



SensiStat™ Energy Saver Refrigeration Controller

Revision 1.14

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The SCAD SensiStat™™ Energy Saver refrigeration controller works with your 12 or 24-volt holding (aka holdover) plate refrigeration system and reduces your battery usage by:

- Providing extremely precise thermal control thus reducing excess running of your refrigeration compressor
- Automatically utilizing available “excess” power while your batteries are charging. This reduces the amount of battery energy used each day for refrigeration and saves you hours of battery charging time each week. This savings translates to real dollars as you will use less fuel for battery charging and reduce wear-and-tear on your engine or generator.

HOW IT WORKS:

A typical thermostat turns on your refrigeration compressor to freeze holding plates solid. The plates are then allowed to defrost to a temperature approximately 8° F higher before the compressor is turned on again and the plates are refrozen. The difference between the freezing temperature and the “defrosted” temperature is known as hysteresis or differential. This is the most energy efficient method and the more precise the control, the more efficient the system and the more likely your ice cream will remain solid. The SensiStat™™ refrigeration controller, with a resolution of 1/10° F provides unparalleled precision of control. What’s more, the SensiStat™ comes with temperature sensors to allow you to monitor and display both the holding plate temperature and refrigeration box temperature.

Normal thermostats also do not take advantage of randomly available “free” power provided whenever your engine or generator are running and charging your batteries. Since batteries can only charge so fast, there is normally plenty of extra generation capacity available to run your refrigeration system “for free”, that is using energy without depleting your batteries. When the SensiStat™ refrigeration controller detects charging level voltages, it closes down the hysteresis to only 1° F and uses the available free power to “top-up” the freeze on your holding plates. For example, when you are motoring into an anchorage at the end of the day, The SensiStat™ will automatically run your refrigeration compressor while your engine is running and save you all the battery energy that would have been used later in the evening running the refrigeration compressor for the same amount of time directly off the batteries.

You can also tell the SensiStat™ refrigeration controller to ignore extra power (such as while plugged in a dock) or to force a freezing of the holding plates for up to 60 minutes.

Additionally, the SensiStat™ detects excess voltages which might damage your refrigeration system alerts you and does not over-ride the differential when excess voltages are present.

Finally, although the factory settings will work for most sailors, you can custom program the voltage threshold at which the SensiStat™ overrides the differential. You can also set the holding plate freezing temperature, the normal and override differentials, the displayed temperature scale (Fahrenheit or Centigrade), and whether the holding plate or box temperature is displayed by default.

INSTALLATION:

The SensiStat™ refrigeration controller simply replaces your current thermostat, switch, or timer. Find a convenient place to mount your SensiStat™ and cut the appropriate hole using the template included with your SensiStat™.

If your current thermostat does not have a ground wire (a third wire), you need to add one. This wire is typically color-coded black and should tie back eventually to the battery's negative terminal. Most thermostats and all switches or timers use two wires. One is +12 volts when the refrigeration circuit breaker is turned on, the other returns to the refrigeration system to turn on the compressor. By disconnecting both of these wires from your current thermostat, switch, or timer you can determine which is the +12V wire by testing each in turn with either a light bulb or a voltmeter. One lead of your test bulb or voltmeter would go to ground (battery negative) and the other to the wire being tested. The wire which lights the bulb (when the refrigeration circuit breaker is turned on), or shows around +12 volts on your voltmeter, is the +12V lead. You may want to mark it with some red tape. **TURN OFF POWER TO THE REFRIGERATION SYSTEM** until all connections to the SensiStat™ are completed. Connect the +12V wire to terminals 2 and 4 of the SensiStat™, per the illustration below. The other wire connects to terminal 1 per the illustration below.

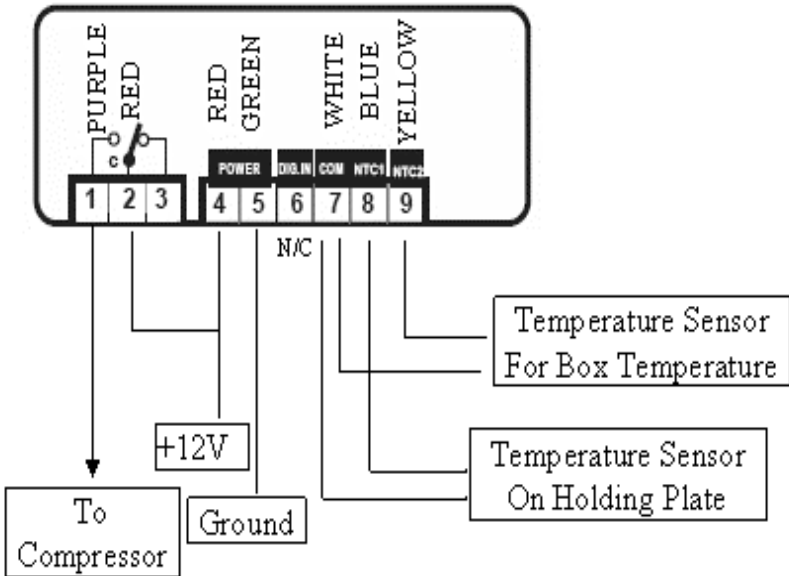


Figure 1

Your new SensiStat™ includes two temperature sensors. They are both the same, but each is color coded to help you trace which is used for the box temperature and which is used for the holding plate temperature. It is critical that the holding plate temperature sensor be placed in intimate contact with the holding plate as close as possible to the point where its coolant line returns to the compressor. If you have multiple plates in series, place the sensor on the last plate. You can tell which line is the return line by feeling the lines shortly after starting the

compressor. The warmer line is the return line. There will typically be frost on the source line and none on the return line.

Some holding plates have wells specifically intended to hold the temperature sensor. If your plates have such as well, insert the sensor into the well. You can seal the hole and hold the sensor in with a bit of silicon sealer, putty, chewing gum, or the like.

If your holding plates do not have a temperature sensor well, you will need to tape the sensor to the holding plate. You should be able to tell where the cooling coils run within the holding plate by observing a light layer of frost on the holding plate. Avoid placing the sensor directly over the coil. The silver tape provided with your SensiStat™ will adhere well to a holding plate BUT YOU MUST ONLY APPLY IT WHEN THE PLATE IS A ROOM TEMPERATURE. The tape will not stick at all if applied to a cold holding plate. If applied to a warm holding plate, the tape will bond well and not come off when the plate is frozen. Smooth any air bubbles out from under the tape. It is best to have the wire lead downward so moisture will not collect under the tape.

The temperature sensor for monitoring the ice box temperature should be mounted away from the plates and may be taped to the wall of the box. Route the wires in such a manner that they will not be easily snagged or caught on food items.

The temperature sensor wires may be shortened or just coiled up behind the thermostat with the provided wire ties. Should you shorten the temperature sensor wires, you may replace the color-coded heat shrink tubing with the short pieces provided. Use only warm air to shrink the tubing, such as well above a candle; do not pass the tubing through an open flame.

One conductor from each temperature sensor is connected terminal 7 of the SensiStat. These are the white coded wires. The second conductor from the holding plate sensor (blue) is connected to terminal 8. The second conductor from the box temperature sensor (yellow) is connected to terminal 9 on the SensiStat. DO NOT connect anything to terminal 6.

OPERATION:

Components of the SensiStat™ refrigeration controller:The SensiStat™ consists of an industry standard digital thermostat manufactured by the world leader in thermostatic controls, Carel married to a SCAD designed microprocessor-based daughter board mounted within the thermostat. The thermostat is custom programmed to respond to the daughter board's commands to override its differential. The daughter board recognizes the voltage of the battery system of your boat and decides when to override the differential. It also monitors over voltage conditions, allows you to manually override the differential for a period of 60 minutes, to disable the override function, or to change the threshold voltage at which the override function is enabled.

You control the functions of the daughter board via the function button (# 10 on figure 2) and receive feedback from the daughter board via the function LED (# 9 on figure 2).

You may change the settings of the thermostat, including the holding plate freezing temperature, differentials, and display units (Fahrenheit or Centigrade) using the buttons on the thermostat (#5 through #8 on figure 2).

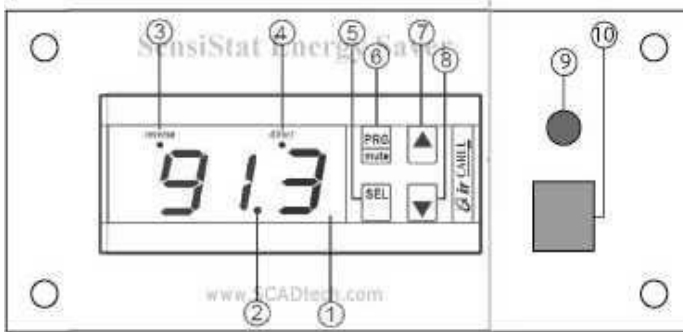


Figure 2: Front Panel of SensiStat™ Energy Saver

Power-on self-test: Each time the SensiStat™ refrigeration controller receives power, it conducts a self-test and determines the voltage of your batteries. The indicator LED (“9” in figure 2) will display a string of 8 rapid flashes, pause, flash the revision code of the firmware (such as one long, and three short flashes for revision 1.3), pause, and then display another string of 8 rapid flashes. At this point you are assured the system is working correctly.

Factory Settings: The SensiStat™ refrigeration control comes from the factory set for most marine freezer holding plate systems with the freezing point set to 0° F and the differential set to 8° F. Consult your refrigeration manual or manufacturer to determine their preferred settings. Refrigerator-only holding plates typically freeze at 24° F.

Normal Thermostat Mode: When battery voltages are below charging voltage, the SensiStat™ will operate as a very precise thermostat. When demanding the compressor to run, the “direct” LED (#4 in figure 2) will flash slowly. By default, the temperature of the ice box is displayed. Pressing the down key (#8 in figure 2) will briefly display the holding plate temperature. (see “Customization” below if you prefer the holding plate temperature to be displayed by default).

“Free Power” Mode: The SensiStat™ will override the differential, down to 1° F when “free power” is available for 30 seconds. “Free power” means charging voltage exceeding 14 volts on a 12 volt system or 28 volts on a 24 volt system. The SensiStat™ automatically determines if you have a 12 or 24 volt system each time it is turned on. Should the voltage exceed 15 volts on a 12 volt system or 30 volts on a 24 volt system, the SensiStat™ indicator LED will light and the differential will not be overridden.

The SensiStat™ indicator LED flashes (1/2 second on - 1/2 second off) when “free power” first becomes available. After 30 seconds, the LED will light continuously and the differential will be overridden. When the SensiStat™ is asking the compressor to run, a small LED under the word “Direct” and indicated by the number 4 on Figure 2 will flash.

Over Voltage Alert: Should the SensiStat™ detect an over voltage condition, the Free Power and Manual Override modes will be temporarily disabled and the function LED will illuminate. The thermostat will otherwise function normally during an over voltage alert. The over voltage level is factory set at 15 volts for 12 volt systems and 30 volts for 24 volt systems.

Manual Override Mode: Manual override mode allows you to force a “topping-up” of your holding plates. When in manual override mode, the differential is overridden, unless an over-voltage condition is detected. The manual override mode resets automatically after approximately 60 minutes.

To start the manual override mode, briefly press the function button (#10 on figure 2). The function LED will flash once per second during manual override mode. The “direct” LED (#4 on figure 2) will flash indicating the thermostat is asking your refrigeration compressor to run. The “direct” LED will continue to flash until the holding plate is re-frozen or 60 minutes have elapsed.

To cease the manual override mode, briefly press the function button (#10 of figure 2). The function LED will cease flashing once per second. The SensiStat™ will return to normal operation. If “Free Power” is available, the SensiStat™ will respond accordingly.

Disabled Mode: You may choose to prevent your SensiStat™ from responding to “Free Power” for example, when you are plugged in at a dock. The thermostat will continue to operate normally. Only “Free Power” mode will be defeated while in disabled mode.

To enter disabled mode, press and hold the function button (#10 in figure 2) until one string of rapid flashes is displayed, then release the function button. The SensiStat™ will enter disabled mode. The function LED will flash briefly once every 15 seconds or so. This brief occasional flashing is just a reminder to you that the SensiStat™ is in disabled mode.

To exit disabled mode, press and hold the function button until one string of rapid flashes is displayed, then release the function button. The SensiStat™ will exit disabled mode and resume normal operation.

Compressor Protection: The SensiStat™ provides protection against short cycling your refrigeration compressor. Once your compressor is turned off by the SensiStat™, it will not be turned on again for at least 5 minutes.

CUSTOMIZATION:

If the factory settings do not meet your needs, you may easily change the settings. *Please do not attempt to change any setting other than those outlined below. Changing other setting may make the unit behave in unpredictable ways and could void your warranty. ONLY CHANGE THE SETTINGS OF VARIABLES St1, St2, P1, P2, and C18.*

To change default temperature sensor display:

Your SensiStat™ by default displays the temperature sensed by the ice box temperature sensor. By pressing the Down key (#8 in figure 2) you may momentarily view the holding plate sensor reading.

Caution: This procedure will place the thermostat in advanced programming mode. DO NOT CHANGE ANY SETTINGS OTHER THAN C13 with this procedure. Doing so could create unpredictable behavior, render your unit inoperable, and void your warranty.

To reverse this and have the holding plate sensor reading displayed by default:

1. Press and hold the PRG and SEL keys down for 5 seconds.
2. The display will show “0”.
3. Release the PRG and SEL keys.
4. Use the UP and Down keys to change the display to show “77”.
5. Briefly press the SEL key.
6. The display will show “C0”.
7. Use the Up and Down keys to change the display to show “C13”.
8. Briefly press the SEL key.
9. The current setting for C13 will be shown. 1= display ice box temperature , 0=display holding plate temperature. If you wish to change the default displayed temperature, use the Up or Down key to change the value.

10. Briefly press the SEL key to lock-in your selection.
11. Briefly press the PRG key to exit the advanced programming mode.

To display or set the freezing temperature:

1. To enter the set point programming mode, press and hold the SEL key (#5 in figure 2) for 5 seconds.
2. The display will show "St1", the variable for the freezing temperature for normal operation.
3. Release the SEL key. The display will now show the current setting for St1. (Factory default is 0° F).
4. If you wish to change this value, press either the Up or Down keys (#7 or #8 in figure 2) until you reach the new desired value.
5. Press the SEL key briefly to confirm the current or new value of St1.
6. The display will show "St2". This is the variable for the freezing temperature for override mode. This value should be set to the same value as St1.
7. The value of St2 will be displayed. (Factory default is 0° F).
8. If you wish to change this value, press either the Up or Down keys (#7 or #8 in figure 2) until you reach the new desired value.
9. Press the SEL key briefly to confirm the current or new value of St2.

To display or set the differential settings:

Generally, there is no need to change the differential settings unless you change the display units from Fahrenheit to Centigrade or your refrigeration manufacturer specifies a different differential. Remember, the override differential is critical for the "Free Power" mode to operate correctly. Avoid changing the "P2" value unless you are certain you know why you are changing it.

1. To enter the differential programming mode, press and hold the PRG key (#6 in figure 2) for 5 seconds.
2. The display will show "P1".
3. Release the PRG key.
4. Press the SEL key briefly to select the P1 mode (differential for normal operation).
5. The current setting of the P1 differential is displayed. If you do not wish to change the value, press the SEL key now. (The factory default setting for this value is 8° F)
6. To change the differential value, press either the UP or Down keys (#7 or #8 in figure 2) until you reach the desired value.
7. Press the SEL key briefly to confirm the new value.
8. Press the UP key to display "P2".
9. Press the SEL key briefly to select the P2 mode (differential for override operation).
10. The current setting of the P2 differential is displayed. If you do not wish to change the value, press the SEL key now. (The factory default setting for this value is 1° F)
11. To change the override differential value, press either the UP or Down keys (#7 or #8 in figure 2) until you reach the desired value.
12. Press the SEL key briefly to confirm the new value.
13. Press the PRG key briefly to exit the programming mode.

NOTE: Do not attempt to change any variables other than the "P1" and "P2" here. It is not necessary to change other programming variable here and your results may be unpredictable and render your SensiStat™ inoperable and void your warranty.

To Change Displayed Units (Fahrenheit or Centigrade):

Caution: This procedure will place the thermostat in advanced programming mode. DO NOT CHANGE ANY SETTINGS OTHER THAN C18 with this procedure. Doing so could create unpredictable behavior, render your unit inoperable, and void your warranty.

1. Press and hold the PRG and SEL keys down for 5 seconds.
2. The display will show "0".
3. Release the PRG and SEL keys.
4. Use the UP and Down keys to change the display to show "77".

5. Briefly press the SEL key.
6. The display will show "C0".
7. Use the Up and Down keys to change the display to show "C18".
8. Briefly press the SEL key.
9. The current setting for C18 will be shown. 1=^o F, 0=^o C
10. If you wish to change the displayed unit setting, use the Up or Down key to change the value.
11. Briefly press the SEL key to lock-in your selection.
12. Briefly press the PRG key to exit the advanced programming mode.

After changing the displayed units, you **MUST** change the freezing temperatures (St1 and St2) and the differentials (P1 and P1) to correspond to the new units of measurement. They are not converted automatically.

To Display or Change the "Free Power" Threshold Voltage:

The voltage at which the "Free Power" mode will be engaged is factory set to 14 volts for 12 volt systems and 28 volts for 24 volts systems. The ranges of settings are:

- For 12 volt systems: 13.0 volts to 14.5 volts in 0.1 volt steps.
- For 24 volt systems: 26.0 volts to 29.0 volts in 0.2 volt steps.

You may only change the value for the voltage at which your SensiStat™ is currently operating. That is, if you are on a 12 volt boat, you can only change the settings for 12 volts systems.

1. Press and hold the function button (#10 on figure 2).
2. Release the function button only after two strings of rapid flashes are displayed. (but before three strings of rapid flashes are displayed)
3. The function LED (#9 on figure 2) will begin to flash out voltage setting options in a Morse code-like fashion. The selections will be displayed as follows:

12 Volt Systems		
Volts	Long Flash	Short Flash
13.0	1	3
13.1	3	1
13.2	3	2
13.3	3	3
13.4	3	4
13.5	3	5
13.6	3	6
13.7	3	7
13.8	3	8
13.9	3	9
14.0	1	4
14.1	4	1
14.2	4	2
14.3	4	3
14.4	4	4
14.5	4	5

24 Volt Systems		
Volts	Long Flash	Short Flash
26.0	2	6
26.2	6	2
26.4	6	4
26.6	6	6
26.8	6	8
27.0	2	7
27.2	6	2
27.4	6	4
27.6	6	6
27.8	6	8
28.0	2	8
28.2	8	2
28.4	8	4
28.6	8	6
28.8	8	8
29.0	2	9

4. If you wish to display the value of the current threshold voltage setting your SensiStat™ is using, press and hold the function button until a long string of flashes is displayed. As soon as the long string of flashes is displayed, release the function button. After a brief pause, the function LED will flash out the current threshold voltage setting, for example: “-”, one long, four shorts, for the factory default for 12 volt systems, 14.0 volts. The SensiStat™ will then exit the threshold voltage programming mode, retaining the current setting, and resuming normal operation.
5. If you wish to change the value of the threshold voltage, simply briefly press the function button immediately after your desired setting is displayed. The function LED will display a brief rapid string of flashes to acknowledge acceptance of the new setting. The SensiStat™ will return to normal operation, using your new threshold setting. This setting will be retained in memory until you wish to change it again.
6. *If you enter programming mode and fail to select any of the threshold voltage choices, the SensiStat™ will execute a factory reset of the set the threshold value to the factory default values.*
7. *Should you enter the programming mode accidentally, the easiest way to exit, retaining current setting, is to enter the display of threshold voltage mode. You may do this at any time while the threshold voltage choices are being displayed. See step 4 above.*

To Change Free Power Threshold Hysteresis:

When Free Power is detected at the set threshold voltage, Free Power will be considered to be available until the voltage drops to the set threshold voltage minus the threshold hysteresis. The factory default for the threshold hysteresis is 0.1 volts. If you find your battery voltage drops by more than 0.1 volts when the refrigeration compressor starts while your engine or generator is charging your batteries, you may need to increase the threshold hysteresis. You may view the threshold hysteresis or set the threshold hysteresis to a value between 0.1 and 0.5 volts in increments of 0.1 volts.

To view the current threshold hysteresis setting:

1. Press and hold the function button (#10 on figure 2).
2. Release the function button only after two strings of rapid flashes are displayed. (but before three strings of rapid flashes are displayed). You are now in threshold voltage programming mode.
3. Press and hold the function button once again.
4. Release the function button only after two strings of rapid flashes are displayed. (but before three strings of rapid flashes are displayed). You are now in threshold hysteresis programming mode.
5. To only view the current threshold hysteresis setting, press and hold the function button until a string of rapid flashes is displayed. Shortly thereafter the function LED will flash the threshold hysteresis level; one flash for each tenth of a volt. After displaying the threshold hysteresis level, the SensiStat™ returns to normal operation.

To change the threshold hysteresis:

1. Press and hold the function button (#10 on figure 2).
2. Release the function button only after two strings of rapid flashes are displayed. (but before three strings of rapid flashes are displayed). You are now in threshold voltage programming mode.
3. Press and hold the function button once again.
4. Release the function button only after two strings of rapid flashes are displayed. (but before three strings of rapid flashes are displayed). You are now in threshold hysteresis programming mode.
5. The function LED will begin to flash your options for the new threshold hysteresis value. Each group of flashes indicates a number of 0.1 volt increments:

Flashes	Volts
1	0.1
2	0.2
3	0.3
4	0.4
5	0.5

6. To select one of the options, just press the function button briefly after your choice is displayed. A string of rapid flashes of the function LED will indicate acceptance of your choice. The SensiStat™ will then return to normal operation.

If you do not select any of the five options, the SensiStat™ will continue to use the currently set threshold hysteresis value. A long string of flashes will be displayed by the function LED to indicate that no new setting was selected then the SensiStat™ will return to normal operation.

TROUBLE SHOOTING:

- **“ER0” is displayed:** This error indicates that one or both of your temperature sensors is not connected correctly to the SensiStat™. Turn off power at the refrigeration system circuit breaker. Check the connections at the back of the SensiStat™. Turn power back on. If this does not correct the problem, check the temperature sensors and wires for physical damage.
- **I can’t understand the pattern of flashing of the function LED:** Although we have tried to capture all possible software glitches in our design and testing, the microprocessor may have found itself lost at sea. Usually just turning off the

refrigeration system at the circuit breaker and turning it back on after 30 seconds or more will fix the problem. If that does not work for some reason, you may conduct a hard reset of the daughter board by holding the function button (#10 on figure 2) down until after three strings of rapid flashes are displayed on the function LED (#9 on figure 2). The daughter board will reset all its values, including the “Free Power” threshold voltage to factory defaults, conduct a power-up self-test, and then resume normal operation.

- **I failed to listen to your cautions and changed variables on the thermostat that I should not have. Now I can't get the thermostat to operate correctly:** Well now you've done it... If you have any friends left to go along with your warm or frozen beer, grab one, the first part of this procedure is a two person job...

You must first conduct a factory reset of the thermostat and then re-program it. Please read these instructions through and understand them completely before attempting this procedure.

1. With your friend at the refrigeration circuit breaker and you at the SensiStat™, turn off the power. Now, hold down the PRG key (#6 on figure 2) while your friend turns the power back on. The center digit of the display will show two bars and after a few seconds display a temperature. Release the PRG key. Your thermostat is now completely dumb, but in a known state.
2. We can now return the unit to the settings it had when shipped to you. See the steps above **“To Change Displayed Units (Fahrenheit or Centigrade)”** to set all of the following values:
 - a. “C0” to 7
 - b. “P1” to 8.0
 - c. “P2” to 1.0
 - d. “C7” to 5
 - e. “C13” to 1
 - f. “C18” to 1
3. Now using the procedure from **“To display or set the freezing temperature”** above to set the following values:
 - a. “St1” to 0.0
 - b. “St2” to 0.0
4. When your SensiStat™ was assembled and tested, the two temperature probes were matched to each other and calibrated. The P14 calibration value is handwritten on the label on the top of the SensiStat body. For example “Cal 1-23-08 P14 = -0.2:”. Find this value. (Early models of the SensiStat may not have this value written on them (if the value is not there, you can skip this step). To enter the P14 value, press and hold the PRG key until the display changes. Use the Up Arrow key to select P14. Press the SEL key. Using the up and down arrow keys enter the P14 value then press SEL. Briefly press the PRG key to return to exit programming mode.

Your SensiStat™ should now behave exactly as it did when you first installed it.

FACEPLATE TEMPLATE

This template may not be to scale.

