

Owner's Manual

For

The SolarTrak® Industrial Solar Tracking Controller Revision 2



The Powertracker™ Single-axis Tracking System

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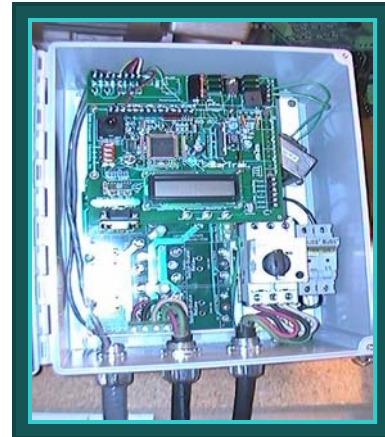
The Powertracker™ Drive Unit



Powered by
The SolarTrak®
Industrial Solar Tracking Controller



**Single-Phase 208 AC
Solid-State Power Control**



**Three-Phase 208 AC
Solid-State Power Control**

Designed and manufactured by
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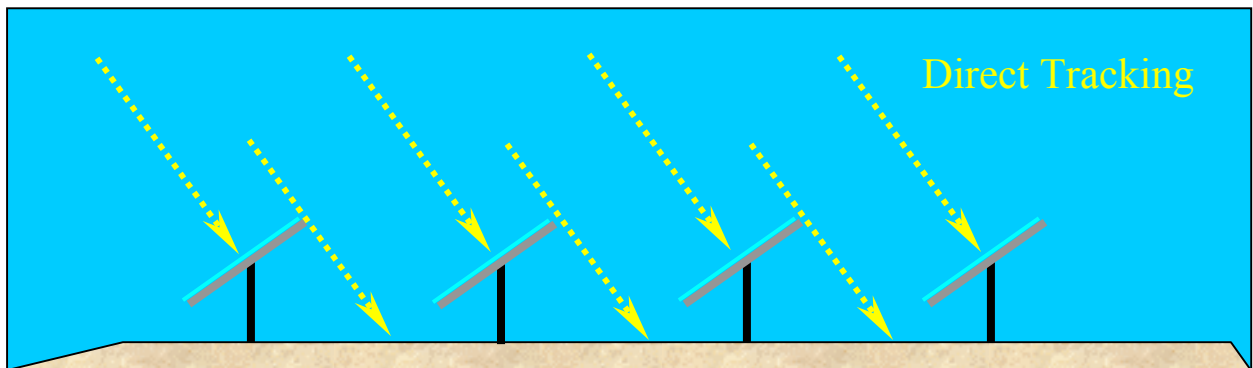
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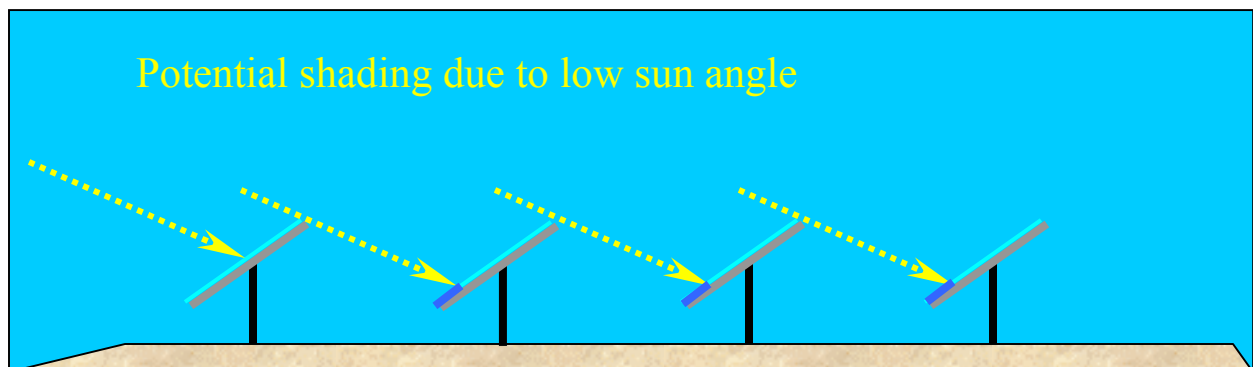
The Powertracker™ Drive Unit Standard Operation:

The Powertracker™ Drive Unit is equipped with a ½ horsepower AC bi-directional motor. The motor is controlled by the SolarTrak® Controller software via three high-power solid-state relays, two for directional control on one of the AC phase legs and one more to disconnect the second phase leg, leaving the motor cold to AC power when the unit is not actively driving. The 3-phase version utilizes a solid-state H-bridge which swaps two legs of the 3-phase power to produce the reversing function as well as switching the third leg on and off to create the same effect and requires five solid-state relays.

The Powertracker™ utilizes an optional SolarTrak® function referred to as 'Backtracking'. This function, when applied to single-axis flatplate PV at low sun angles such as in the early morning and late afternoon, prevents shading of one row by another thereby maintaining equal illumination on all of the cells at all times.

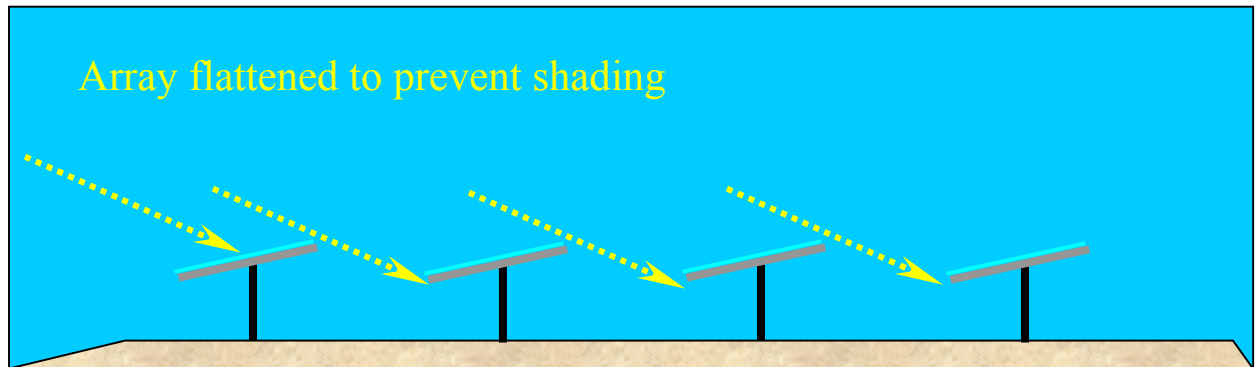


The range of motion of a typical multi-row system is seldom more than +/- 45 degrees. As long as the Sun is higher than that in the sky, the panels can be positioned to maximize the isolation angle of incidence, however, as the Sun angle decreases in the afternoon or before it has risen high enough in the morning, shading of panels by those in adjacent rows will occur.



Although PV cells in parallel can be individually shaded and simply lose that much proportional power, those that are in series are affected differently. If a single cell in a chain is shaded, it will stop conducting and deactivates the entire chain. If there is enough power involved, the shaded cell can be permanently damaged.

In a trade-off between power output and cell damage, the SolarTrak® instructs the array to discontinue tracking the Sun directly and moves away from it instead, hence, backtracking. This tracking strategy further reduces the already diminishing angle of incidence but provides illumination of all cells equally thereby preventing damage and continuing to put out energy.



A normal daily cycle of Backtracking-based control has the array beginning in a level position at sunrise then moving incrementally *toward* the Sun, always keeping the shadow of one row just off the adjacent row, until facing directly at the Sun without shading the adjacent row. The array then tracks normally until one row would otherwise begin shading the next row as the Sun sets, then begins incrementally *backing away* from the Sun, again keeping the shadow of one row just off the next row, until the array is once again level just at sunset.

Overnight, the Powertracker™ can be stowed at a slight angle such that chance rain showers will tend to clean the panels and drain properly without puddling or collecting dirt.

The following is a diagram of the major I/O components of the SolarTrak® Controller Board:

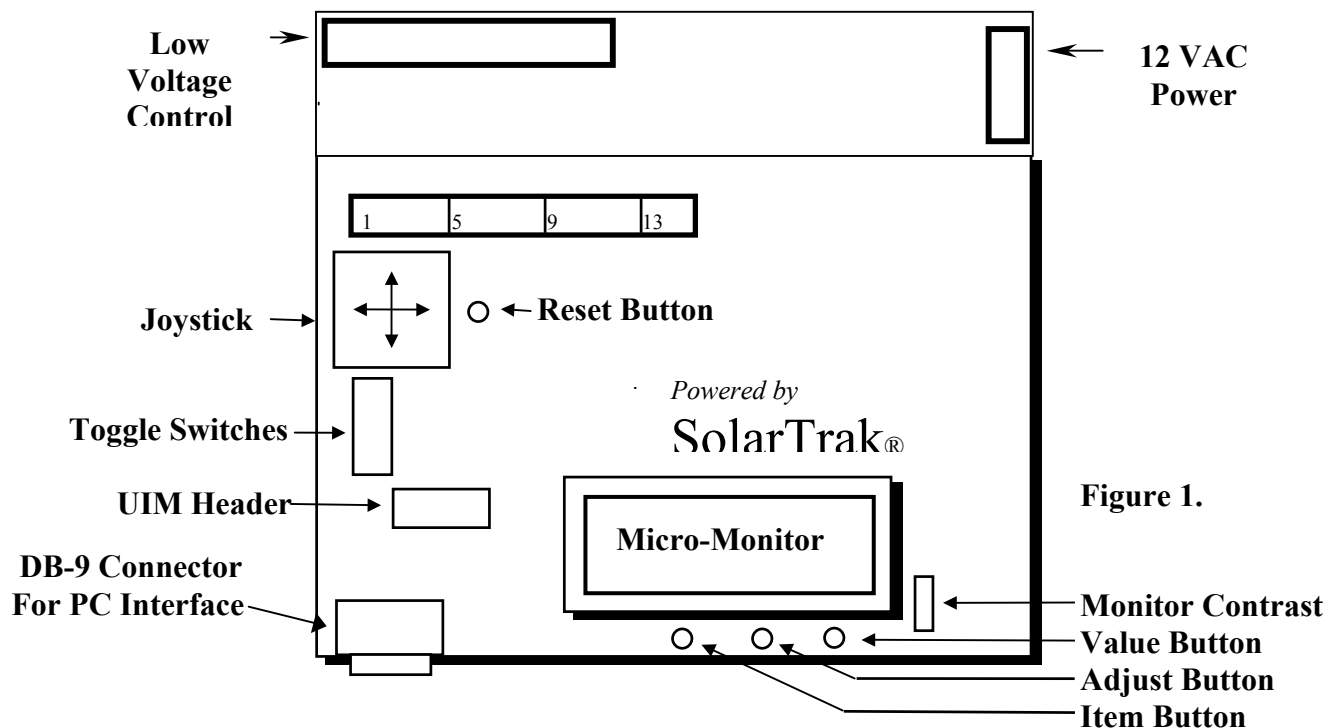


Figure 1.

Determining the Current Operational Mode

The current operational mode is displayed on the micro-monitor (Figure 1) alternating once per second with the current time. This alternating status screen is the default display and implicitly indicates that the SolarTrak® Controller is functioning normally in one mode or another. Other display screens are available containing status or configuration data that can be viewed by pressing the *Item Button*, and when applicable, edited with the *Adjust Button* and *Value Button*. The display will return to the default display screen after one minute of idleness except while in the *Adjust* mode. Please see section on Displaying and Editing Parameters.

Operational Modes

- **Tracking Mode:** All toggle switches to LEFT (Joystick Inoperative)
System goes through standard tracking scenario: Track during the daytime and assume a programmable Night Stow position while the Sun is below the horizon.
- **BackTracking Mode:** Indicates direct tracking will produce shading.
- **Night STOW:** Normal tracking Function for standard overnight position.
- **Emergency STOW:** Bottom switch (STOW) to RIGHT (all others LEFT)
Array moves to level (facing up) position.
- **Manual Mode:** Top switch (MANUAL) to RIGHT (Overrides STOW and tracking). All motion other than Joystick input is prevented.

Manual Control Mode - The manual control mode is an override to all motion functions of the controller. It is used when the array motion must be halted for safety while maintenance is performed or when the array must be moved to some unusual position.

Manual mode is turned on using the MANUAL toggle switch at the lower left of the controller board under the joystick. The Manual switch is at the top of the red and white switch block.

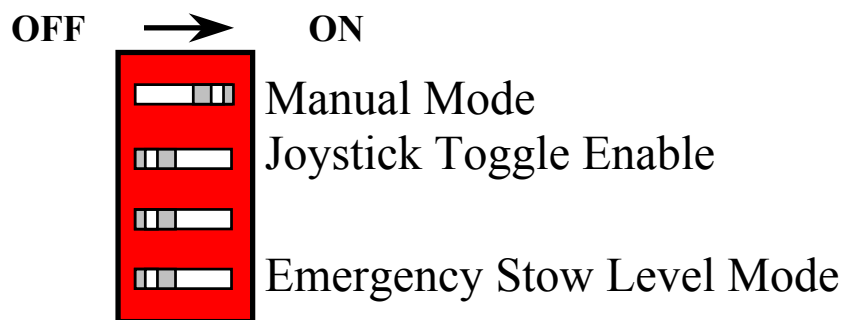


Figure 2.

Joystick Operation – Manual Mode – SolarTrak facing north, operator facing south:

EAST ← LEFT
RIGHT → WEST

- With MANUAL switch only ON, joystick runs motor only while held and only when six seconds have passed since the last joystick input. The delay prevents ‘pounding’ the systems, mechanical and electronic.

- With ‘Opt 1’ switch (second from top) as well as MANUAL, Touch and release to toggle ON then touch joystick in any direction to turn OFF. Toggle activation may be delayed by 6-second delay function but cut-off is immediate. If toggle fails to catch, press the joystick down (towards the bottom of the box) and release, wait the six seconds then try left or right again.

The Controller enclosure is always to be mounted facing to the NORTH, to minimize direct sun and heat build-up in the Controller enclosure. While performing any Controller calibration or troubleshooting operation, the operator will therefore always be facing SOUTH while looking into the controller enclosure.

Once MANUAL mode has been activated, the joystick may be used to move the array. Pushing the joystick toward the EAST (toward the LEFT side of the Controller board) will always move the array to point further to the EAST. Pushing the joystick toward the WEST (toward the RIGHT side of the Controller board) will always move the array to point further to the WEST.

To EXTEND the screw, push the joystick TOWARD the side of the array where the screwjack is mounted or AWAY to RETRACT it.

If the direction of travel of the array or the drive screw does not coincide with that described above, the Controller must be reconfigured, possibly including wiring changes. Until the Controller configuration has been performed, the array should remain in the horizontal position, with the power OFF.

***** NOTE:** The Manual switch should always be **ON** and the **FINGER GUARD** in place when powering-up the controller to prevent unexpected motion of the array or electric shock.

Emergency Stow Mode - Emergency stow mode is used to manually interrupt tracking and move the array to a pre-defined position, typically where wind resistance is minimized and the array can be left parked without incurring damage. The Emergency stow switch is at the bottom of the toggle switch bank.

Installation and Check-out Instructions

*** **WARNING** ***

This device operates on 208 VAC (with spikes to 600 VAC), develops over 10,000 pounds of force and 30,000 foot-pounds of torque.

Installation, operation and maintenance by unqualified, inexperienced or inattentive individuals could result in bodily harm by dismemberment or electrocution, possibly resulting in death.

Use **CAUTION** at all times while working with this machinery.

Do not remove Finger Guard while power is ON!!

Do not use fingers, screwdrivers or other tools to check or modify controller wiring while power is ON!!!

Troubleshooting should be coordinated with Powerlight Corp. or EEInc.

BE CAREFUL!!

Enhancement Electronics, Inc. will not accept responsibility for accidents or damage resulting from ignorance, inattention or unwillingness to exercise appropriate caution while working with this machinery or failure to follow these instructions including failure to supervise motion tests prior to completion of installation and certification for unattended operation.

Component Layout

Powertracker™ – Single-Axis in NEMA 4X J-Box

Single-Phase Power Option

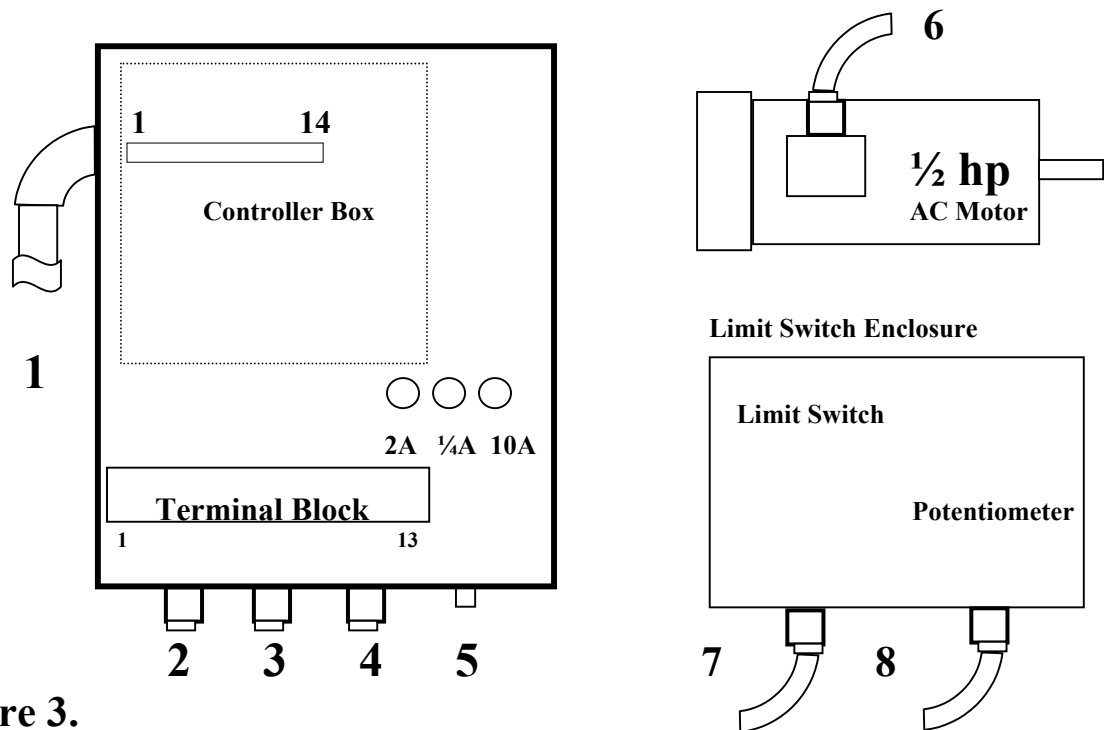


Figure 3.

Single-Phase Connections:

1. Potentiometer Conduit – SolarTrak® Terminal

Black	– Ground	1
Red	– +5V	3
Green	– Signal	14

2. Limit Switch Cord --> Connection 7 Term Block

Red/White	-- Extension Limit Sw. Pair	1,2
Green/Black	-- Retraction Limit Sw. Pair	3,4

3. Motor Power Cord --> Connection 6

Red	– CCW Direction Lead	5
Black	– CW Direction Lead	6
White	– Common Lead	7
Green	– Chassis Ground	8

4. Dual 208 VAC Power Source w/Ground

Green – Earth Ground

Black – } 208 VAC phase pair

White – }

Orange – } 208 VAC phase pair

Red – }

9

10 SolarTrak® Power

11

12 Motor Power

13

5. External Earth Ground Lug

6. Motor Power Cord – Motor Lead

White – Common 1

Black – Retract

Red – Extend

7. Limit Switch Cord

Green/Black – Retraction Limit Switch

Red/White – Extension Limit Switch

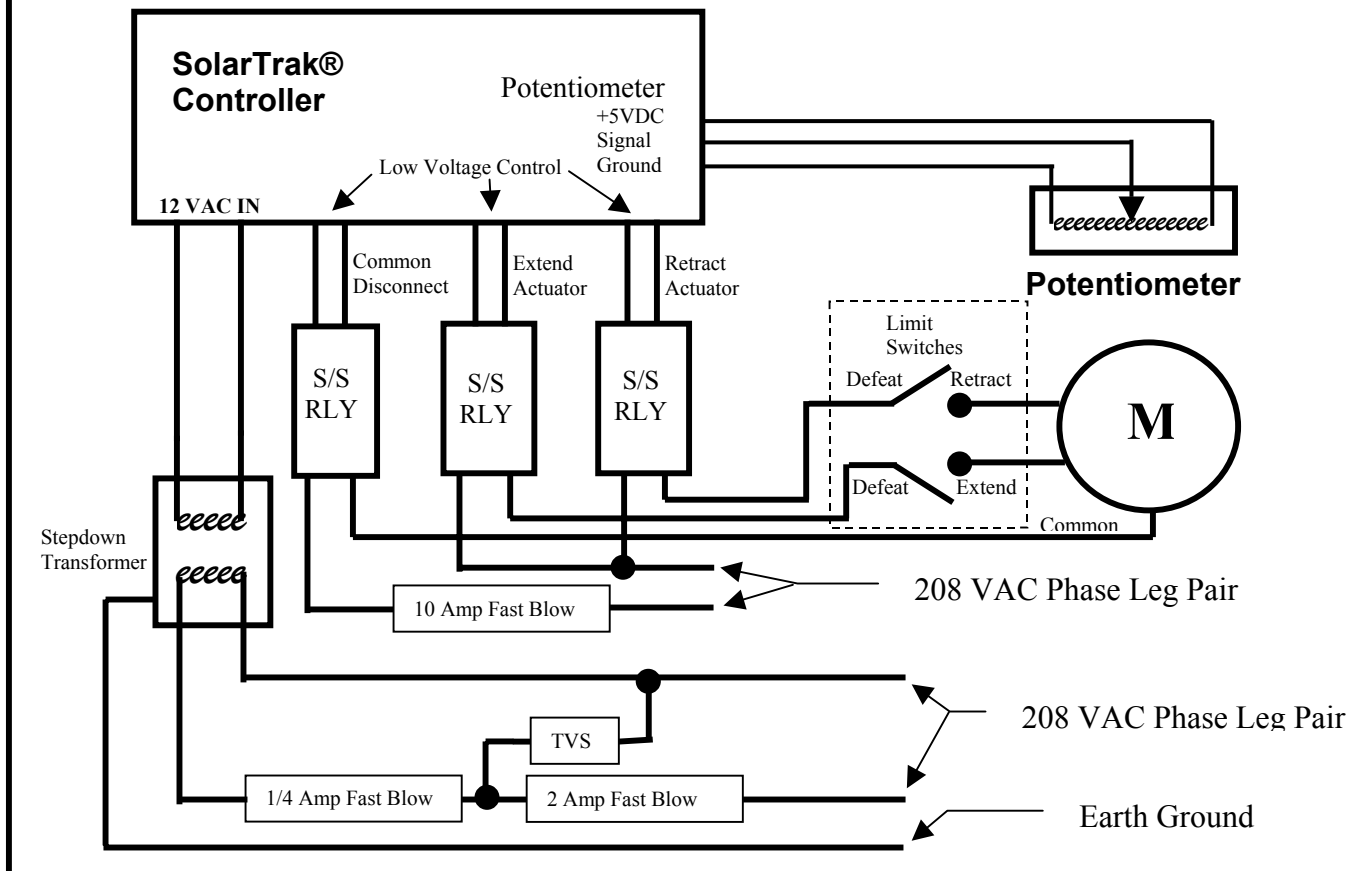
8. Potentiometer Conduit

Black – Retracted End Potentiometer

Red – Extended End Potentiometer

Green – Wiper

Schematic: Standard 3-Wire Reversible Solid State Controller



Powertracker™ – Single-Axis in NEMA 4X J-Box

3-Phase Power Option

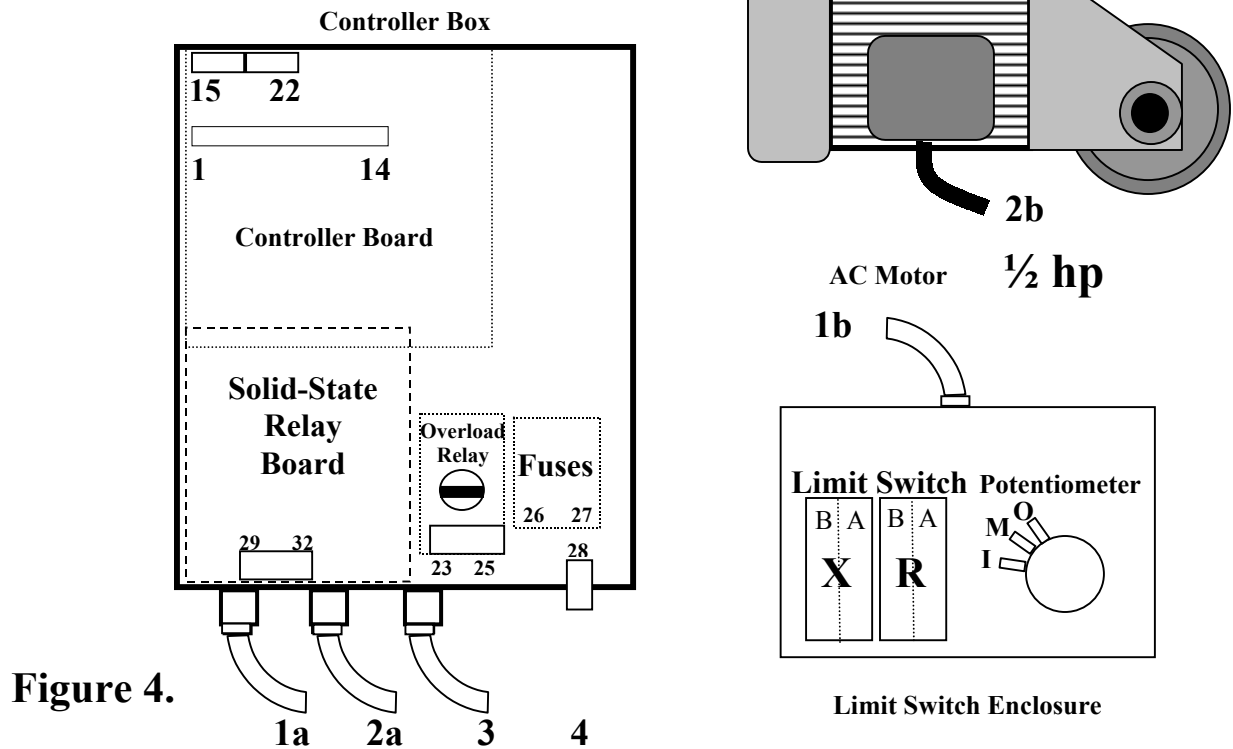


Figure 4.

3-Phase Connections:

1. Potentiometer Conduit – 1a – SolarTrak® Terminal #

Black	– Ground	1
Red	– +5V	3
Green	– Signal	14
2. Limit Switch Cord --> Connection 1a

Green/Black	– Retraction Limit Sw. Pair	15, 16
Red/White	-- Extension Limit Sw. Pair	17, 18
3. Motor Power Cord --> Connection 2a

Red	– T3	29
Black	– T2	30
White	– T1	31
Green	– Chassis Ground	32

4. 208 VAC Power Source w/Ground --> Connection 3

Red	– 208 VAC L3 phase leg	23
Black	– 208 VAC L2 phase leg	24
White	– 208 VAC L1 phase leg	25
Green	– Earth Ground	28 Ground Stud

5. External Earth Ground Lug --> Connection 4

6. Motor Power Cord – Motor Lead # --> Connection 2b

White	–	T1
Black	–	T2
Red	–	T3
Green	–	Ground Stud

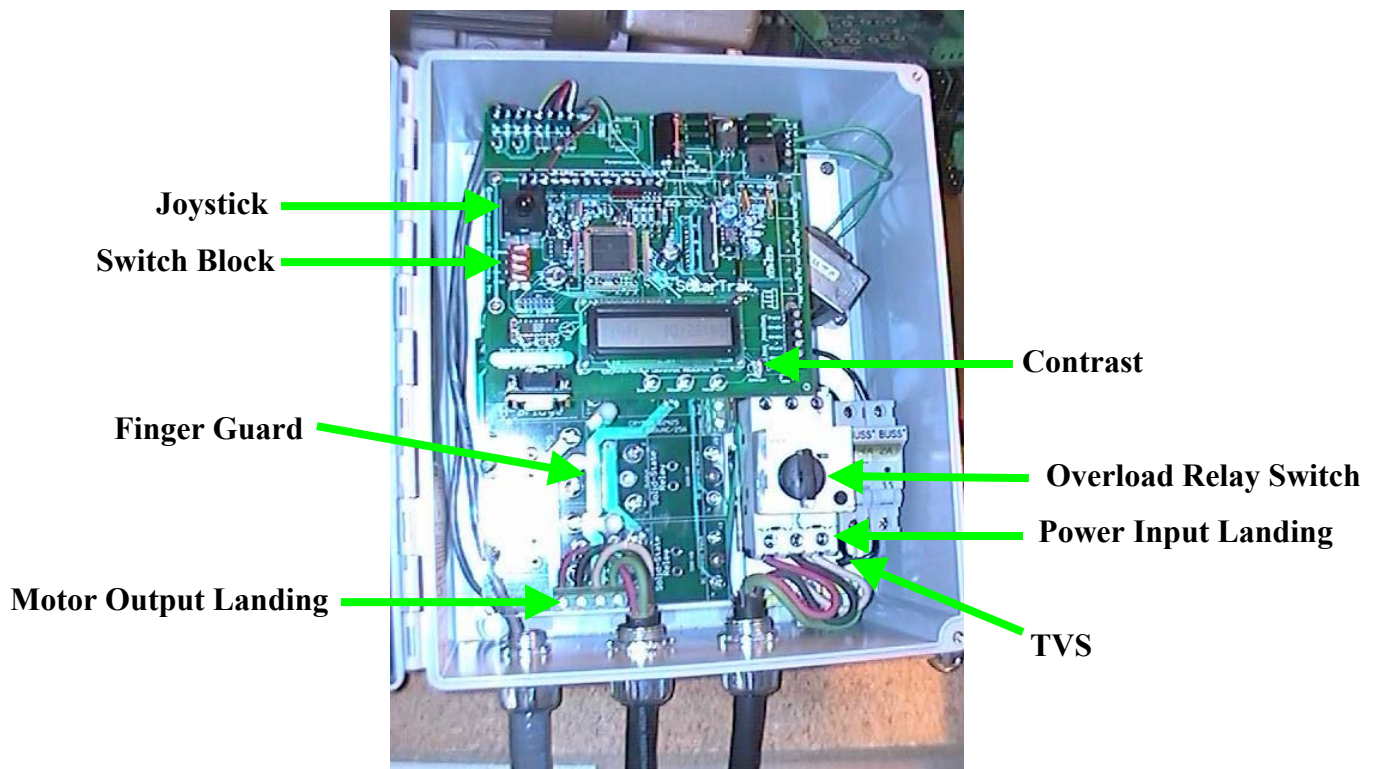
7. Limit Switch Cord --> Connection 1b

Green/Black – Retraction Limit Switch (R, B-Side)
Red/White – Extension Limit Switch (X, B-Side)

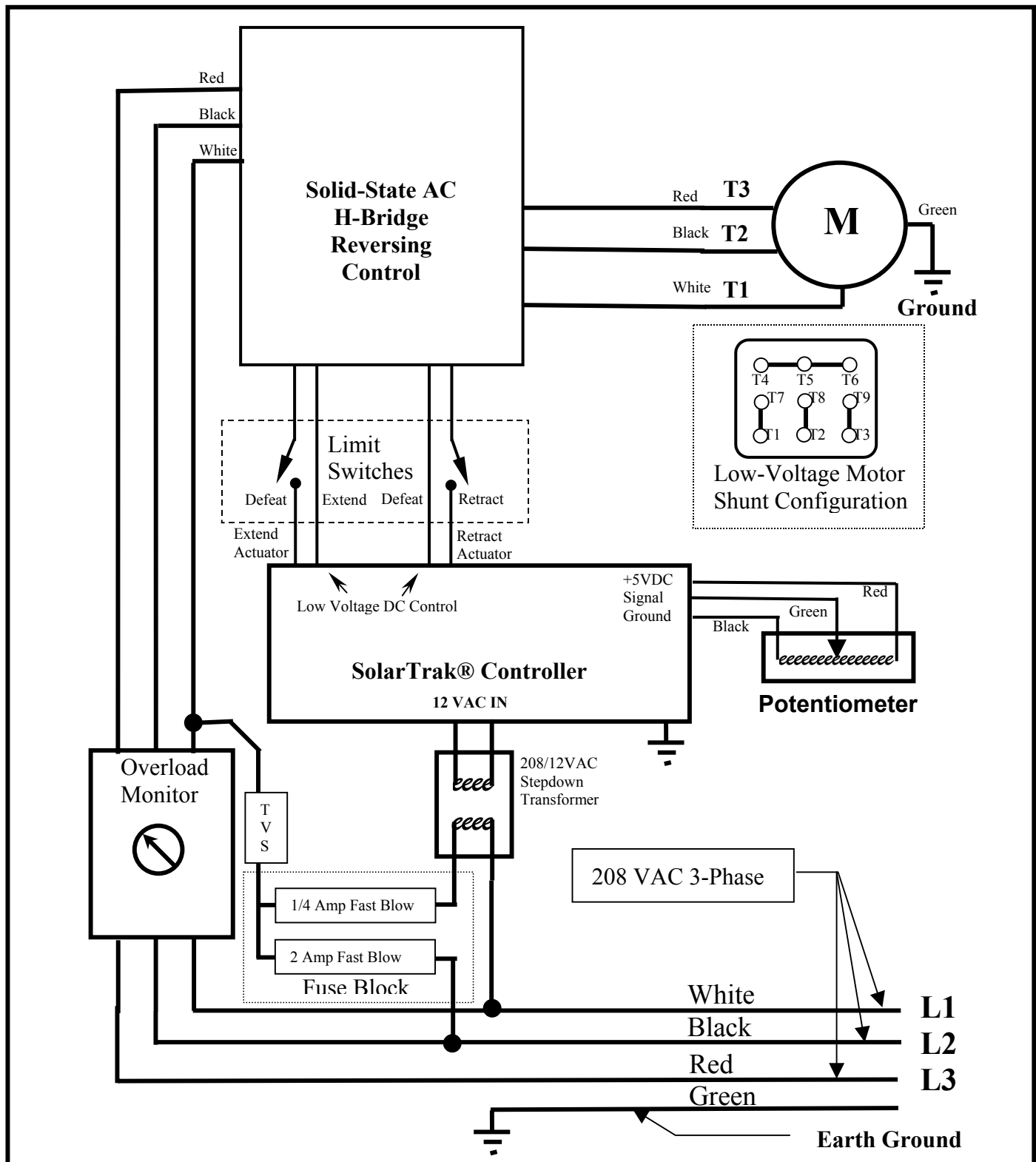
8. Potentiometer Conduit --> Connection 1b

Red	– +5VDC Power	- I(nner)
Black	– Ground	- M(iddle)
Green	– Wiper	- O(uter)

9. Transient Voltage Suppressor (TVS) attaches between 25 & 26



Schematic: 208VAC/3-Phase Reversible Solid-State Power Controller:



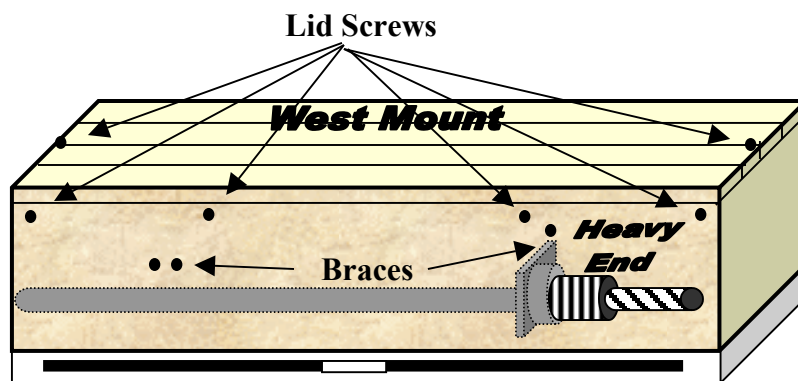
Uncrating and Installation:

Each shipping crate is marked with the orientation of the drive unit. **East Mount** means the drive unit is configured to be installed on the EAST end of the PV array it is driving, a **West Mount** goes on the WEST end.

These instructions assume that the array is level prior to attaching the screwjack. The pre-configured Powertracker™ screwjack is shipped at the software LEVEL position with the screw manually retracted to fit in the box.

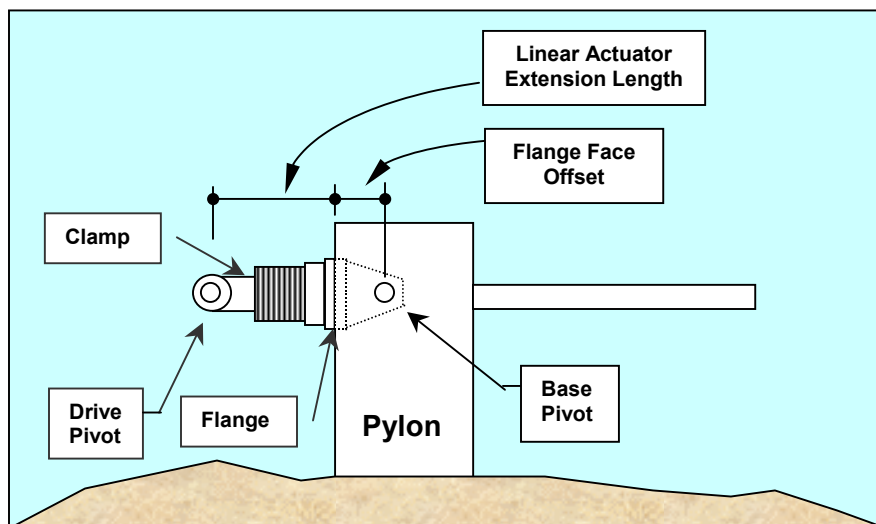
Remove screws around the top/side of the crate lid. There is a hidden one at each end of the lid in the center crack. The lid comes off in one piece.

Remove the screws from the cross braces over the motor/geardrive and control box. The one holding down the cover tube can stay.



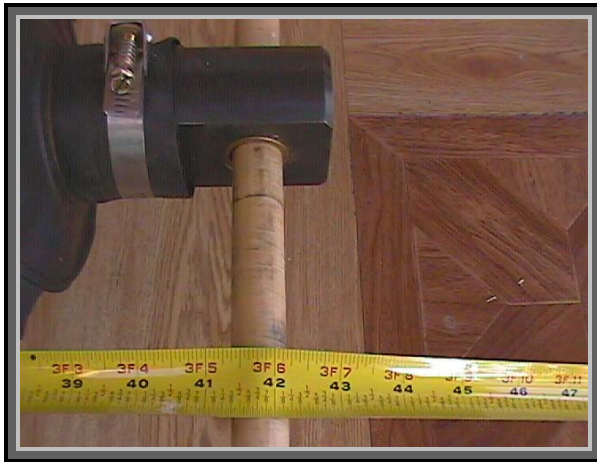
Place the control box and coiled cable on top of the geardrive and screw then lift that end slightly while sliding the cover tube out from under its hold-down brace.

Attach the geardrive to the pylon then mount the control box to its mounting plate.

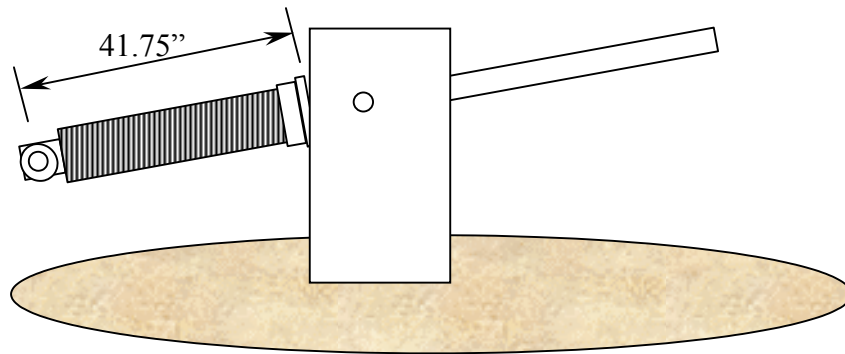


The two points of measurement for the Linear Actuator Extension Length are the centerline of the clevis kingpin opening and the back face of the actuator mounting flange where it joins with the base pivot bracket.

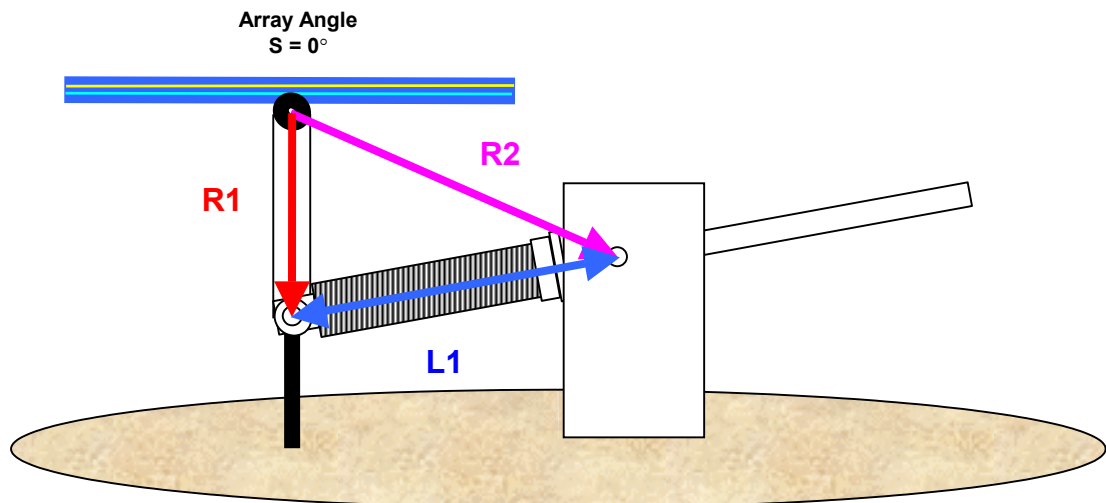
Loosen the clamp at the clevis end of the screw and boot.



Unscrew the actuator screw until the measurement **L** is 41.75 inches. All other things being correct, the clevis pin should fit right through the clevis and torque arm of the array. If the holes do not align it will be necessary to measure **R1** and **R2** then recompute the actuator parameters as defined in Appendix C. Lengthen or shorten the screw to fit with the torque tube and note the actual length.



Pull the boot out to cover the metal stop at the clevis and reattach the clamp.



Western Mount Position – View Facing South

Level, Face-up Position

Power Connection and Startup Sequence:

1. Attach the three 208 VAC phase legs, WHITE to L1, Black to L2 and RED to L3. L1, L2, and L3 may be referred to as A, B, C or X, Y, Z or even T1, T2 and T3. The official 3-phase polarity is CBA. GREEN is Earth Ground/Chassis. The unit is shipped with a five-foot, 4-conductor, 12-gauge power pigtail.
2. Just below the Joystick on left of SolarTrak® board, verify the top toggle switch is flipped to the RIGHT – Manual ON.
3. Power-up the 3-phase circuit. Turn ON the activation knob on the Overload Relay. ON is when the handle of the rotary switch is straight up and down. Turn the handle slowly to be certain that the relay latches on properly. The motor will jump slightly at power-on but will stop immediately as the computer takes control.
4. Verify SolarTrak® display is alternating between MODE MANUAL and TIME.

***** NOTE: The following test will assure proper polarity of the motor before full operation is initiated. It is important to carefully monitor the retraction/extension length during this process to avoid damage to parts of the actuator.**

At both ends of screw travel, there are both software limits of operation which have effect only in automatic tracking mode and hardware limit switches which are to prevent accidental over-travel when all else fails. The hardware limits, not reached during normal controller operation, are set just outside of the software limits, and would only be reached in Manual operation or in the event of controller failure. The hardware limit switches interrupt the power to the drive motor relays. The hardware retraction limit switch is set to interrupt power at 13.5 inches. The extend limit is at 67.5 inches. These values are measured from the mating side of the drive mounting flange to the center of the drive screw kingpin.

IF THE POLARITY IS WRONG, THE LIMIT SWITCHES DON'T WORK RIGHT!!!

1. Using the Joystick (Manual ON without the 'Latch function'), run the actuator in the **Retract** direction. (See page 6: Joystick RIGHT for drives on array EAST side; Joystick LEFT for drives on array WEST side.) If the screw extends instead of retracting, the polarity must be reversed. Assuming the declared color code is correct, this should be done at the 3-phase source by swapping the L2 and L3 legs.

2. Once the polarity has been verified, the unit should be run in retract until it stops at the 13.5-inch hardware limit. If it does not stop before a minimum of 13.25 inches, it **MUST** be turned off before the actuator reaches 13 inches. If it does not turn off in time on its own, terminate the Installation Procedure immediately, leave the unit with Manual mode ON, and turn power off. The limit switch will need to be reset to conformity but there may be other considerations as well. Contact EEInc for further instructions, 505-281-0399.

3. If the unit successfully stops at the 13.5-inch limit, switch the Manual toggle OFF, and switch the Emergency Stow toggle (bottom one) ON. After a brief delay, the unit should begin to extend the screw, eventually reaching and automatically stopping at a screw extension that corresponds to a horizontal array position, at a distance of about 41" from the screw pin to the mating side of the drive mounting flange surface. It will probably stop one or two counts (~1/2") from exactly level. Check the Ax1 Count screen using the ITEM button to verify that the count is ~121. If the unit does not extend or stop at the horizontal array position, terminate the Installation Procedure, switch the unit to Manual ON, and turn power off. Contact EEI for further troubleshooting instructions, 505-281-0399.

4. If the unit successfully stops at the horizontal array position, switch the Manual toggle ON and switch the Emergency Stow toggle OFF. Using the Joystick, move the array to exactly level using some type of levelling device. Go to the 'Set Level Offset' screen, Press the Adjust button to display 'Level Array' (it's already level) so then push and hold the VALUE button until the display returns to the Time/Mode heartbeat.

5. Leave the unit in Manual Mode and continue extending the drive screw (you may want to use the Joystick "Latch" function at this point) until the screw reaches the fully-extended hardware limit, at a distance of about 67.5". During this process, which will take 30-40 minutes, carefully monitor the progress of the screw, periodically checking the inches of screw extension. If the unit does not stop at the fully-extended hardware limit before it reaches 68", terminate the Installation Procedure, leave the unit in Manual ON, and turn power off. Contact EEInc for further troubleshooting instructions, 505-281-0399.

6. If the unit successfully stops at the fully extended hardware limit, switch the Manual toggle OFF, and switch the Emergency Stow toggle ON. After a brief delay, the unit should begin to retract the screw, eventually reaching and automatically stopping at a screw extension that corresponds to a horizontal array position, at a distance of about 45" from the screw pin to the mating side of the drive mounting flange surface. If the unit does not retract or stop at a horizontal array position, terminate the Installation Procedure, switch the unit to Manual ON, and turn power off to the controller and drive motor. Contact EEI immediately for further instructions, 505-281-0399.

If Step 6 is successful, the Installation and Check-Out Procedures have been successfully completed and the array will be ready to go into automatic tracking mode after the time, date, latitude, longitude and time zone have been checked.

Display/Edit Parameters on SolarTrak® Controller Board

Displaying Parameters with LCD Micro-Monitor

The LCD Micro-Monitor allows display of a limited combination of calibration parameters and status values. It may be necessary to adjust the contrast using the thumb-pot just above the LCD. (See Figure 1). The standard display shows the current Time alternating with the current controller Mode. The three pushbuttons just below the monitor are, from left to right, ITEM, ADJUST and VALUE.

The mode will be one of the following:

- | | |
|-------------------|--|
| 1. Tracking | Array is tracking normally |
| 2. Night Stow | Array is parked for the night (will wake in morning) |
| 3. Emergency Stow | Array is parked manually |
| 4. Manual | Array is in Manual Mode |

There are several parameters and status values that may be displayed on the micro-monitor screen. The following values are accessible:

- | | |
|---------------------|--|
| 1. Time/Mode | Local 24 Hr. Standard, <u>NEVER</u> Daylight Savings |
| 2. Date | Year 2000 compliant |
| 3. Turncount | Potentiometer reading (0 – 255) |
| 4. Temperature | Use 'VALUE' to toggle between C & F |
| 5. Set Level Offset | Calibration Command Function |
| 6. Seconds/Day | Clock Correction each day |
| 7. Seconds/Week | Clock correction once per week |
| 8. Latitude | + Northern Hemisphere, - Southern (+/- 90 degrees) |
| 9. Longitude | 0 = Greenwich, UK (Range 0 – 360 degrees West) |
| 10. Time Zone | 0 = Greenwich, 5 = East Coast, 8 = West |
| 11. West Error | |
| 12. BackTracking | Use 'VALUE' to toggle to Width/Spacing Ratio |
| 13. Version | Version Series and Date |

These values may be displayed, one at a time, by pressing the ITEM button, located just above the monitor. (See Figure 1). Due to space limitations on the screen, the above item descriptions will most often be abbreviated. The buttons are scanned once per second so it may take a moment to see the response. The button should be held down until it registers. The button will repeat its function once per second as long as it is held. After the last screen is displayed, it will start over with the Time. After approximately one minute of inattention, the display will revert back to alternating between the Time and Mode.

Editing Parameter Values: On-board LCD/Button I/O

***** NOTE: It is strongly recommended that the array be placed in MANUAL mode prior to changing parameters to avoid jumps, spurts and wasted time.**

ADJUST MODE is indicated by a flashing cursor square on the screen. This must be turned OFF by pressing the ADJUST Button before the ITEM Button can be used to change screens again.

To Modify a Parameter:

- Select a parameter that needs to be changed using the ITEM Button.
- The VALUE Button may be required to access a 'second-screen' value.
- Press the ADJUST Button
- Use the ITEM Button to move the cursor Right to the digit to be changed.
(The cursor position will 'wrap' back to the center of the screen at the end)
- Press the VALUE Button to increment the value or change the sign.
 - . All values have bounds and will wrap automatically in most cases
 - . In order to create a negative number from or through zero (the sign will go positive at zero), the number must be made non-zero before changing the sign to negative.
- When all digits are changed, press the ADJUST Button to revert to the normal mode.

Section 5. Calibration to Onsite As-Built Parameters

In the extreme, the hardware limit switches on the screwjack may need adjustment to allow enough extension. **Do not exceed the linear actuator operational extension limit.**

There is NO MORE ROOM at the fully retracted limit! Further retraction will crush the boot spacers. Instructions for adjusting the limit switches and the required hex Allen wrench can be found inside the cover plate of the limit switch enclosure. The switch with the RED wire and the RED hex adjuster are the extension pair. Green and green are the retract pair.

Several software configuration parameters must be redefined if the as-built measurements are out-of-spec.

1. The Level Reference Offset – Calibrate array to Level (Facing straight UP)
2. The East and West software limits – Set mathematical limits inside actual hard limits
3. The Night Stow position – Overnight ‘Sleep’ Position
4. The Emergency Stow (Level) Position – Position to assume with Stow Switch ON
5. The Screwjack Mount Geometry definitions – Coefficients for Law of Cosines

The first two can be performed using the buttons and joystick on the SolarTrak®. The rest require either a User Interface Module (UIM)* or a PC Interface (PCI)* software hookup. Only small adjustments on the order of ½” to ¾” of extension should be made without changing all of the above parameters.

It will first be necessary to record the turncount values where the new soft limits should be as well as the two stow positions. The turncounts are displayed on the third screen (right after the date).

The new screwjack parameters can be computed from the equations in the screwjack appendix. Care must be taken in choosing signs and angle quadrants. Making the Law of Cosines work is not an exact science.

Once all the new parameters have been determined they will need to be stored in the controller’s memory. To do so, use the following procedures.

* Available separately from Enhancement Electronics, Inc. (505) 281-0399

Set Level Offset

1. Use the Item button to select the screen that displays ‘Set Level Offset’
2. Press the Adjust button until the screen reads, ‘Position Array’
3. The array is now in Manual Mode though it will not be displayed.
4. Use the joystick on the controller board or the UIM to position the array level.
5. Press and hold the Value button on the controller board until the display reverts back to the Time/Mode display screen.

Set East and West software limits

Position the array to each soft limit and record the turncount from the SolarTrak® screen (third screen right after the date). This should be at + and – 45 degrees (East and West, respectively), however, do not reduce the lower limit (Ax1 –Lmt) below the factory setting (18 - 22).

If you will be using the UIM to do screwjack parameters and such, these values can go in more easily when you do the rest or use the following steps on the SolarTrak®:

1. Use the Item button on the controller board to scroll to the screen that displays 'Ax1 +Lmt 215'
2. Press the Adjust button so the dark, blinking cursor appears.
3. Change the number to the desired value.
4. Press ADJUST to end first edit.
5. Press VALUE to change screen to 'Ax1 –Lmt 19'
6. Press the Adjust button so the dark, blinking cursor appears.
7. Change to desired value (>18).
8. Press ADJUST to end edit.

Set Limit, Stow and Geometry Parameters with UIM

Compute the three screwjack parameters, C1, C2 and C3 from the equations in the screwjack appendix. R1 and R2 will be the values changing. R3 will remain zero since the screw goes directly through the base pivot. C1 must be chosen so that substitution of +45, 0 and –45 all produce the same result for C1 (Beta). In addition C2 will be negative for an East mount and positive for a West mount.

Plug in the UIM to the Interface Header with the ribbon cable downward. The UIM display should show the Version date, if not, repeat the power cycle, it should show up on the second try, or press the reset button (on the left side under the joystick).

You will be changing parameters directly in SolarTrak® memory so:

1. Press the second white button (down arrow) until the display reads:

Status Display_
Parameter View/Set_

With the cursor blinking at the last underscore.

2. Press the third white button (Enter/Select). The display will read:

Control Params_
User Board Params_

With the cursor at the end of the 'Control' line

3. Press Enter/Select again. The display will read:

Limit and Stow Parameters_ This parameter set contains the + and – software limits and stow positions – change as necessary.

4. Press Enter/Select again. The display will read:

Ax1 +Limit Active Hi

5. Press the down button until the display reads:

Ax1 Night Stow Pos.
+70

6. Change the value according to the UIM instructions in the appendix.

7. Press Down once more to display:

Ax1 Emer. Stow Pos.
+84

8. Change the value.

Setting the screwjack parameters:

1. Press the fourth button (Prev. Menu) Display will read:

Limit and Stow Parameters_

2. Press the second button until the display reads:

Site Parameters_
Drive Parameters_

With the cursor at the end of the ‘Drive’ line

3. Press Enter/Select.

Display will read: **Ax1 Gear Ratio**
+3.789

With the cursor over the ‘3’.

4. Press the down button until the display reads:

Ax1 Screwjk Param #1

+56.66°

6. Change the value according to the UIM instructions in the appendix.

7. Press Down once more to display:

Ax1 Screwjk Param #2

+3663.0

8. Change the value.

9. Press Down once more to display:

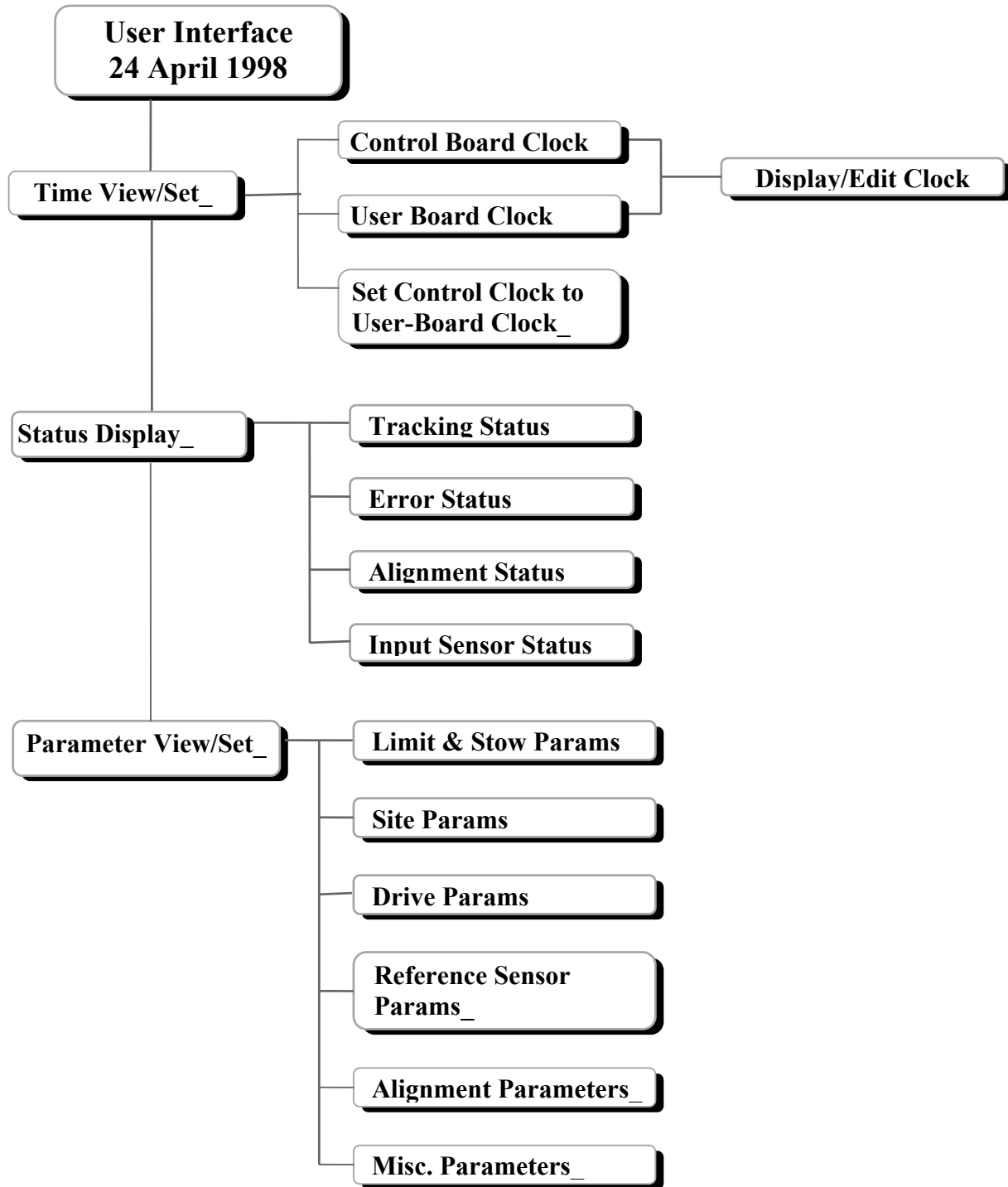
Ax1 Screwjk Param #3

+3819.25

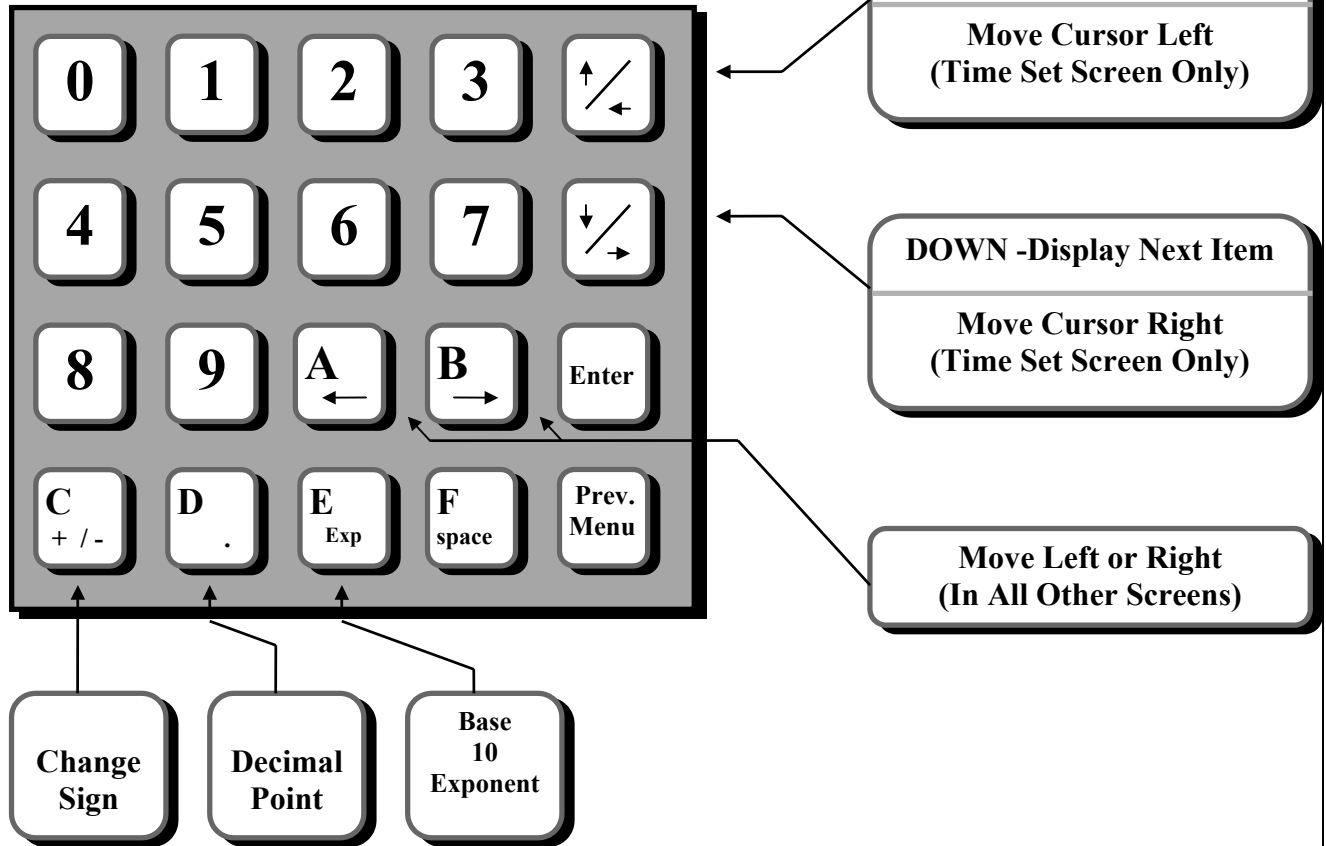
10. Change the value.

User Interface Module

Section 1. Menu Structure



Section 2. Keypad Layout



Section 3. Basic Operation

The typical scenarios for use of the UIM are to:

1. Set the TIME
2. Adjust the Focus
3. Tweak a tracking parameter (very satisfying, you should try)

In general one navigates to the appropriate screen through use of the Up and Down keys and the ENTER key. To move from the TOP to BOTTOM and back in a list of parameters or menu items, press the Up or Down key. When a screen (specific phrase) is displayed, if it leads to another group of screens (menu items, parameters, commands), pressing ENTER will place you at the top of the new list. To move BACKWARD through the menus press the PREV MENU key, it will return you to the entry that got you where you are.

If the screen is a parameter, the value will be displayed along with its description. If the value is changed using the keypad, it will be changed in EEPROM, non-volatile, re-programmable memory.

After navigating to the correct screen, in both the Time/Date and Parameter View/Set sections, there is a choice to access either the User Interface memory, or the Controller memory. Beyond that choice, the screens will appear the same. In most screens, while editing quantities,

pressing the A or B button moves the cursor Left or Right. The exception is in the Set Time/Date screens where, once the Edit mode is entered, the Up and Down buttons function as Left and Right, respectively.

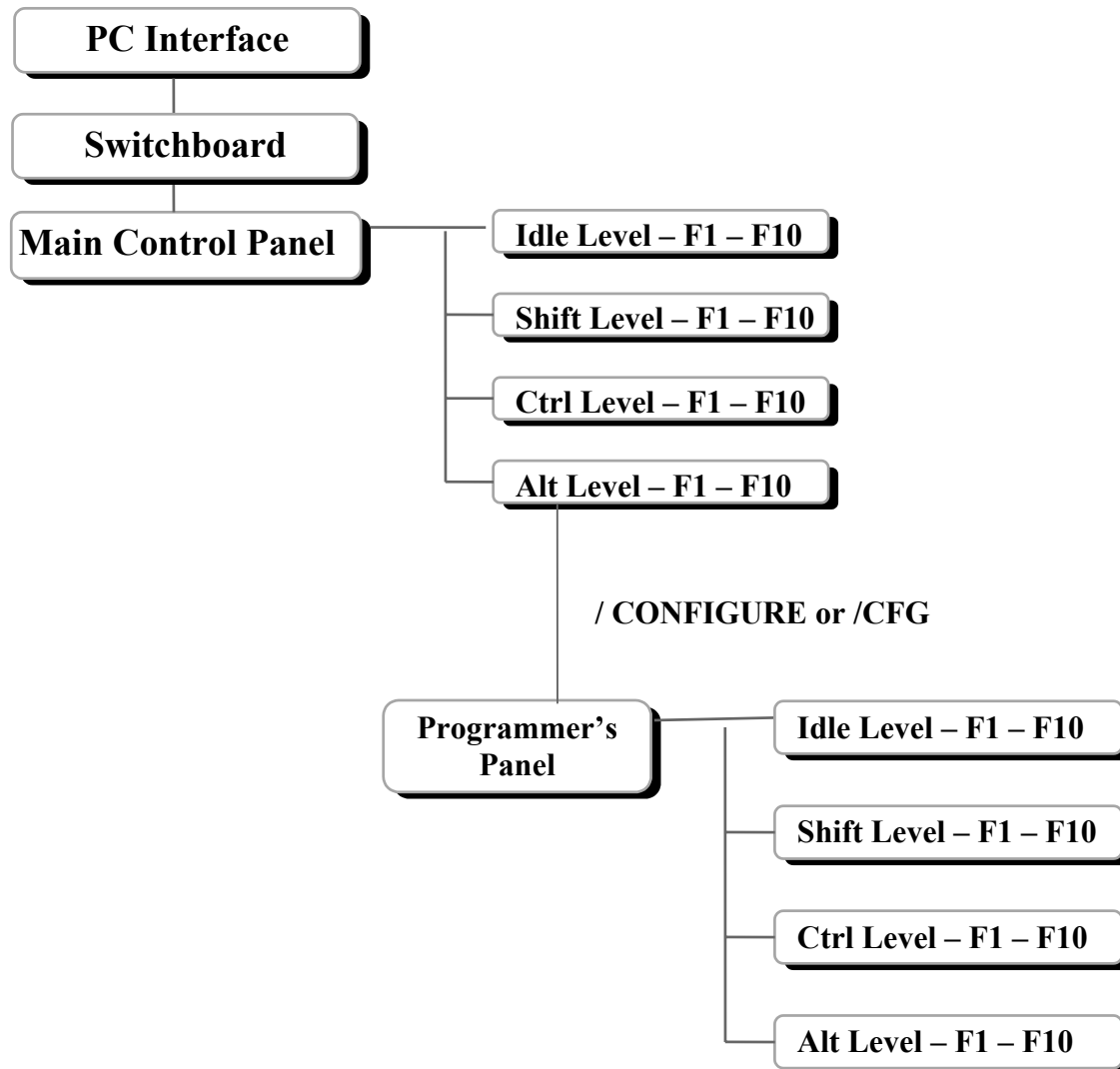
When changing the Time/Date, one enters the Edit mode by pressing, 'ENTER' The delimiters (':' and '/') will not be overwritten by keystrokes. The Date notation is MM/DD/YY and the Time, HH:MM:SS. Simply overwrite the current values with better ones and press ENTER again.

An embedded function in the SolarTrak® Controller is to calibrate its clock crystal self-correction algorithm. This only occurs when the Controller time is set from the UIM time via the appropriate command. This is a specific function in the Time/Date menu. First set the User Interface time to atomic Solar (Standard) time using the Edit User Interface clock menu. Then back-up to the previous menu and select the item that sets the Controller clock to the User Interface clock. This function automatically computes the error in seconds per day and seconds per week since the last time this command was performed on a given Controller and adds it to any existing error correction.

In the parameter lists, once a chosen quantity is displayed, to change the value, type in the new value over the old, placing at least one space ('F' key) after the new value, then press ENTER. In some screens, the first keystroke will make the blinking cursor appear if it was not already visible. After the ENTER key is pressed, a slight delay may occur then the screen will display the new value with the cursor at the beginning of the line and no residue from the previous screen. This signifies that the value has been stored. If, after entering a new value on the screen, the user chooses to cancel the input, pressing the Up or Down button clears the buffer then one can begin again by returning to the original selection and starting over.

PC Interface Software

Section 1. Menu Structure



DOS Command Line Option Switches

Standard Invocation:

C:\SolarTrk\> STNG <enter>

The following command line switches (preceded by a '/', forward slash) allow special initialization options and the ability to work with stored data without being connected to a SolarTrak®. Template files and the Internal Template will be discussed in Section

/Cn n = a COM port number, i.e. /c3 designates COM3 as the active port

**/Tfn fn = filename of Template file (.TPL), i.e. /tEAST01 will use EAST01.TPL
 This switch preloads EAST01.TPL but still contacts the SolarTrak®**

**/Ifn Same as /Tfn but goes directly to the internal template
 i.e. /iWEST01 loads and displays the data saved in WEST01.TPL without
 attempting contact with the SolarTrak®**

/M Monochrome screen operation (graphic plots will be hard to read)

/Pn n = a PRINTER port number, i.e. /p2 designates LPT2 as the active printer.

**/Ffn fn = filename of PC Interface configuration file to use (default =
ST_NET.CFG)**

Ex: /fNONET uses the file NONET.CFG

**/W Data from the on-board thermometer and the wind anemometer (if installed)
 will be collected and stored at 1-2 second intervals in daily files named
 WTymmdd.DAT. Each file is approximately 2.5 Mb. File names change
 automatically at midnight.**

**/Dn Position data (screw length, sun angle, etc.) from the on-board computations
 will be logged every 'n' minutes in a file named PDymmdd.DAT.**

D: The SolarTrak® PCI Configuration File

```
% This is a Remark
/begin          % A slash marks a keyword
/network No % Yes % Declare Network or Not
%
% if network is yes, specify # of nodes and unit #'s
%   nodes <= 32 ; For the moment
% Network set-up CONFIG file example
/nodes 2
%   Index  name
/unit  1    2
/unit  2    3
% Index must be 1 -> nodes
% names can be any number from 1 to 65535  ie: /unit 1 1
%                                           /unit 2 64231
% Hex (0001 - FFFF) can also be used: /unit 1 0xC3E0
%                                           /unit 2 0xA2D2
%
/Calibrate ON
/Troubleshooting ON
/DaylightSavings OFF
/end          % Lets CONFIG routine end gracefully
%
```

The PCI takes direction from both the configuration file and the command line. The elements of the configuration file reflect things that change little if at all. Those on the command line are more apt to change from use to use.

E: Setting up Batch File Execution

Since typing all these things in every time is tedious, putting them in a '.BAT' file is recommended. Type the following:

C:\SOLARTRK\> EDIT ST.BAT

You will get a blank screen with menus all around it. Basically you will want to include any standard switches such as /Cn or /M that you will need each time, and perhaps a default template file if you eventually find that handy. Then add the '%1 %2 %3' to allow extra switches to be declared on the command line as necessary each time the program is run, i.e.

ST will run the program with the standard switches as defined in the batch file lines below.

ST /IWEST01 will override the /TEAST01 entry stored in this ST.BAT file and go directly to the internal template WEST01.TPL without attempting to contact the SolarTrak.

Switches are interpreted in the order they appear on the command line and the last will always apply.

Moving right along.... Type:

@echo off

c:

cd \solartrk

stn /c3 /tEAST01 /m %1 %2 %3

(put in the one's you really need)

Press Alt-F
Menu)

(displays dropdown File

Press X

(initiates Exit)

Press Y

(answer 'Yes' to

Saving File)

C:\SOLARTRK\> COPY ST.BAT ..

(Puts a copy in the root directory)

Or copy ST.BAT to any directory you normally use for such things in the standard DOS system search path.

B: PC Interface Basic Keyboard I/O Techniques

Use of the keyboard in the PCI software is fairly well standardized. Each function key, F1 – F10, can be pressed by itself or with one of the three combo keys, Shift, Ctrl or Alt. The bottom two lines (of 25) on the screen are always devoted to the current function-key menu. While idle with no keys pressed, the menu will indicate which function keys are active in the set of F1 – F10 for the current screen. In general there are four menu levels on each of three command levels but not all are necessarily active. Pressing one of Shift, Ctrl or Alt will change the menu displayed on the bottom two lines and reveal any available commands on that menu level.

The PC Interface Panels and Menus

The Network Switchboard



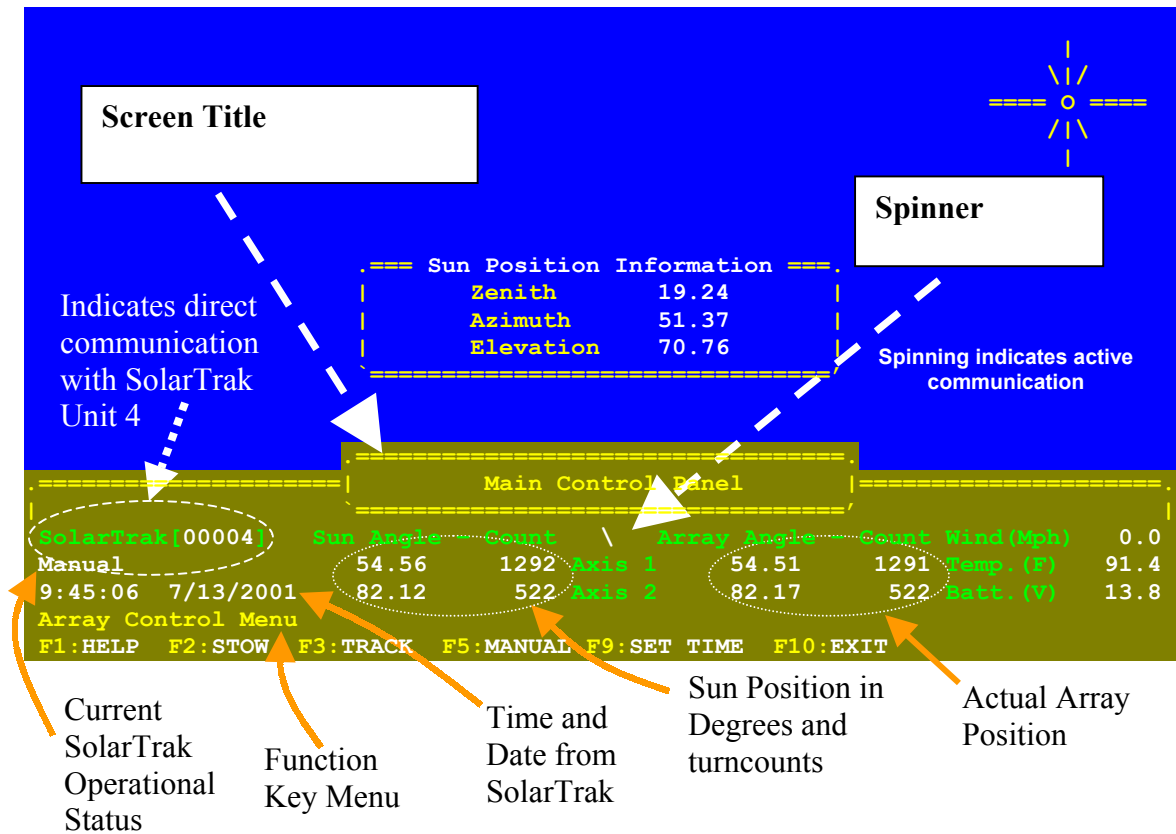
Connect a serial extension cable (specifically **not** a Null-Modem cable) to the portable's male 9 pin comm port and the SolarTrak's female 9 pin connector. The important pins are 2,3 and 5. They must connect directly to their counterparts at the other end. A cable can be made from good quality telephone wire or shielded signal wire and can be as long as 100 feet and work perfectly.

***** Warning: Do not leave cable attached to SolarTrak® or computer when not in use!**

The first screen in a non-networked system will be the 'Network Switchboard' screen. To continue, press **ESC**, if there is a single SolarTrak® attached, it will download the parameters and open the Main Control Panel, otherwise it will quit.

INITIAL STARTUP:

“Main Control Panel” - After the PC Interface program starts, you should see the screen shown below. Later as one enters different sections of the program, this title bar will change. The following instructions will reference the appropriate title bar for each set of instructions.



Please note the spinning indicator in the center of the 5th line above the “Axis 1” label. Proper communication between the PC and the SolarTrak produces the effect of the ‘Spinner’ spinning clockwise, moving about one position (1/8th turn) per second. The spinner must be spinning in order to enter commands to the program.

There are two reasons why the ‘Spinner’ may spin rapidly instead of its normally slower rate.

1: When the PC Interface is accessing the internal copy (called a Template and must be downloaded from the SolarTrak or Loaded from a file, see File Operations) the ‘SolarTrak[00004]’ is replaced by ‘File[filename]’ and the spinner spins rapidly because there is no communication delay when accessing internal memory. ‘Filename’ will read ‘download’ if the template was just downloaded from the controller. Toggle back and forth between the SolarTrak and the internal template by pressing ‘T’ on the keyboard.

2: There is a communication problem between the computer and the SolarTrak. Likely causes of communication problems include: computer serial port turned off, computer serial port is set to a comm port other than comm port 1 (the default value for the PC Interface program).

If the communications between the computer and the SolarTrak are correctly set, the spinning indicator should step slowly from one position to the next. This indicates that the computer is polling the SolarTrak.

If the spinner is not spinning there are two typical reasons.

1: The communications have been interrupted on a working comm line, in which case the current operating status should read 'Off-Line'.

2: The program is waiting for user input to an activated command such as changing a parameter value.

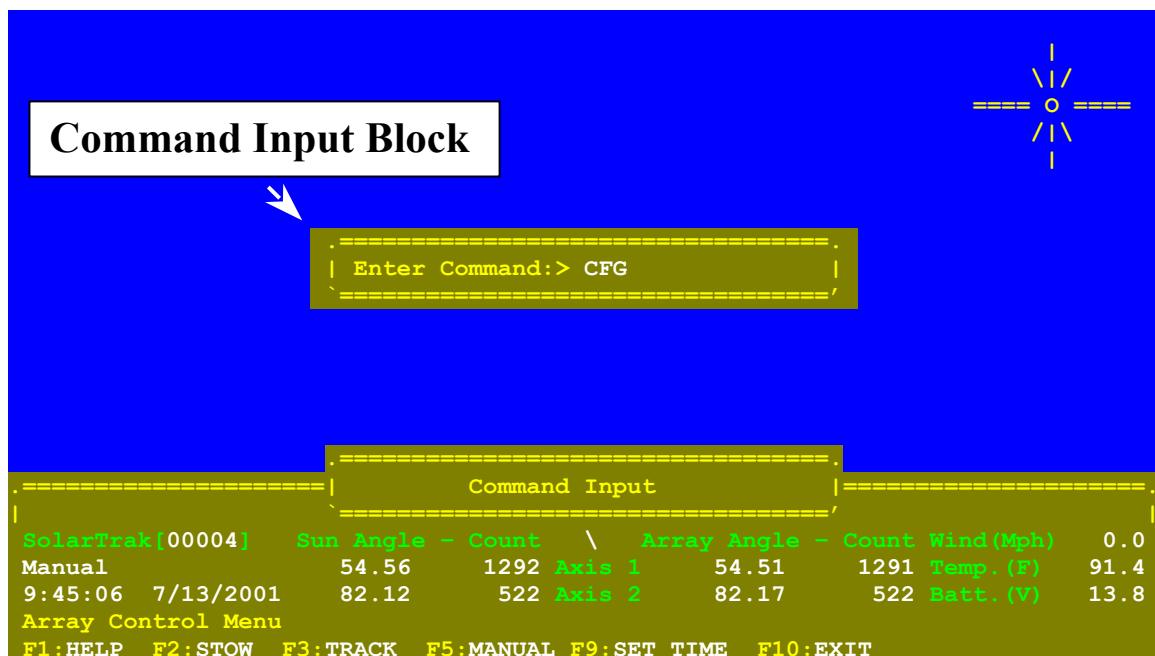
If the PC Interface software is incorrectly directed to a non-existent comm port it will get garbage in the comm port status and think there is always a new character to read and spin fast as a result. If it is directed to a comm port that exists but is not properly connected to the SolarTrak® it will never get a new character and not spin at all.

Entering a Command

To invoke a command, begin by pressing the forward slash '/'. The Command box will replace the standard sun position display.

The available commands are (abbreviation):

- 1: Configure (CFG) – Set geometric, mathematical and logical parameters for tracking.
- 2: Calibrate (CAL) – Collect, reduce and display data and error function for tilted tower.
- 3: Target (TGT) – Set beam target bearing for HelioTrak® Units



The Configure (CFG) Command:

The CFG command will initially produce the following screen:

```
Ax1 Array Positn Cnt: 1291
Ax2 Array Positn Cnt: 522
Latitude (-90 to 90): 35.0525
Longitude (0 to 360): 106.0055
Time Zone (0 to 23) : 7
Clock Adjust:Sec/Day: -4
Clock Adjust:Sec/Wk : -3
Batt Charger State : off
Batt Stw A/D (0-255): 186
Battery Conver Factr: 0.1175
Battery Charger On : 240
Battery Charge Limit: 245
```

===== SolarTrak Basic Configuration Parameters =====

```
SolarTrak[00004] Sun Angle - Count \ Array Angle - Count Wind(Mph) 0.0
Manual          54.56      1292 Axis 1      54.51      1291 Temp. (F) 91.4
9:45:06 7/13/2001 82.12      522 Axis 2      82.17      522 Batt. (V) 13.8
Configuration Menu
F1:HELP F4:Set Screwjack F5:MANUAL F9:Set Time F10:Done
```

There are two avenues of approach to adjust things. Press a function key to execute an operation or input information directly into the SolarTrak® using the parameter tables displayed on the upper screen. There are several groups (screens) of adjustable parameters. They can be accessed using the PgUp and PgDn keys. To change a parameter, highlight the offending value using the UP and DOWN arrows then press 'ENTER':

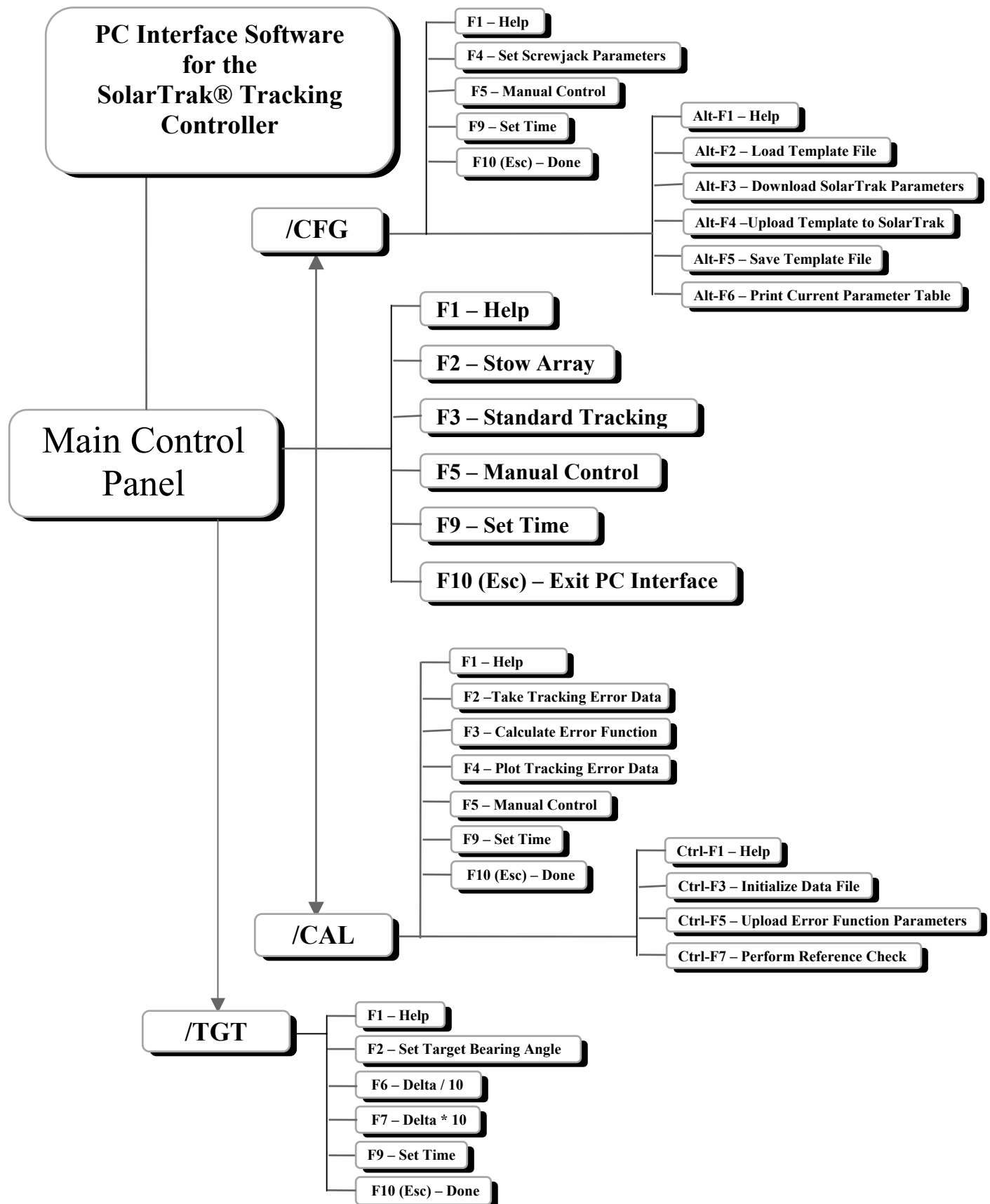
```
Ax1 Array Positn Cnt: 1291
Ax2 Array Positn Cnt: 522
Latitude (-90 to 90): 35.0525
Longitude (0 to 360): 106.0055
Time Zone (0 to 23) : 7
Clock Adjust:Sec/Day: -4
Clock Adjust:Sec/Wk : -3
Batt Charger State : off
Batt Stw A/D (0-255): 186
Battery Conver Factr: 0.1175
Battery Charger On : 240
Battery Charge Limit: 245
```

===== SolarTrak Basic Configuration Parameters =====

```
>> Longitude (0 to 360) [106.0055]: 85.0773
SolarTrak[00004] Sun Angle - Count \ Array Angle - Count Wind(Mph) 0.0
Manual          54.56      1292 Axis 1      54.51      1291 Temp. (F) 91.4
9:45:06 7/13/2001 82.12      522 Axis 2      82.17      522 Batt. (V) 13.8
Array Control Menu
F1:HELP F4:Set Screwjack F5:MANUAL F9:Set Time F10:Done
```

Parameter Input Line Current Input Value Note that spinner will freeze while waiting for input

Press ENTER to keep the current value or enter a new value then press ENTER. To TOGGLE a value ON or OFF (or whatever binary function), press ENTER then the SPACE BAR.



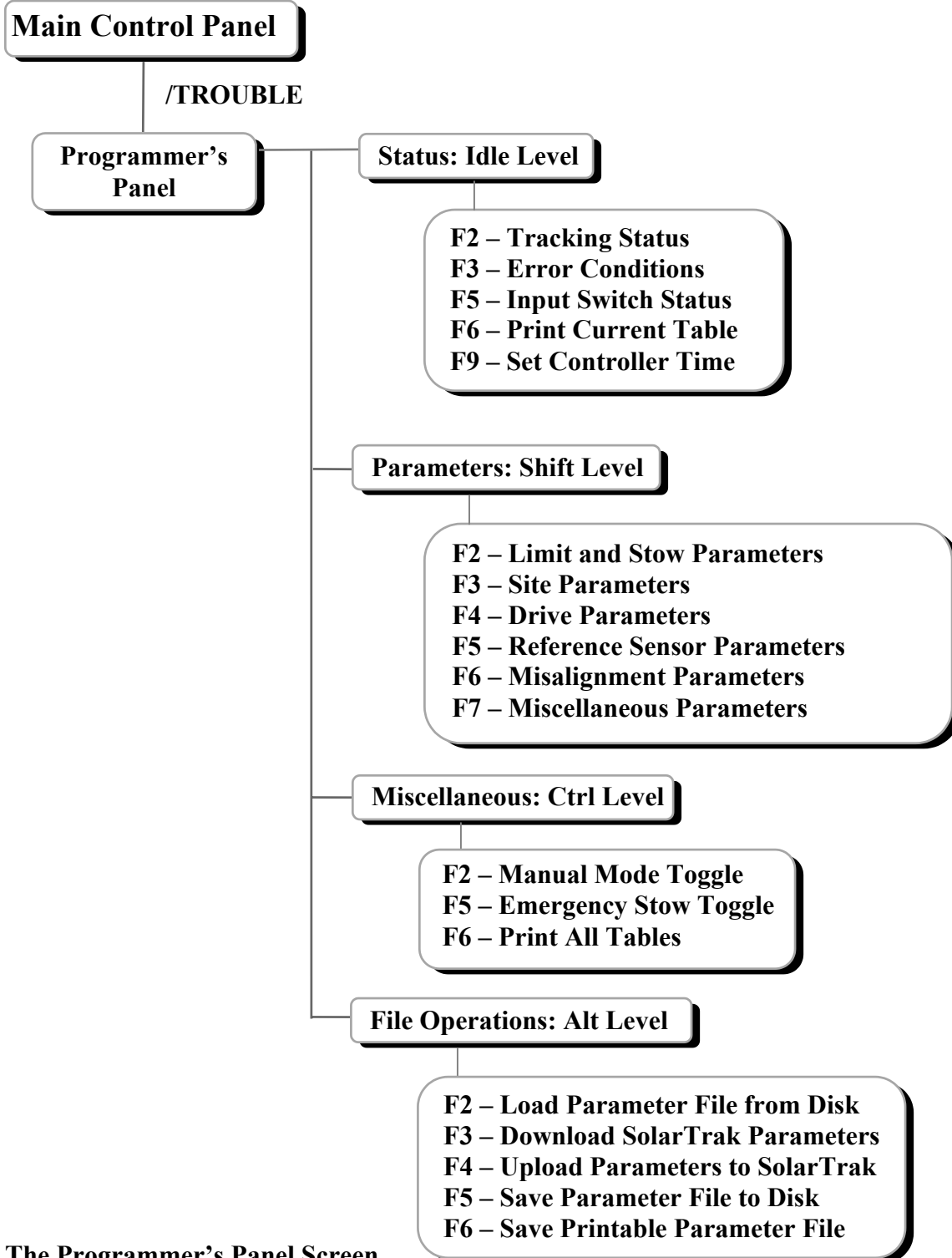
Parameter Tables:

Once in either the configuration or calibration menu, there are several groups of parameters that can be displayed on the screen by using the PgUp and PgDn keys. They are:

Basic Configuration Parameters	- Common Setup Values
Useful Calibration Parameters	- Status and Adjustment Parameters
Limit and Stow Parameters	- Software Limits and Stow Conditions
Site Parameters	- Site and Array General Description
Drive Parameters	- Geometric Descriptive Parameters
Reference Sensor Parameters	- Reference Check Conditions and Offsets
Misalignment Parameters	- Tower Misalignment Error Correction Function
Miscellaneous Parameters	- Unit #, Battery Charge Parameters and more...
Tracking Status	- Stow status, current Sun Values, Array Position
Toggle Switch Settings	- Access to keyboard control, on-board switch status
Thermal Clock Correction Values	- Data on thermal clock correction function
OUCH Circuit Control	- Control of Optional OUCH (defocussing) function

Section 3. The Programmer's Panel

The programmer's panel can be reached by entering the command **/TROUBLE** from the Main Control Panel. The first screen reached will be 'SolarTrak Reference Sensor Parameters'. From there, the following menu tree applies:



The Programmer's Panel Screen


```

Ax1 Gear Ratio      :      3.7800   Timed Motor-On Mode?: No
Ax1 Screwjk Param #1:    120.8222   Full-Deadband Mode? : Yes
Ax1 Screwjk Param #2:   3731.9041   Backtracking Mode?  : Yes
Ax1 Screwjk Param #3:   3927.2490   Width/Spacing Ratio :      0.5000
Ax2 Gear Ratio      :      0.0000   Absolute Encoder?   : Yes
Ax2 Screwjk Param #1:      0.0000   Ax1 +Joystick Mask  : 0x10
Ax2 Screwjk Param #2:      0.0000   Ax1 -Joystick Mask  : 0x04
Ax2 Screwjk Param #3:      0.0000   Ax2 +Joystick Mask  : 0x20
Ax1 Coast Counts    :      1        Ax2 -Joystick Mask  : 0x08
Ax1 Time/Coast Swch:      1        Mtr Stall Chk (Sec) :      60
Ax1 Deadband Counts :      3        Motor Delay (Sec)   :      4
Ax2 Coast Counts    :      0        Mtr-Turn Chk Intervl:     250
Ax2 Time/Coast Swch:      0        Trk Output Active Hi: Yes
Ax2 Deadband Counts :      0

=====
SolarTrak Drive Parameters
=====
SolarTrak[00004]  Sun Angle - Count \ Array Angle - Count Wind(Mph)  0.0
Manual          54.56      1292 Axis 1      54.51      1291 Temp. (F)  91.4
9:45:06  7/13/1999                      Batt. (V)  13.8
F1 | F2 | F3 |----| F5 | F6 |----|----| F9 | F10
HELP | TRACKING | ERROR |----| SWITCH | PRINT |----|----| SET TIME | DONE

```

To change screwjack parameters, press Shift-F4 to get to the Drive Parameters screen. Use the Up/Down arrows to highlight a value, press Enter to select for change. A prompt for new data will appear just below the screen title. Type in the new number, (the old one is in brackets) and press Enter again.

Press Shift-F2 to change the software limits in the Limit and Stow Parameters screen.
Press Shift-F3 to change the Latitude and Longitude in the Site Parameters screen.
Press Shift-F7 to change the clock correction values in the Miscellaneous Parameters screen.

Swapping or Installing the SolarTrak® Microcontroller Chip

The most appropriate method to exchange the controller chip is to use a PLCC chip extractor. It uses little prongs extended into the slots at the lower-left and upper-right of the chip, hooks under the chip and lifts it out evenly and smoothly without tipping or cocking the chip in the socket which causes the pins to bind and bend. BAD!

If one uses **Great Caution!**, there is an alternate method of extracting the chip. Use a small jeweler's screwdriver to slip into one slot at a time. Gently pry the corner up only a fraction of the necessary amount to free it. Move the screwdriver to the other slot and repeat the gentle pry up. Use your fingers to keep the chip level on the other two corners without slots. Two or three complete repetitions should do it.

When inserting the new chip, there is a corner shaved off that goes on the upper-left of the socket, near the RESET button. Settle the chip into the socket gently and verify all the pins line up and the chip is square with the socket. Gently rocking the chip with a couple of fingers will produce a 'floating' effect on the pins indicating a good placement, then push the chip straight into the socket, again keeping the chip level with several fingers.

Verify that the Manual switch is flipped to the right, power up and check for proper operation.

Moving Parameters between SolarTrak's

When adding new trackers or creating a backup tracking system, it can be tedious to transfer all the parameters unique to your system. Using the download and upload functions as a transfer mechanism is the easiest and least error-prone method.

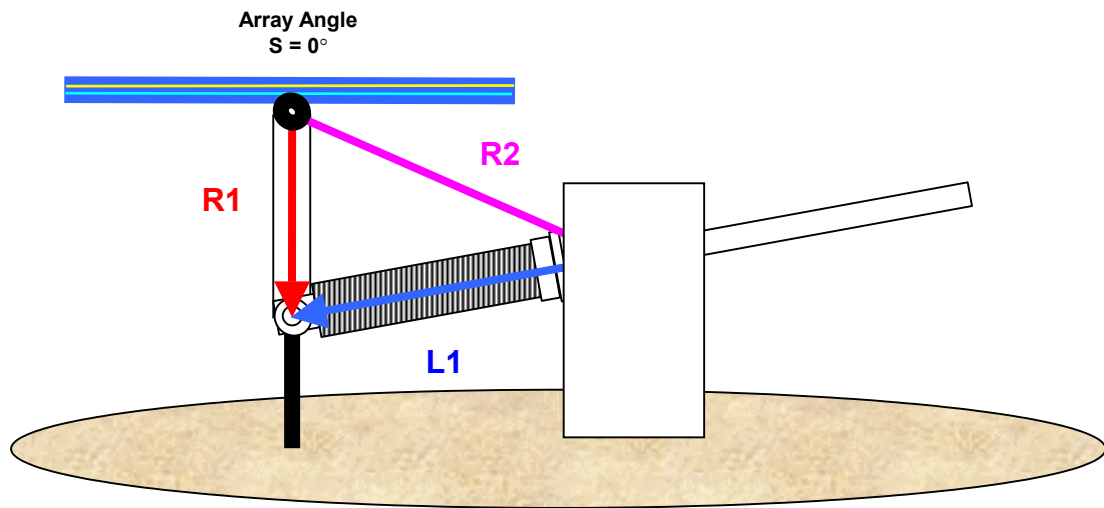
- Step 1: Download the template from the SolarTrak being duplicated. (Alt-F3 from Main Menu)
- Step 2: Save template on disk in swap file. (Alt-F5)
 Press ESC to enter a filename directly
 Type: SWAP then press the 'Enter' key
- Step 3: Either power down the SolarTrak and swap the controller chip then power back up...
 or
 Connect the PC to the new SolarTrak.
- Step 4: Load the swap file SWAP.TPL, just to make sure. (Alt-F2)
 Press ESC to enter file name directly.
 Type: SWAP then press 'Enter' key
- Step 5: Upload swap data to New or Replacement SolarTrak (Alt-F4)

When this step completes, it will ask if you want to remain in Manual Mode where it was put to inhibit motion during the upload. Press 'N'.

If one is cautious to keep the PC program running while changing chips or connections, Step 2 & Step 4 can be omitted. The internal data integrity is maintained once loaded as long as the PC interface software remains running so saving a swap file is just a precaution. The safest approach is to save the file and reload if you think something happened to the data. The internal data set is accessed by pressing 'T' on the keyboard to toggle back and forth. The Unit # changes to a file name designating the difference.

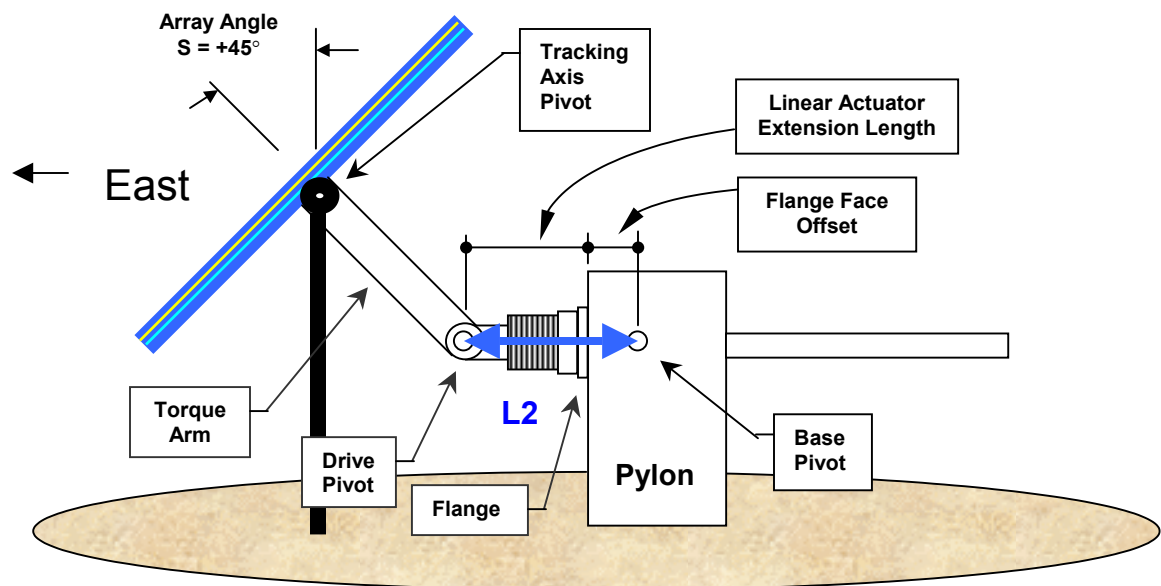
Appendix C:

SCREWJACK Parameter Computation

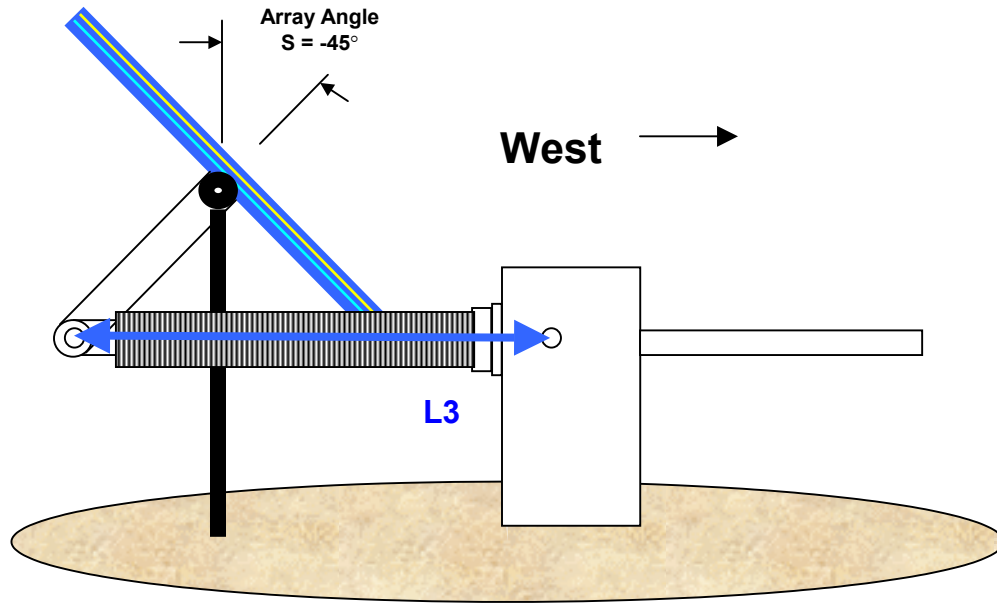


Western Mount Position – View Facing South

Level, Face-up Position



Unit Retracted to Soft Limit, $S = 45^\circ$



Linear Actuator at Full Extension to Soft Limit. $S = -45^\circ$

There are three screwjack parameters stored in the SolarTrak® in the 'Drive Parameters' screen, **SJP #1-3**, computed from the quantities **R1**, **R2**, **L1-3** defined above. Lengths are in inches.

The Law of Cosines is applied to convert the requested angular position to a specific actuator extension. The fundamental equation relating the actuator length and array angle is:

$$(1) \quad L = \sqrt{R1^2 + R2^2 - 2 * R1 * R2 * \cos(S + \beta)}$$

Where **L** is the length of the actuator, **S** is the requested array angle and **β** is an angular offset based on the relative positions of **R1** and **R2** when the array is facing straight up (**S = 0**). Since some of the computations for these terms need only be performed once, the parameters are stored as pre-combined coefficients producing the equivalent equation (2).

$$\begin{aligned} \text{SJP \#2} &= (+/-) 2 * R1 * R2 & (+\text{West Mount, -East}) \\ \text{SJP \#3} &= R1^2 + R2^2 \end{aligned}$$

$$(2) \quad L = \sqrt{\text{SJP\#3} + \text{SJP\#2} * \cos(S + \beta)}$$

$$(3) \quad \beta = \text{ACOS} \{ (L^2 - \text{SJP\#3}) / \text{SJP\#2} \} - S \quad \text{SJP \#1} = \beta$$

Equation (1) above is used for converting a specific Sun angle to a specific screwjack extension point. Equation 3 should be used to determine **β** for **L** equals each of the measurable quantities **L1** (**S = 0**), **L2** (**S = 45, in radians**) and **L3** (**S = -45**). The result found for **β** should be the same in each case.