Solar PV tracker

by **bwitmer** on December 27, 2008

Table of Contents

Intro: Solar PV tracker

For a class project (PV Design, Appalachian State, Dr. Dennis Scanlin) I decided to try making a low cost PV (photovoltaic) tracker. Being able to follow the sun's path through the sky can raise your solar panel system's output considerably (30-50%), but the argon filled ones can be a bit pricey, and seem to be a bit unsteady in wind. I looked at several different designs, looked at what materials I could find, and this is how I did it.

The panel is mounted to a frame, which is attached to two bike wheels. The wheels are mounted to a larger wooden frame, and the wheels and panel are moved by a 12 volt linear actuator. The sensor is an LED model and is purchased from Redrok Energy.

The LED sensor senses the path of the sun and tells the actuator how much to move to keep the panel properly oriented. At the front of the tracker are two legs that can be adjusted to the proper altitude for seasonal changes.

I used bicycle wheels because they are durable, strong enough to handle some weight, and best of all, in my case, free!

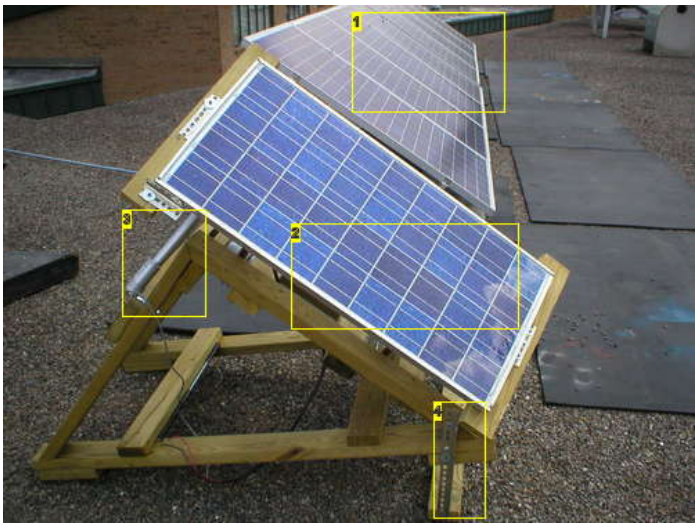


Image Notes
1. Poor bored, unmoving solar panels
2. Happy panel following the sun.
3. 12v. linear actuator
4. Height adjustment (36 degrees for Boone, NC)

Step 1: What do you need?

Here is what I used to make this tracker, and where obtained:

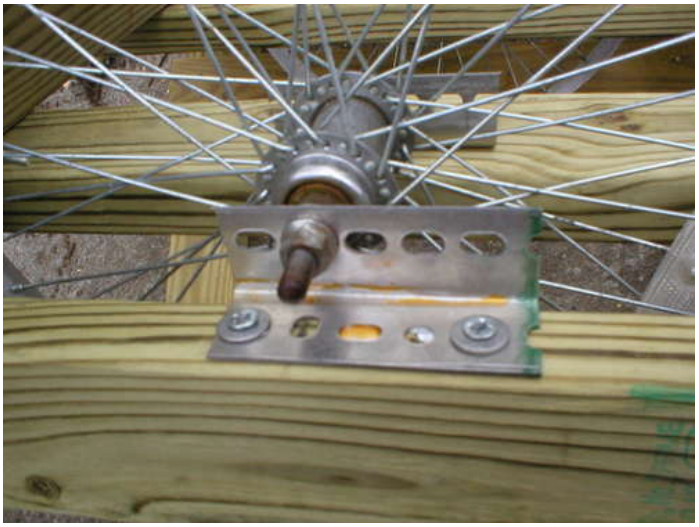
*Several treated 2x4's (Lowes)
*Two wheels from a free bicycle- free or almost free bikes are pretty easy to find from the local landfill or thrift store
*A piece angle iron with pre-punched holes (Lowes)
*A 12 volt linear actuator-(~$75?)- (Ebay)
*An LED tracking sensor- (~$40)(http://www.redrok.com/led3xassm.htm#led3xforsale)
*Various nuts, bolts, screws, cable and wire -(scrounging around my workshop)

Step 2: Making the base, and mounting the wheels

To make a nice, sturdy base I cut the 2x4's at angles and put them together to make two triangles. You can make them whatever size you need, depending on the size of your panels. I then tied them together with a couple of 2x4's at the base, and a couple up top. This made a nice, sturdy base to mount the wheels to.

I cut a couple of small pieces of angle iron with a hacksaw, found the mid point on the cross members, and attached them exterior woodscrews. I put the wheels through the holes, and spun them with satisfaction.

Here is a picture of the top wheel being mounted.



Step 3: Adding the wooden frame to the wheels

I then mounted the 2x6 piece to the bike wheels by drilling holes through the bike rims and the 2 x 6 and bolting them together. I also used big U-bolts to clamp the rims to the board by drilling holes through the board and clamping it down tight. The board pivoted nicely on the two bike rims.

The 2 x 6 isn't wide enough to mount the panel to, so I added some smaller 2 x 4's to the top and bottom of the board, cut to the size of the panel. Each 2 x 4 board is as long as the solar panel is wide, and was attached to each end of the 2 x 6 with screws and bolts.

This allows a nice flat place on which to mount the panel. I attached small pieces of angle iron to the holes on the end of each panel, and then screwed them to the wooden frame. This secured the panel to the frame.

Image Notes
1. I used a U-bolt to secure the rim to the board, as well as a through bolt going through the rim and the board

Step 4: Adding the linear actuator

I purchased the 12 volt linear actuator on Ebay. It's built to hold up in the weather, is strong enough to move however many panels I would want to add to it, and has a long enough stroke to move the panels all the way from one side to another. (I think the stroke is 8", but I'd have to double check.)

I mounted it on the one side of the frame with a through bolt, and attached it to the movable solar panel frame. To mount it to the side of the frame holding the solar panel I just used a staple on the board that moves on the bicycle wheels. A short piece of cable goes through the hole on the linear actuator and the staple, and iIused a small cable clamp to secure it. This allows everything to move around and flex as needed when it's moving. When hooked to the battery the actuator moves the panel all the way to one side, and reversing it moves it all the way back.

The next step is giving the tracker the smarts to know when and how much to move.

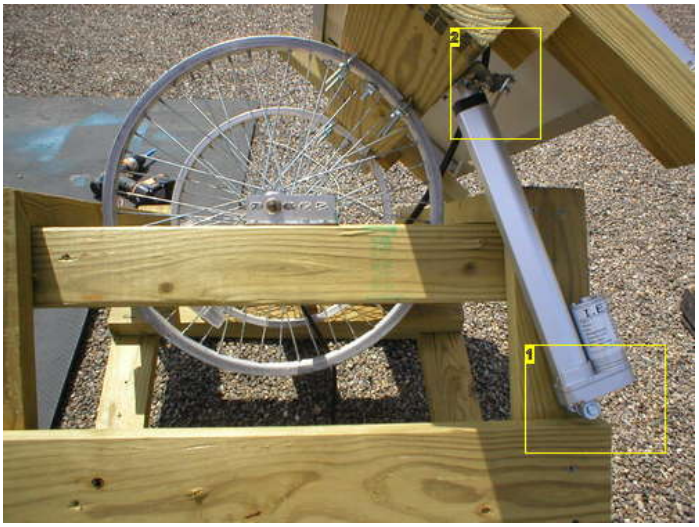


Image Notes
1. Linear actuator is held to the main frame by a small through bolt.
2. I attached a wood staple to the moving frame. I then used a small piece of cable that goes through the hole on the end of the actuator and through the staple, and

is then closed with a cable clamp.

Step 5: Adding the LED tracker

I wish I had more pictures of the LED tracking unit, but there is plenty of info at Redroks website. The unit uses LED's to measure the position of the sun and tells the linear actuator how much to move and where to position the panel. It's really a slick little unit, and at a great price.

Go to http://www.redrok.com/led3xassm.htm#led3xforsale to purchase one if you want to try this yourself. There are plenty of pictures of how other folks have mounted them at http://www.redrok.com/electron.htm#led3x . I put mine in an empty peanut butter jar and mounted it to a 2 x 4. I attached the 2 x 4 to the side of the unit to get the LED tracker up above the panel to give it an unobstructed view of the sun.

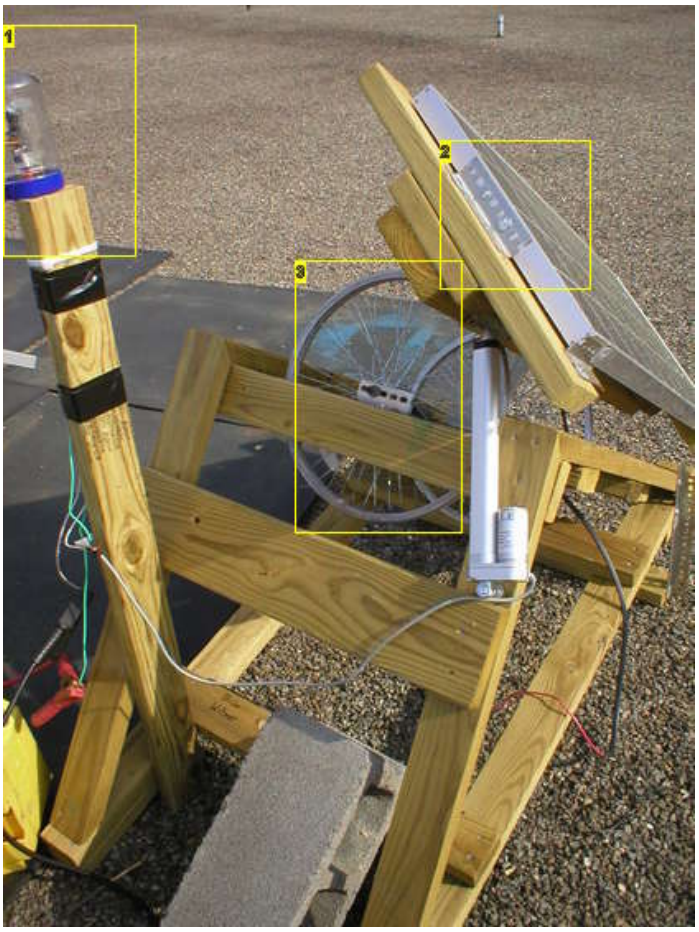


Image Notes
1. LED tracker mounted to the 2 x 4
2. Small piece of angle iron that attaches the panel to the board
3. Bicycle wheels, working tirelessly (no pun intended.)

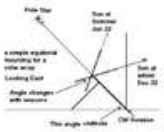
Image Notes
1. Sorry about the frost, but it was a little cold in Boone, NC. You can see the sensor mounted in the peanut-butter jar at least.

Step 6: Finishing it up

This is pretty much the finished product, and it works well. I had an issue of condensation accumulating inside the peanut butter jar and had to seal it better. The size of the tracker can be made to fit however many panels you need, and there are many ways to configure a tracker like this. I hope this was a helpful, and good luck in your tracker project!

Related Instructables

Solar tracker using an old hard drive (video) by scraptopower



A Strong Simple Sun Tracker by Cowboywindmillbui

Portable Sun Tracking Solar Panel With A Windup Clock Drive by shastalore

Adapt a clock today! Cheap trackers boost solar panel and solar cooker performance. by gaiatechnician

Clock Based solar tracker experiment (video) by gaiatechnician

Solar powered Preheater for Tankless Water Heater by Davetech

Comments

50 comments **Add Comment** **view all 91 comments**

hdb111 says: Jan 30, 2011. 6:35 PM **REPLY**

Should two Linear Actuators be used for a larger array? Say Four Panels?
Thanks folks.

brassmonkey666 says: Dec 9, 2010. 11:18 AM **REPLY**

I want to add this tracker to my solar array over the next month or two. It seems the largest consideration is going to be which linear actuator to use.

Obviously if you can find a free or cheap one from someone who is junking an old satellite dish that would be great.

But if left to buy one, other than the stroke and finding one of the appropriate voltage, how much force should one be able to exert on say, 2 45W panels and still be able to operate in blowing winds? It seems like you would want to minimize this in order to draw the lowest amount of current from your battery bank so that you gain the maximum power from your tracker and invest as little power as possible into driving the thing. Thoughts?

Gunkarik says: Dec 4, 2010. 9:43 PM **REPLY**
Very helpful, thanks for sharing!

kd4uwk says: Dec 2, 2010. 3:42 PM **REPLY**
Thanks for sharing the photos are good

segarza says: Dec 2, 2010. 9:55 AM **REPLY**
A nice simple and effective design. Thank you for sharing it. Isn't it funny how the minute you share your project with the public, we instantly began re-analyzing and re-designing it to death and flooding you with a million ways you could have done it better? Oh well, that's just human nature I guess. You did a great job!

playfair1965 says: Dec 2, 2010. 12:32 PM **REPLY**
You know you could have said that a better way LOL 9-)

segarza says: Dec 2, 2010. 2:16 PM **REPLY**
Yeah, I know...I had that one coming didn't I? lol

tbone56 says: Dec 2, 2010. 2:04 PM **REPLY**
Thanks for making this. It is truly instructable.
I have a question about the movement.
How many degrees do the panels move each day?

kosme says: Dec 2, 2010. 1:53 PM **REPLY**
great project

jakesnake says: Dec 2, 2010. 1:26 PM **REPLY**
red rock just keeps your money

playfair1965 says: Dec 2, 2010. 12:35 PM **REPLY**
Great work.. Now I just got to get a solar panel to put on it hehe Thxz for the post.

Shiftlock says: Dec 2, 2010. 7:57 AM **REPLY**
"Bicycle wheels, working tirelessly (no pun intended)"

No pun intended? Really? Because it sure looks to me like you absolutely intended to make that pun.

jolshefsky says: Dec 2, 2010. 7:38 AM **REPLY**
I really like the design where you bolted boards to bicycle wheels -- it's an elegant, strong solution that uses (as you mention) free resources. Even bent rims would work fine.

I'll have to give this some thought ... I'm working on a design for an "external Trombe wall" which I can attach to an existing window for the venting. Of course, making it insulated, situated off an existing wall, and now pivoting, I'm getting away from the simplicity of Trombe's design.

ktkeith says: May 16, 2010. 2:30 PM **REPLY**
Not to denigrate the work you did, but do you really need the photo sensor? The position of the sun can be calculated for any time of day, any day of the year. Why not just program an EPROM to store a lookup table for the correct angle, hour by hour, day by day (about 4,000 data values for the daylight hours of a single year), and use it with a simple microcontroller to adjust the angle incrementally? A bit more complicated at setup, but probably about the same total price, more accurate, and likely more reliable.

lloydrmc says: Nov 20, 2010. 10:33 PM **REPLY**
Uh... How about because his approach is considerably easier and cheaper? And didn't you read about the brightest part in the sky not necessarily being where the sun is?

bwitmer says: May 16, 2010. 4:06 PM **REPLY**
Sure, there are many ways to do it without using any sensors, this is just how I chose to take a crack at it. The reason I went with the sensor over the EPROM is that I know how to hook up the sensor, but have no idea what an EPROM is.

ensoarts says: Jan 14, 2010. 5:08 PM **REPLY**

ALL electronics has a linear actuator for 36$ but its also 36volts, Do you think you could string 3 panels together to power the actuator. Will the redrock run on 36vs?

redrok says: Oct 31, 2010. 7:54 AM **REPLY**

These types of actuators use permanent magnetic DC motors. Just run the 36V, or 24V, actuator on 12V. They will move slower, a good thing, with little loss in force.

Duane
Red Rock Energy
redrok.com/led3xassm.htm

doctorbigdaddy says: Mar 4, 2010. 1:43 PM **REPLY**

This is a well thought out project! I may have missed it ;but, how does the device return to the morning position after it follows the sun until sunset?Again many thanks for sharing your work!

redrok says: Oct 31, 2010. 7:52 AM **REPLY**

Parking is built into the LED3X.

When it gets dark or with heavy storm clouds it heads toward the Eastern limit switch. If the sun comes back out it resumes tracking.

Duane
Red Rock Energy
redrok.com/led3xassm.htm

shetonus says: May 8, 2010. 3:50 PM **REPLY**

I like the concept of pointing your solar panels at the sun, and have suggestions for improvement:

1. I would suggest that the wheels be mounted on an A-frame so that struts could be placed from the outside edges of the panels to points tangent to the wheel to provide bracing against strong winds.

2. I find that sun position sensors aren't really necessary for pointing since we already know where the sun will be at any given time of the day. Also, some sun trackers may have difficulties tracking the sun's position on overcast days and may operate erratically on partially sunny days when clouds intermittently block and reveal the sun. A system built around small uProcessor with an on-board clock can be programmed to provide positioning information to your drives, and if you want to get fancy, the sky's the limit for adding sensors, providing web connections, what have you.

redrok says: Oct 31, 2010. 7:48 AM **REPLY**

For PV panels and the like the sensor method is superior to the clockwork methods because they find the brightest part of the sky. Yes this may not be where the Sun is behind the clouds.

If you measure the power from the panel this other direction will be greater.

Furthermore, the sensor is influenced by other sources of light such as reflective sand and snow adding even more power.

Duane
Red Rock Energy
redrok.com/led3xassm.htm

shetonus says: May 8, 2010. 8:51 PM **REPLY**

Just a thought about item #1... Cables could be used instead of struts if the PV panel were sufficiently sturdy.

spicegal27 says: Jul 3, 2010. 8:32 AM **REPLY**

can you please help me in buildind a similar model for ma project....plz suggest me some books

Laral says: May 17, 2010. 9:02 AM **REPLY**

Looking at the finished design, I see an easy mod you can make to compensate for the sun's declination. You can mount the panel on hinges at the top with metal straps with holes at the bottom like you did for the front of the mount. You need to add enough wood at the top to allow a -23.5 degrees tilt at the bottom and a long enough metal strap to allow a +/- 23.5 degree tilt. You can add a simple scale with markings for each week or 2-week period of the year for manual adjustment, or you could theoretically add another actuator. BTW why didn't you just cut the angle of the 2x6s the same as your latitude. You're not going to be moving this around are you?

gaiatechnician says: May 20, 2010. 1:00 PM **REPLY**

Good suggestion. I have something very similar on the tracking solar accumulator videos. At this time of year and in the winter there is only a tiny adjustment in 2 weeks. Around equinox there is a large adjustment. You might adjust every week to get maximum performance. The image has the seasonal adjustment shown as you suggest. Hopefully it is clear enough at this size.
Brian

speedstix says: May 11, 2010. 10:19 AM **REPLY**

Cool! For a class project our group and I decided to make a Maximum Power Point Tracker. It did not track the sun but it did try to find a point where the panels were operating at their maximum power. I am wondering what sort of efficiencies have you achieved using this setup. Did you do any tests between stationary vs tracking power measurements? I am very curious.

azapplewhite says: May 17, 2010. 12:23 PM **REPLY**

Speedtix, FYI NREL has a huge data base with measured solar radiation data that compares fixed vs. 1-axis and 2-axis trackers. It even even includes the impact of tilt (declination) and there is data for every month of the year. Very useful resource for anyone out there trying evaluate the potential benefit of various schemes for their particular location.
Go to: http://rredc.nrel.gov/solar/pubs/redbook/
I suggest going down to the middle of the page where they have individual state data. Note that for EVERY location they provide annual data for ALL the relevant mounting and tracking schemes. Your tax dollars actually at work!
Hope this satisfies your curiosity on this topic!

bwitmer: great instructable!!

arjannugteren says: May 16, 2010. 7:10 AM **REPLY**

Is there and equation to calculate the inclination i need to set the panel to for any given place on the world? Or is a matter of guessing towards optimization?

Laral says: May 16, 2010. 7:26 PM **REPLY**

Again, that's DEClination, and here's a simple equation to calculate it:

http://pvcdrom.pveducation.org/SUNLIGHT/DECLIN.HTM

You then need to add the result, which can be positive or negative, to your COlatitude to get the current angle that the normal to the rotational axis should be at.

filmnuts says: May 16, 2010. 11:39 PM **REPLY**

I would not call that equation simple (yikes!), but it is helpful for finding the solar declination on a given day and would definitely come in handy with a PV panel that pivoted on two axes. However, as I said below, this equation is not necessary, as long as you are dealing with a PV panel with fixed inclination. The optimal angle will always be the same as the latitude of the PV panel. It's a fact.

Laral says: May 17, 2010. 8:00 AM **REPLY**

Well what's NOT simple about a multiplication, a subtraction, a division, and a sine? If that's not simple to you why did you even ask if there is an equation if you are not prepared to use it?

filmnuts says: May 16, 2010. 4:26 PM **REPLY**

If your panel has a fixed inclination (as the one in this Instructable does), you usually want the angle to be the same as the latitude of the panel's location. A location's latitude is very close to the mean sun height over a year.

Laral says: May 16, 2010. 7:17 PM **REPLY**

That's DEClination and you need to set the normal to the axis to the COlatitude (90-latitude).

redrok says: Oct 31, 2010. 8:01 AM **REPLY**

Some also call this Zenith Angle

Laral says: Oct 31, 2010. 10:13 AM **REPLY**

There seems to be enough confusion without adding yet another layman's term. Why not just stick with standard astronimical terms?

http://en.wikipedia.org/wiki/Declination

filmnuts says: May 16, 2010. 11:40 PM **REPLY**

You're arguing over semantics. Inclination and declination are complimentary, as are latitude and colatitude (the equation you give for colatitude *is* the equation of a complimentary angle). To say the inclination and the latitude are equal is the same as saying the declination and colatitude are equal; the former is just easier for most people to understand because they already know what latitude means and how it relates to their geographic location.

Also, the original question asked about the inclination of the PV panel, not mean annual solar declination, so I gave my answer in terms of inclination. Declination is primarily a astronomical term, and though using it here would give you the same results, it's not technically the correct nomenclature, as we are not directly discussing the sun.

Laral says: May 17, 2010. 8:43 AM **REPLY**

The word is complEmentary and I'm not arguing about anything. You seem to be doing that for both of us. ;-) And yes, declination IS an astronomical term and it is highly relevant to the discussion since ignoring the solar declination will definitely reduce the overall energy efficiency. If we're not "directly discussing the sun", then what are we discussing? And no, the declination is not the same thing as the "inclination", as you put it, or the latitude, at all. Declination is the angle that the sun makes relative to the earth's equatorial plane and it varies between +/- 23.5 degrees. At either extreme, only about 90% of the light energy is reaching the cells if you don't compensate. The astronomical term "inclination" refers to something entirely different from the latitude:

http://en.wikipedia.org/wiki/Inclination

If by "inclination" you mean the angle that the axis of rotation of the mount makes with the horizontal plane then OK. You need to align the axis in your local meridional plane, that's the plane that cuts through a north-south line at your location, and tilt the axis toward the sun so it is at an angle equal to your latitude. Then you need to add the declination angle throughout the year for maximum efficiency. You can easily calculate the angles or find a table and make a simple scale that allows you to quickly change the angle for any given week.

To put it simply, for your sake, make the angle of the frame equal to your latitude and align the axis in a north-south direction.

Before replying, do some homework this time.;-)

skwerp says: May 16, 2010. 7:31 PM **REPLY**

HELL YEAH APP STATE

gaiatechnician says: May 16, 2010. 9:34 AM **REPLY**

I think you did a very good job.
I have been working on a model for equatorial mount. Mine is for solar concentrators but it is much easier with pv panels. The model is for the norther hemisphere up as far as Calgary.
Rotate the frame at 15 degrees per hour to keep it pointed at the sun.
The actuator can do that. The panels can have adjustment manually for sun elevation with this mount.

bwitmer says: May 16, 2010. 4:17 PM **REPLY**

Very cool, and thanks. I enjoy reading your Instructables, by the way!

Laral says: May 16, 2010. 9:40 AM **REPLY**

I like the overall design of this but one big improvement that would take very little extra effort would be an equatorial mount. You need to align the bicycle wheel axis to the earth's polar axis and keep it there as the sun's declination varies throughout the year. You already have your right ascension (RA) axis so all you need do is add a declination axis. You need an axle at a right angle to your RA axis mounted on two triangles of plywood. It would be very simple to do.

bwitmer says: May 16, 2010. 4:17 PM **REPLY**

That is a great improvement, thanks for the idea.

bplaisted says: May 16, 2010. 2:59 PM **REPLY**

Sensors Schmensors!
All you need is a timer. If the sun ain't where it's supposed to be at any given time of the day then perhaps we're on a different planet. With a single axis tracker its easy.

bwitmer says: May 16, 2010. 4:15 PM **REPLY**

Sounds like a good idea! Looking forward to seeing your Instructable on how to do that.

stringstretcher says: May 16, 2010. 2:19 PM **REPLY**

Linear actuators are one way. Have a lookie at ATM, website for amateur telescope making. They have tried everything under the sun (pun intended!) and there are articles on helioscopes for solar tracking. nice job! enjoy it.

winnerceramics says: May 7, 2010. 1:59 AM **REPLY**

I would think you could use the one tracker to control multiple actuators. you would probably need to set up a relay to accommodate the increased power load when the actuators are on.

shetonus says: May 8, 2010. 8:59 PM **REPLY**

A mechanical linkage between PV modules with one larger motor driving all would be less expensive than a motor on each module.

winnerceramics says: May 7, 2010. 1:57 AM **REPLY**

If you are having difficulties with the condensation in the peanut butter jar, you could always use a descant. like the little packets that come in shoes, and with dried foods. they usually have little clear balls and are in a paper packet.

chrwei says: Mar 4, 2010. 7:38 AM **REPLY**

how strong is the actuator? Could you build several of these stands and link the tilting parts with static arms and have one actuator and tracker move all of them in unison?

view all 91 comments