screws in the first layer of the rectangular pipe and then make the hole bigger. When I will insert the screw again, it will drill in the second layer securing the aluminum bar in place.

You can get specific dimensions to install the bars in the scheme from the E-book.

I will do the same thing to install the rest of two rectangular pipes.

If you don’t want to use self drilling screws for this process, you can make the holes bigger and use screws with washers and nuts to secure the aluminum bars in place. The self drilling screws worked just fine for me, but you may consider using screws, washers and nuts as well.

This is how it should look after the aluminum bars are in place.

Now I will build some clamps made of aluminum to secure the solar panels in place. I will cut a piece of L aluminum profile in half to get two separate pieces.

I will mark 2cm then 1.5cm and the last mark on 2cm again.

I will secure and bend the aluminum piece.

The final piece should look like and “S”.

I will need 8 of this clamps for the solar panels installed on the bottom.

The other solar panels will be secured in place with a straight piece of aluminum 5 cm long with a hole in the middle. Keep looking on the videos and you will see what I am talking about.

I will drill a pilot hole first, then I will insert the self drilling screw securing the first clamp in place.

I will do the same thing on the other end.

I will drill the pilot holes for the next clamps as well.

Now I will use the straight aluminum pieces to keep both panels secured to the aluminum rectangular bar.

I will do the same thing with the rest of the solar panels.

I am using solar panels that I've built by myself. If you are interested to learn how to build such panels, you can go on www.greenenergyjunkie.com .

I will have 8 solar panels installed on this sun tracking device. Each of them capable to produce over 85 Watts, so I will have around 700 Watts/hour from this system, which I think it's great.

For the top clamps, I will use screws and nuts because I can't reach to insert the self drilling screws on the other side.

I will drill the hole bigger in order to get the screw through and then I will tighten the nut.

I will start now working on the box which will hold the sun tracking circuit. I am using a 10 by 10 cm box.

I will make a cut on the top of the lid, 5 by 8 cm using the angle grinder.

The piece of plastic that I just cut, will be used for the shadow block.

Now I will cut a piece of glass. If got the kit, you should use the piece of glass that's inside.

The piece of glass should be 6 by 9 cm.

Now I will fix the glass in place using silicone.

This is how the box will look.

The piece of plastic that I've just cut, will be used as a shadow block.

The circuit will be mounted inside of this box.

Now, I am soldering the wires on photo resistors.

The resistance of this photo resistor will change depending on the light intensity.

I will do the same thing on the second photo resistor.

I will also test this sensor to see if everything is ok.

I want to mark the East and West on the box so I know how to install it on the solar tracker.

Now I will fix the photo resistors in place with silicone. They should be fixed in same, but opposite sides.

Make sure that the silicone will touch just the wires and you are not placing any silicone on the photo cell. This will make the photo resistor to act strange and the circuit will not work well.

I will let the silicon dry for a couple of minutes. Until then, I will fix the board in place to measure and cut the shadow block, in order to make it fit inside the box.

I will put some tape to keep the resistor in place until the silicone hardness and I will apply silicone on the other side to fix the second resistor in place.

Now I can leave it dry for a while.

Now that the resistors are in place, I will fix the shadow block on the glass with some silicone.

I will use this bar to keep it straight.

After the silicone hardness, I will test and see if it will fit inside. I actually need to make some adjustments to make it fit.

Ok, it’s fitting nicely now.

I accidentally cut one of the wires of the resistor and I need to solder it back now.

I will test and see if everything is ok.

I will make a mark on the box as well to make sure that the lid will be installed in the right place.

This is the box that I will use to keep the 12v battery and the charge controller which will charge the battery.

I will find a place for the box first, and then I will drill the holes in the box where I will insert the self drilling screws.

I am using 2.5 cm self drilling screws with a washer to secure the box in place.

Make sure that you place it high enough, so it won’t touch the actuator.

The box is in place now and I can fix the charge controller.

The circuit should be powered day and night, that’s why I am using a small 12V battery. When the sun goes down, it will reset the position of the solar panels to face East.

Now I will connect the panels in parallel. I will join the panels in pairs of two. So I will have 4 cables going inside the box.

Now, using the zip ties, which also come with the kit, I will pose the cable to the box and then cut it to size.

I need to make a hole in the box to insert the wire through.

After the cover it’s installed, I can insert the wire now and cut it to size.

I will do the same thing with the rest if three wires.

If you've made the hole to large and the robber cover is not big enough, you can use some silicone to seal that.

I have one set of panels to connect and then I can connect the wires to the charge controller.

I will connect the panels to the charge controller from this box and I will also connect them to a cable which will exit the box and go to the main charge controller or grid tie inverter to power your home.

I will create new videos on how to connect the solar panels on a grid tie inverter or to the batteries and I will post them in the members section. It's a good idea to be subscribed as a member, you will learn everything that you need about solar panels and devices to power your home.

Now I will connect the panels together and one cable will go to the charge controller and another one will exit the box.

Make sure that all the connections are made in parallel to keep the voltage down and get higher amperage.

This is the wire which will go on the charge controller.

The green light is on, that means we are getting power from the solar panels.

I actually forgot to connect the wire which will exit the box.

I will connect two sets of solar panels together, then I will use a patch cord to connect them with the other two sets. Another patch cord will go from the solar panels into the charge controller.

If your charge controller doesn't support more than 20 amps, you can use a diode to connect both sets of solar panels, so into the charge controller from the box will enter the energy from 4 solar panels and in the main charge controller you will have the energy from all of them.

The diode will drive the current in one way, so the electricity from the others 4 panels won't go in the charge controller.

I plan to add more updates on this thing on the members area, if you don't know how to use that diode.

This is the battery that I will use to power the sun tracking circuit. I've found this battery on a damaged motorcycle on the scrap yard. If you prefer, you can buy a new one, it's around $10 or so.

Now I will make a patch cord to connect the charge controller with the battery.

Let me explain you what's with all these wires.

The top wires are connected with the charge controller and with the rest of 4 panels in parallel.

On this connector I will insert the exit wire which will go into the main charge controller.

This is the wire that I will use to get the energy out.

I will close the lid now and I will make sure that the cable is not very tight and the panels can spin freely.

So this is the main power box, now I will mount the box which will hold the sun tracking circuit.

I will use the jigsaw to make the holes rounder.

I will need 4 holes into this box to insert all the wires.

This is how it should look after the robber caps are added.

I will use self drilling screw to secure the box in place.

I will drill the holes into the box and after that I will secure it in place.

Now, I will get the wires from the actuator to the sun tracking box and connect them to the circuit board.

I will add a piece of tape to the wire which is coming from the East Limit switch and two pieces of tape to the one that's coming from the West limit switch.

The 3rd wire is the one that's coming from the motor.

I am going to cut the excess wire and then insert them into the box.

I will add another wire which will go on the power box and it will be connected to the 12V battery.

I will connect the wires on the circuit board first, and then I will connect the wires on the battery.

To connect the wires on the circuit board is very simple, just follow the scheme from the book or e-book to connect all the wires in the right place.

Now I can connect the power wire on the 12V battery and if everything is connected right and the sun is up in the sky, the sun tracking device should start positioning to face the sun.

If it's cloudy day, the device will be in standby until the sun appears.

The red lead will go on the positive contact of the battery and the black lead on the negative contact. After you finish this step, put the lid of the box back.

To make the device more accurate, using a permanent black marker, make a 2cm wide black line to cover the silicone like you see in the video.

I hope you've enjoyed the video guide.

Thanks for watching!

Transcript on how to replace the glass sheet on a broken solar panel.

Hi, Here's Alex.

This is a bonus DVD from www.greenenergyjunkie.com . In this video you will learn how to replace a broken glass of a home made solar panel. This is not happening frequently, but if it's happening to you, it's very cheap to replace the glass sheet if you know how to remove the cells without breaking them.

The first thing that I will do is to cut the silicone that's holding the aluminum pieces fixed to the glass and polycarbonate.

After the silicone is cut out, I will remove the aluminum profile.

I will clean off as much silicone as I can, to make room for the new silicone which will seal off the panel.

Now I have just the solar cells and the glass with the sticker which is holding the cells fixed to the glass.

To remove the cells from the glass, I need to cut all the areas in the sticker where it's pasted on the glass. The sticker which is pasted on the cells will remain intact.

Watch the video to see exactly how I did this process.

Now I will cut the sticker between cells.

After all the pasted areas are cut out, I will start peeling off gently the cells from the glass.

I will start wiping the cells and let them dry for a while. After that I will install them on a new glass sheet and then I will seal everything with silicone.

Until the cells dry out, I will cut another piece of sponge that's used on laminated flooring. The one that I used before was very thin, and perhaps that's why the glass shattered when the ice rain started.

You can also use acetone to clean the cells if they are dirty.

Now I will put the replacement glass sheet on the table and clean it.

After the solar cells are dried, I will place them on the glass sheet.

I will measure to make sure that the cells are positioned right in the middle of the glass sheet so they will look good from outside.

I am going to cut to size a piece of sticker and fix the cells in place with that.

You can use any type of sticker for this step.

I will press to make sure that the sticker is pasted everywhere.

Now I will make room for the wires which will exit the solar panel.

I will lay the sponge between the cells and the polycarbonate sheet now.

The exit wire will go on the J-box, and after that, I can put back the aluminum profile and start applying silicone to keep everything together.

It will also keep the water out.

After I finish applying silicone on the back of the panel, I will gently flip the solar panel and apply silicone on the front as well.

And here you have it, a brand new restored solar panel ready to convert the sun's energy into electricity.

If you enjoyed this video, make sure that you check www.greenenergyjunkie.com to learn how to build such solar panels at home at the lowest costs possible.

Thanks for watching!