SCHMIDT CONSULTING

Window Ventilation Controller

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Our house has a pair of south facing awning clearstory windows; the controller automatically opens the window and turns on exhaust fans during the summer whenever it is warmer inside then out.

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Overview

Our house has a pair of south facing clearstory awning windows. Here in southern NH most summer nights cool down substantially creating an opportunity for passive summer cooling and ventilation. When I designed the house hoped simply leaving the windows open in summer would move enough air to cool the house down to near morning outdoor temperature.

Unfortunately that scheme did not work as well as I had expected. Leaving the window open during the day allows hot air heated by the south facing roof to enter the house. At night even with a significant temperature differential by morning inside air is still much warmer than outdoor. The solution was an active system to control the window so hot daytime air is prevented from entering the house and using exhaust fans to increase nighttime air movement to do a better job cooling off the interior.

Design Goals

I used the same WebControl PLC I've used for other projects as the brains of the system. It supports multiple Dallas/Maxim 1-wire temperature sensors to measure indoor and outdoor temperature. That allows differential temperature to control the windows. As long as outdoor temperature is warm enough whenever inside temperature is higher than outdoor the controller automatically opens the windows and turns on the exhaust fans. The system supports control of two windows, although the initial implementation is a single window.

The actuator is pretty strong so I wanted to include provisions to detect a jam and recover if possible.

A rain sensor overrides normal operation to close the window during rain storms. A web based configuration page selects manual or automatic operation and sets the exhaust fans to high or low.

Window Actuator

The heart of the system is a motorized window actuator. Finding one turned out to be much harder than I expected. I wanted to use a motorized chain drive actuator similar to the manual arrangement we have for our bathroom skylight. Even though the chain is flexible because both ends are fixed it provides a rigid arm to extend and retract the window. When retracted the chain is coiled up within the actuator housing. Electric window operators typically contain a built in microcontroller. The DC units are two wire devices. One polarity opens the window the other closes it. The internal controller also senses motor current and shuts the unit down at full extension and retraction or if it detects a jam.

An Internet search turned up several distributors but they were all in Europe. Actuator cost was high and shipping came close to doubling the price. I finally found a US/Canadian company RollerTrol that makes electric actuators for both windows and blinds. Their support was staff was extremely helpful. The cataloged item operates at 12 volts but they have a special order version that operates at 24 volts. I

wanted to use the higher voltage because that is what I needed for the fans and to reduce current through the H-bridge IC used to control actuator direction.

Since the awning windows were not very tall I was worried the standard full extension range 11 - 13/16" (300mm) was too great so they were able to reduce throw to 9 -7/8" (250mm).

Fans

I found some surplus Rotron and Papst 6.75" 24 volt fans to provide the exhaust function. Each awning window is 4 feet long and 1'-7" tall. Mounted four fans per window in a high/low arrangement where the controller turns on two fans for low and all four for high. The fans are mounted on a polycarbonate sheet on the inside of the window, with the fans located between the polycarbonate sheet and the removable window screen. This arrangement keeps bugs out when the fans are not running and lets in as much daylight as possible.

Window Mockup Test Jig

The design of the controller was part of a larger project to replace our windows. To facilitate debugging the controller I built a crude mockup of an awning window that mounted the actuator, four fans and a switch to detect when the window is fully closed.

During early debug used a small pilot light to indicate when power was being applied to the actuator.

Test jig proved to be extremely valuable; while it did not fully replicate the actual window it provided a good first approximation. Once I had basic open/close and fan control code debugged worked on jam detection. This is an important safety consideration as the actuator has about 20 lbs. (9 kg) of force so if your hand gets caught while the window is closing it is going to hurt. Based on results using the test jig I changed the window closed sensing switch from a magnetic reed to mechanical micro switch. The micro switch is able to deliver accurate detection of window closed position. This was critical for detecting jams during close operation.

Temperature Sensing

Three of the 8 PLC temperature channels are used. Channel 1 is outside air temp near the window, channel 2 is inside temperature near the window and channel 3 is temperature within the chassis itself. Code processes indoor and outdoor temperature deferentially. Assuming outdoor temperature is high enough when indoor temperature exceeds outdoor the windows are opened. The third temperature sensor monitors temperature within the chassis. This is not used by the automated process but provides a way to detect excessive internal chassis temperature.

Relative Humidity Reporting

WebControl supports the Honeywell HIH-4000 humidity sensor. This provides a highly accurate reading of relative humidity. Humidity is not used by the control system it is simply displayed on the web interface.

WebControl Programmable Logic Controller

One of the nice aspects of the CAI networks WebControl is that it includes a built in web server. This allows any PC on the LAN to monitor window ventilator status and multiple temperature measurements.

The device provides 8 digital inputs, 3 10-bit analog inputs, 8 digital outputs, up to 8 Maxim/Dallas 18B20 1-wire temperature sensors, and a humidity sensor using a Honeywell 4000. WebControl implements a simple scripting language. User code is generated offline and pasted into the system.

System Status

The System Status screen displays various values and registers. VAR 1 is overall system hardware health status and is used to report power supply and temperature sensor faults, VAR2/3 report status of each window. The Input and Output bits display the various digital controls.

Temperate and relative humidity readings are displayed on the status page. Due to a wiring screw up analog 1 reports window 2 current, analog 2 is window 1, it was too much work to correct. Analog 3 is ½ the 5V from buck converter. It is on when the 24V supply it enabled, this is used to provide a sanity check of the 24volt subsystem.

CAI WebControl PLC

Version: v03.02.17d IpAddress: 192.168.2.106 Name: WINDOWVENT 06/22/2015 18:14:50

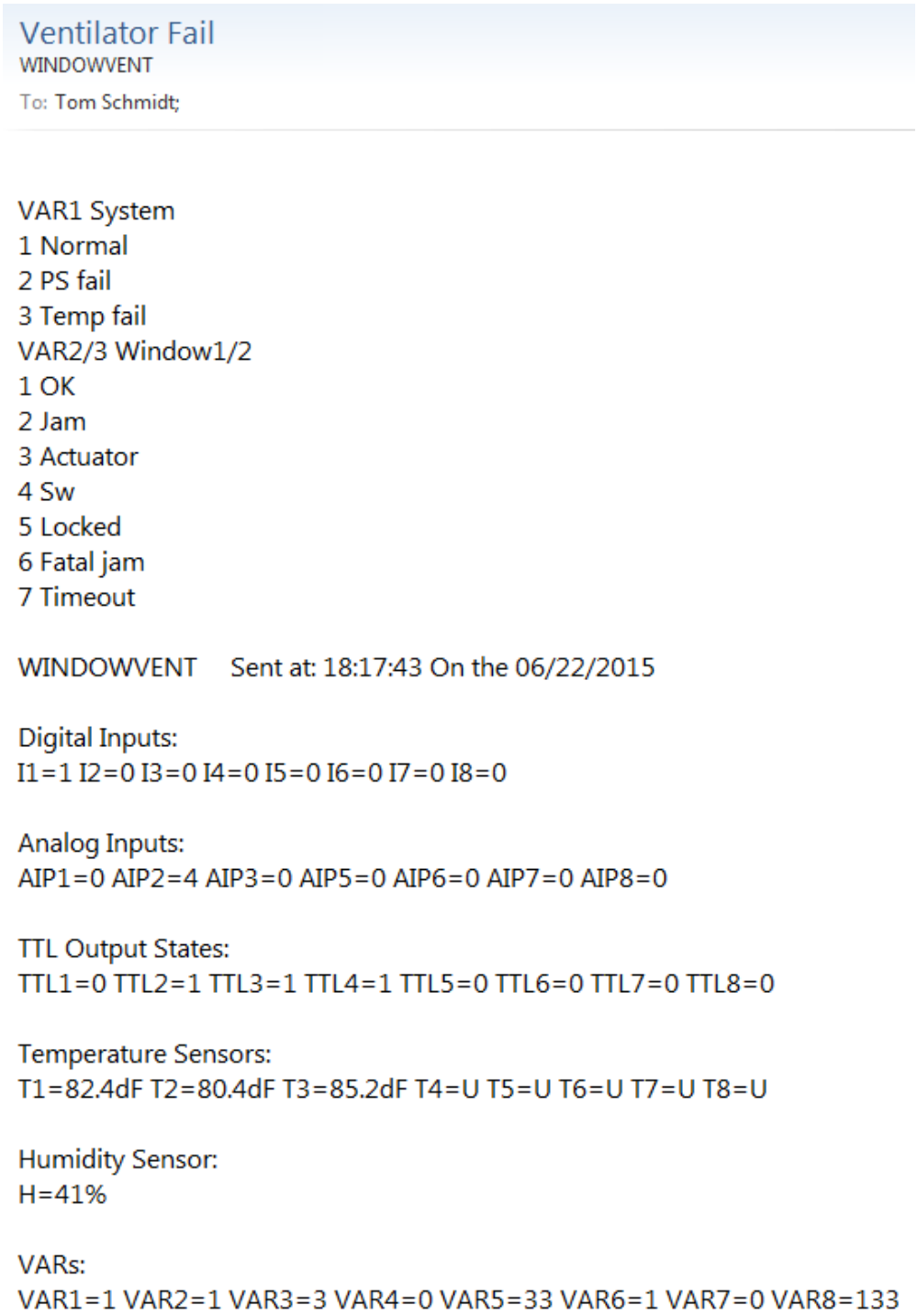
System Status

- System Status
- Output Control
- x10 Control
- I/O Setup
- Notify Setup
- Temperature Sensor Setup
- PLC Program
- General Setup
- Network Setup
- Help

Outputs								
	1	2	3	4	5	6	7	8
TTL Output Bits	0	1	1	1	0	0	0	0
32 Bit Signed Vars	1	1	3	0	33	1	0	133

Inputs								
	1	2	3	4	5	6	7	8
TTL Input Bits	1	0	0	0	0	0	0	0
Temperature Sensors	82.4 F	80.4 F	85.2 F	unbound	unbound	unbound	unbound	unbound
Temperature Sensor Status	ok	ok	ok	unbound	unbound	unbound	unbound	unbound
Analog Inputs	0	5	0	0	0	0	0	0
Humidity Sensor	41 %							
Counter	0							
Frequency	0							

To make the status display easier to interpret when there is a hardware fault the notification email includes a list of status codes for the system and individual windows.



Ventilator Fail
WINDOWVENT
To: Tom Schmidt;

VAR1 System
1 Normal
2 PS fail
3 Temp fail
VAR2/3 Window1/2
1 OK
2 Jam
3 Actuator
4 Sw
5 Locked
6 Fatal jam
7 Timeout

WINDOWVENT Sent at: 18:17:43 On the 06/22/2015

Digital Inputs:
I1=1 I2=0 I3=0 I4=0 I5=0 I6=0 I7=0 I8=0

Analog Inputs:
AIP1=0 AIP2=4 AIP3=0 AIP5=0 AIP6=0 AIP7=0 AIP8=0

TTL Output States:
TTL1=0 TTL2=1 TTL3=1 TTL4=1 TTL5=0 TTL6=0 TTL7=0 TTL8=0

Temperature Sensors:
T1=82.4dF T2=80.4dF T3=85.2dF T4=U T5=U T6=U T7=U T8=U

Humidity Sensor:
H=41%

VARs:
VAR1=1 VAR2=1 VAR3=3 VAR4=0 VAR5=33 VAR6=1 VAR7=0 VAR8=133

Backup Actuator Power Supply

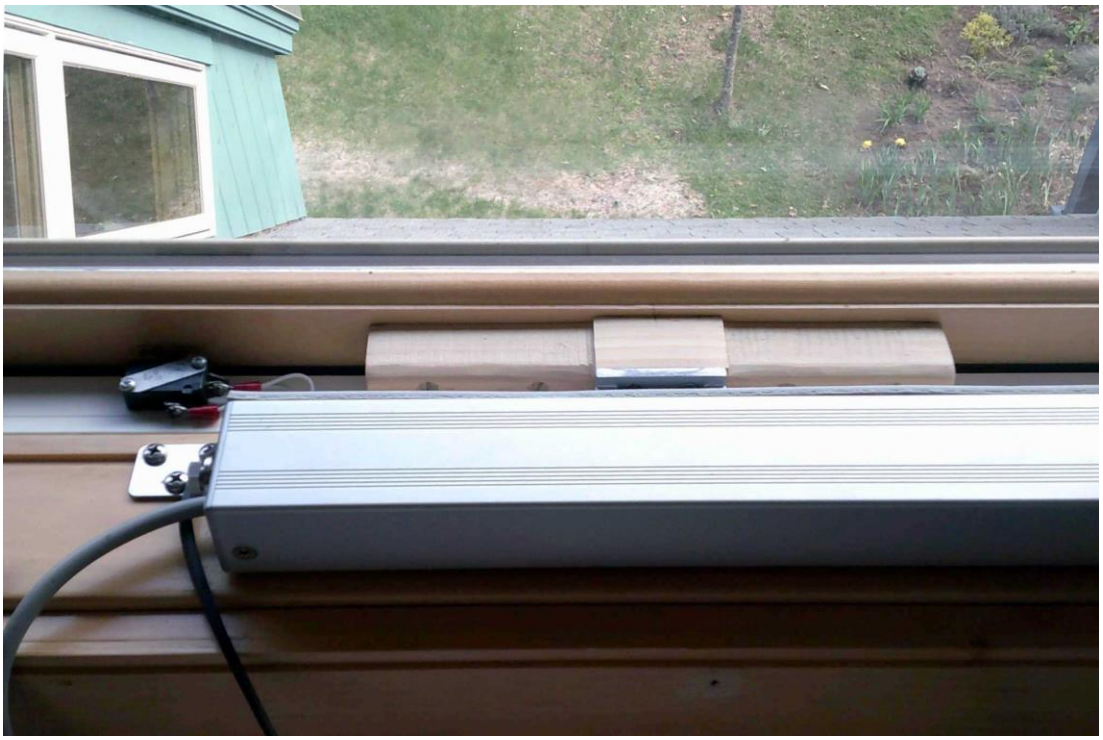
I was worried a controller failure would leave the window stuck in the open position. As insurance I obtaining a small 24V power supply and mounted a spring loaded center off DPDT reversing switch to a bracket. If I ever need to operate the actuator manually I can disconnect it from the controller and use this as a backup. It also came in handy debugging the op amp circuit rather than issuing software commands to the controller.

Installation

The actuator and fans are installed on a Marvin Integrity awning window. The controller was designed to support two windows; so far I have only installed a single window.

The windows have a central operating mechanism and a left and right hand locking levers. I removed the manual operating mechanism and installed the electric actuator. This was fairly difficult as there was very little vertical height available. I removed the bottom trim panel to give me access to the lower jam and the mounting screws for the manual opener. The chain does not exit in the vertical center of the operator so I positioned the chain as close to the lower jam as possible. I positioned the actuator just inside of the lower trim panel and used foam weather stripping to seal the opening to keep bugs out. There was about a one inch gap between the operating window and the chain mounting bracket. I cut a piece of scrap wood to act as a mounting bracket.

To positively detect window open/closed state mounted a roller bearing micro switch to the lower jam.



The chain bracket sticks up rather high so needed to mill out the inside of the lower trim panel to provide clearance.

When I trimmed out the window rabbited the inside trim to accept a clear polycarbonate panel secured with turn fasteners. The four fans are mounted on the outward facing side of the panel with a blade guard on the inside. To minimize noise used EDPM weather stripping between the fan housing and panel. To stiffen the panel screwed an L shaped aluminum extrusion above the fans. A 3-pin Molex connector allows the fan assembly to be easily removed for storage or cleaning.

The TiVo controller chassis sits on a timber below the window.

Theory of Operation

DC power

There are two AC power supplies; a 9V 1A wall wart type supply is used to power the WebControl PLC and a 24V 6.5A supply that powers the actuator and fans. The 9V supply is on constantly. The 24V supply is under software control to reduce system standby power consumption. A small DC/DC buck converter is powered by the 24V supply it provides 5 volt logic power to the relay and H-drive module. A four channel relay board is used to switch the fans. Half the H-bridge and two of the relays are used by each window. A MAX700 reset controller is used to insure the 24V supply is not inadvertently turned on during power up before the PLC has stabilized.

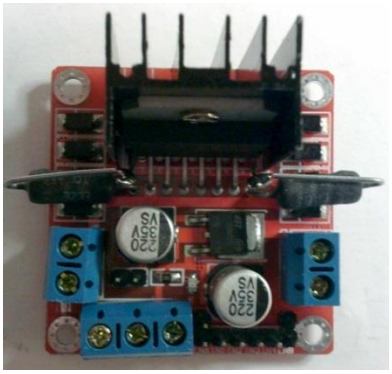
The 24 volt supply has enough capacity to operate two windows with fans set to high speed.

Running the fans at full 24 volts was uncomfortably loud. I added a couple of buck converter, one for each window. Fans now operate at 18 volts. This dramatically reduced noise and power consumption with commensurate reduction in air flow.

Window Actuator Control

UROM registers are used to set the operating mode for each window. They can be set for manual or automatic operation and select fan off/low/high. In automatic operation the PLC uses inside and outside air temperature to automatically open the window when it is warmer inside then out and close the window when that is no longer true.

The key to the entire project is being able to open and close a window under software control. Measuring inside and outside temperature is easy using 1-wire sensors the hard part is controlling the window itself, detecting full open/closed position and problem conditions. The most important error condition is a jam. The actuator can exert up to 20 lbs. of force so getting your fingers caught in the window will be a painful experience.



The window chain drive actuator is a two-wire device, one polarity opens the window, and the other closes it. One half of a dual channel H-bridge is used to control each actuator. The PLC sets direction and enables the H-bridge. I wanted to be able to measure actuator current to detect running condition and jams. The L298 dual driver IC supports measuring load current however the modules I purchased did not implement that feature. Luckily the current sense pins are the outermost pins on the chip so it was easy to unsolder the pins and add a .1 ohm current sense resistor to each channel.

When the actuator powers up there is a momentary surge as the actuator electronics stabilizes and the motor starts. Once the actuator starts it runs to full extension or retraction and then shuts off power to the motor. If the internal actuator controller detects excessive motor current, indicating a jam, it quickly cuts power to the motor.

Jam current is a short event, as the built in actuator microcontroller quickly kills power to the motor. I needed to lengthen the pulse so the PLC analog A/D has enough time to detect it reliably. The .1 ohm current sense resistor develops 100mv per amp of actuator current. A two stage peak detector is used to provide enough time and gain for the PLC to detect the transient event. The first op amp stage has a gain of 20x. The output is stored in a capacitor. The output of the capacitor is buffered by a second op amp with a gain of 2x and feed into the PLC A/D. The op-amps are singled ended powered from the 5V rail. This limits maximum output into the A/D to 3.72v. That is enough to be able to reliably detect current at startup, jam and idle once actuator is fully open or closed.

To unambiguously detect when the window is fully closed I installed a micro switch read by the PLC.

I wanted to PLC algorithm to be able to detect the following conditions:

1) Completion of a normal cycle
2) Locked in closed position
3) Jam while opening or closing
4) No current draw by the actuator
5) Cycle taking too long
6) Window position switch failure

The WINxRUN routine provides low level control of the actuator. The routine sets a watchdog timer, detects lack of current, jam condition and window position switch state. Actuator direction is set outside the routine by CLOSEWx and OPENWx allowing the same routine to open or close the window.

Actuator Result Detection

PLC code detects the following conditions when cycling the window:

1) No current during the first 5 seconds – disconnected actuator
2) Jam current any time later – may or may not be a problem
3) No current during remainder of cycle – normal internal actuator cycle termination
4) Watchdog expired –serious actuator problem
5) State of the window closed switch – detect stuck/failed switch

During the first five seconds of operation code is looking for current draw by the actuator. If it is zero (actually slightly greater to allow for op amp offset voltage error) assumes the actuator has failed or become disconnected. This is performed separately from jam detection to ignore actuator startup current. After the first five seconds a watchdog timer is set and code monitors for: 1) jam current, 2) no current, indicating actuator has reached end of travel and 3) watchdog timeout. When any of these events occur the cycle is terminated and H-bridge motor power it turned off. Then the results are evaluated.

1) In either direction if current is zero during the first five seconds system assumes failed or disconnected actuator.
2) If the watchdog timer has expired operation is taking too long, the result is a fatal fault.

3) In the opening direction if current goes to zero without experiencing a jam condition and the window position switch indicates the window is open all is well and system assumes normal operation.
4) In the opening direction if current goes to zero within the first five seconds, after being nonzero system assumes the window lock has been engaged and window cannot be opened. The actuator is cycled to the close position for a few seconds to relieve any stress on the window.
5) In the opening direction if a jam is detected after the first five seconds assumes something is interfering with outward direction of window. This may or may not be recoverable.
6) In the opening direction if current goes to zero without experiencing a jam and the window position switched indicates the window is closed system assumes the window switch has failed.
7) In the closing direction if current goes to zero and the window switch indicates closed system assumes normal operation. This is where the original sloppy sensing range of the magnetic sensor caused a problem, there could be something jammed in the window and the switch would still indicate closed.
8) In the closing direction if current goes to zero and the close switch is still open system assumes something is jammed preventing window from fully closing. It immediately reverses direction for a few seconds to free the jam. This may or may not be recoverable.

At the end of the cycle the appropriate condition code is set in VAR 1 or 2 and an email set if other than successful completion. If the problem is a jam during opening or closing the system tries to recover. Window is repositioned back to the start position and operation retried. If a jam is detected a second time another email is sent that the system has encountered a fatal error.

Fan Control

If the open operation is successful and UROM value is set for high or low fan operation the fans are turned on. If UROM set for low a pseudo random algorithm is used to select which pair of fans to turn to equalize run time.

Temperature Control

1-wire sensors measure inside and outside temperature. Each window can be programmed for automatic or manual operation. UROM3 sets the minimum outside temperature the windows will operate and UROM4 the inside temperature. Assuming inside and outside temperature is warm enough when inside air temperature (UROM4) exceeds outside temperature by 1 degree the window is opened and if enabled the fans turned on. When inside temperature is equal or lower than outside the fans are turned off and the window closed. Window is also closed in case of rain or if outside (UROM3) or inside (UROM4) temp falls too low.

Rain Sensing

A rain sensor can be used to override normal operation and force the window closed during a rain storm. Currently this feature is implemented in code but I have not installed a rain sensor since the windows are pretty well protected from the effects of rain storms.

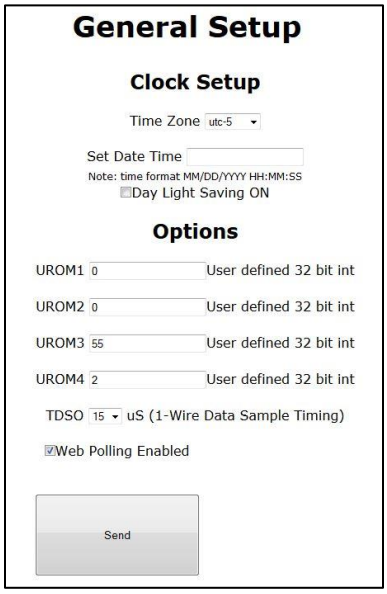
System Health Reporting

At power up and whenever the 24 volt power supply is on A/D channel 3 is used to measure the output of the 5 volt DC/DC buck converter. If it is nominal system assumes all is fine with the 24V and 5V supply. The maximum input to the A/D is 10 volts. The nominal 5V output of the buck converter is feed into a voltage divider before being applied to the A/D to protect it in case the converter fails and passes full 24V. If supply is bad an email is sent.

The PLC has a status flag associated with each temperature channel. If a sensor is reported as bad code waits 3 seconds and tests again. If sensor is still bad an email is sent. If sensor goes back to normal operation the temperature error is reset allowing normal operation to resume. A single email is sent per event.

If a power supply fails or there is a non-recoverable error of either window 1 or 2 the error requires a reboot to clear. Temperature sensor error is cleared automatically if the PLC reports good sensor state. The PLC does not have an explicit way to reboot. However updating network settings causes the PLC to reinitialize or power can be cycled locally.

Email Alerts



The controller has 4 web settable values. This is a convenient way to tune system operation without having to reload PLC code.

1. UROM1 sets Window 1 operating mode
2. UROM2 sets Window 2 operating mode
3. UROM3 set minimum outdoor temperature
4. UROM4 set minimum indoor temperature

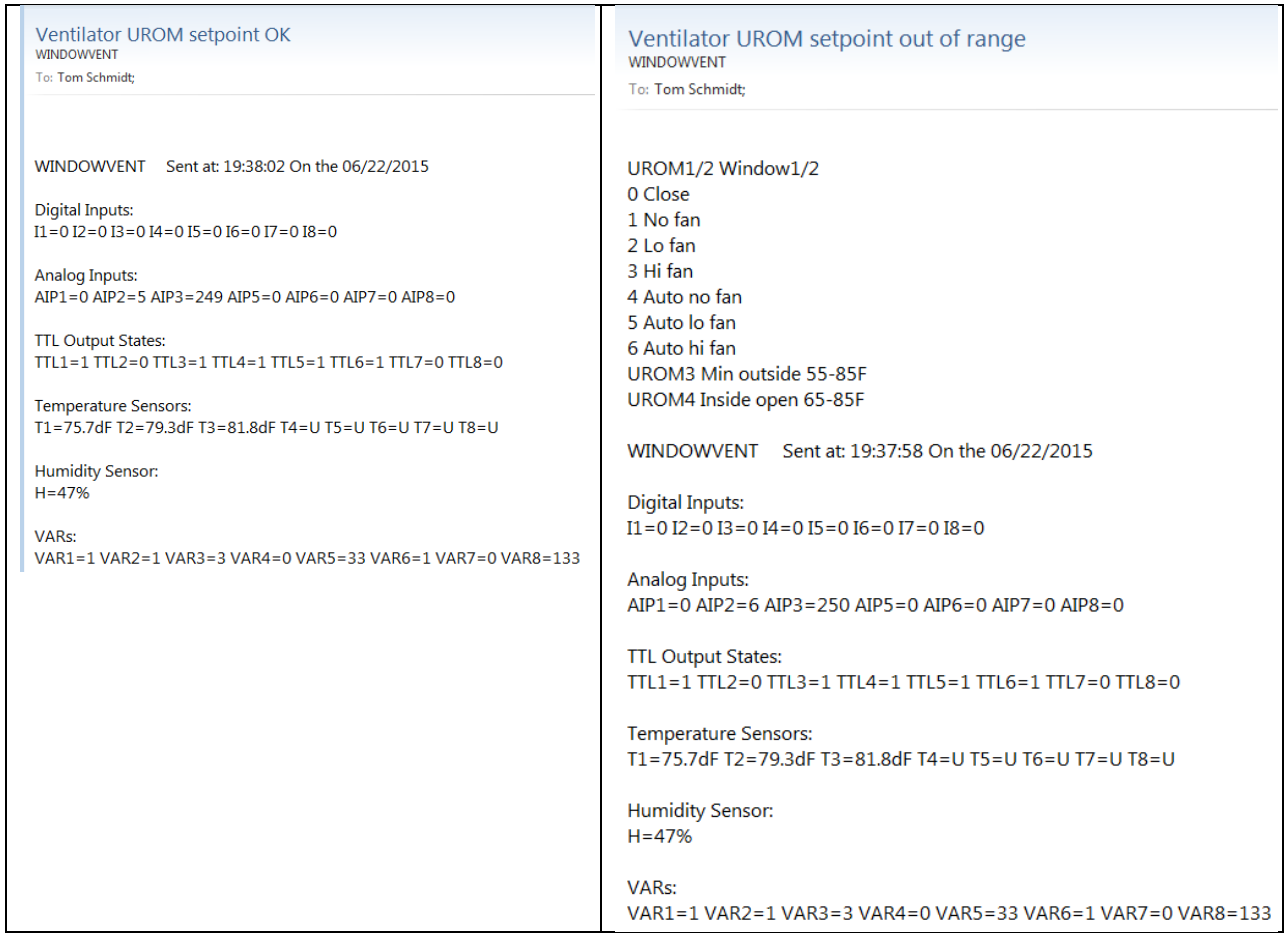
This page also sets time zone for the internal RTC.

If web polling is checked the displayed page is continuously refreshed.

If 1-wire cable is long the TDSO parameter can be used to adjust sample timing.

Configuration Change

Unfortunately title and units of measure are not end-user configurable. To make setting values more user friendly at power up and each time any of the UROMx settings are changed the parameter checker is invoked. An email is sent at power up if any are out of range and each time a value is changed. The email indicates if values are correct and information about the correct range and units. WebControl has limited nonvolatile storage so UROM range information is only sent if system is configured incorrectly.



Ventilator UROM setpoint OK
WINDOWVENT
To: Tom Schmidt;

WINDOWVENT Sent at: 19:38:02 On the 06/22/2015

Digital Inputs:
I1=0 I2=0 I3=0 I4=0 I5=0 I6=0 I7=0 I8=0

Analog Inputs:
AIP1=0 AIP2=5 AIP3=249 AIP5=0 AIP6=0 AIP7=0 AIP8=0

TTL Output States:
TTL1=1 TTL2=0 TTL3=1 TTL4=1 TTL5=1 TTL6=1 TTL7=0 TTL8=0

Temperature Sensors:
T1=75.7dF T2=79.3dF T3=81.8dF T4=U T5=U T6=U T7=U T8=U

Humidity Sensor:
H=47%

VARs:
VAR1=1 VAR2=1 VAR3=3 VAR4=0 VAR5=33 VAR6=1 VAR7=0 VAR8=133

Ventilator UROM setpoint out of range
WINDOWVENT
To: Tom Schmidt;

UROM1/2 Window1/2
0 Close
1 No fan
2 Lo fan
3 Hi fan
4 Auto no fan
5 Auto lo fan
6 Auto hi fan
UROM3 Min outside 55-85F
UROM4 Inside open 65-85F

WINDOWVENT Sent at: 19:37:58 On the 06/22/2015

Digital Inputs:
I1=0 I2=0 I3=0 I4=0 I5=0 I6=0 I7=0 I8=0

Analog Inputs:
AIP1=0 AIP2=6 AIP3=250 AIP5=0 AIP6=0 AIP7=0 AIP8=0

TTL Output States:
TTL1=1 TTL2=0 TTL3=1 TTL4=1 TTL5=1 TTL6=1 TTL7=0 TTL8=0

Temperature Sensors:
T1=75.7dF T2=79.3dF T3=81.8dF T4=U T5=U T6=U T7=U T8=U

Humidity Sensor:
H=47%

VARs:
VAR1=1 VAR2=1 VAR3=3 VAR4=0 VAR5=33 VAR6=1 VAR7=0 VAR8=133

System Fault

As mentioned previously if there is a system or window hardware failure an email is generated that include a list of failure codes.

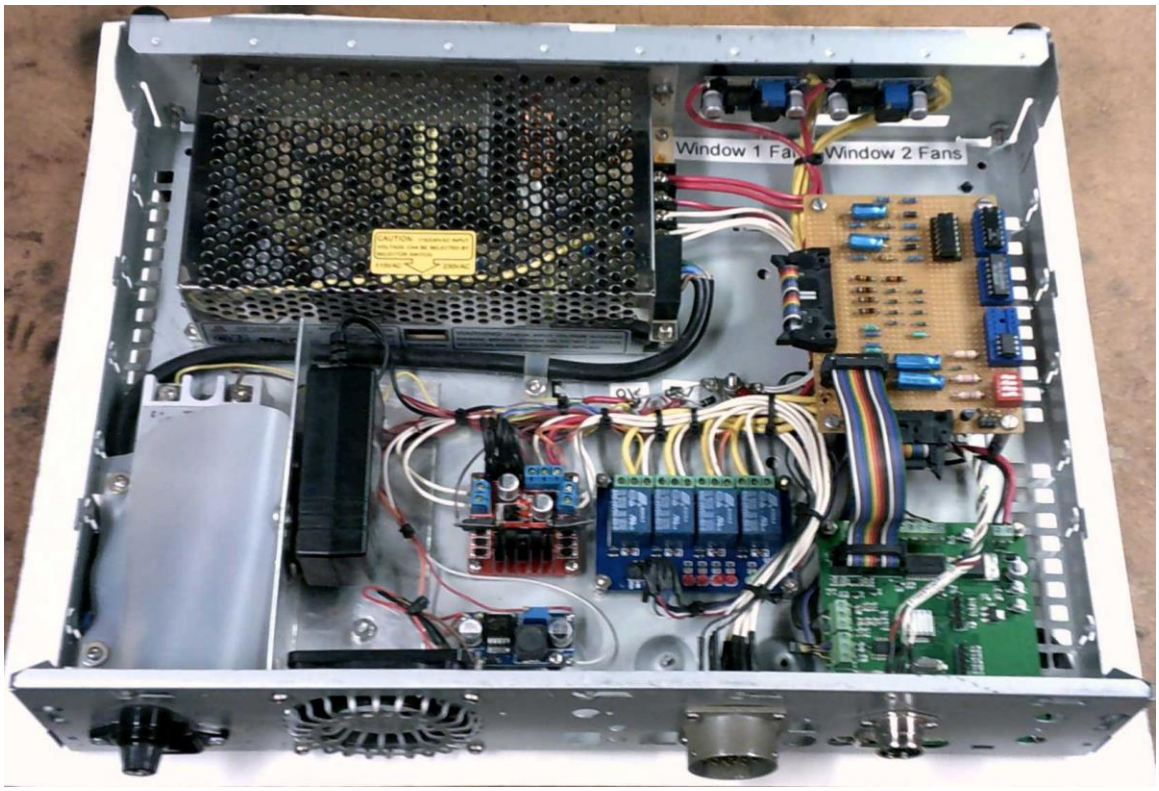
Window Open/Close email

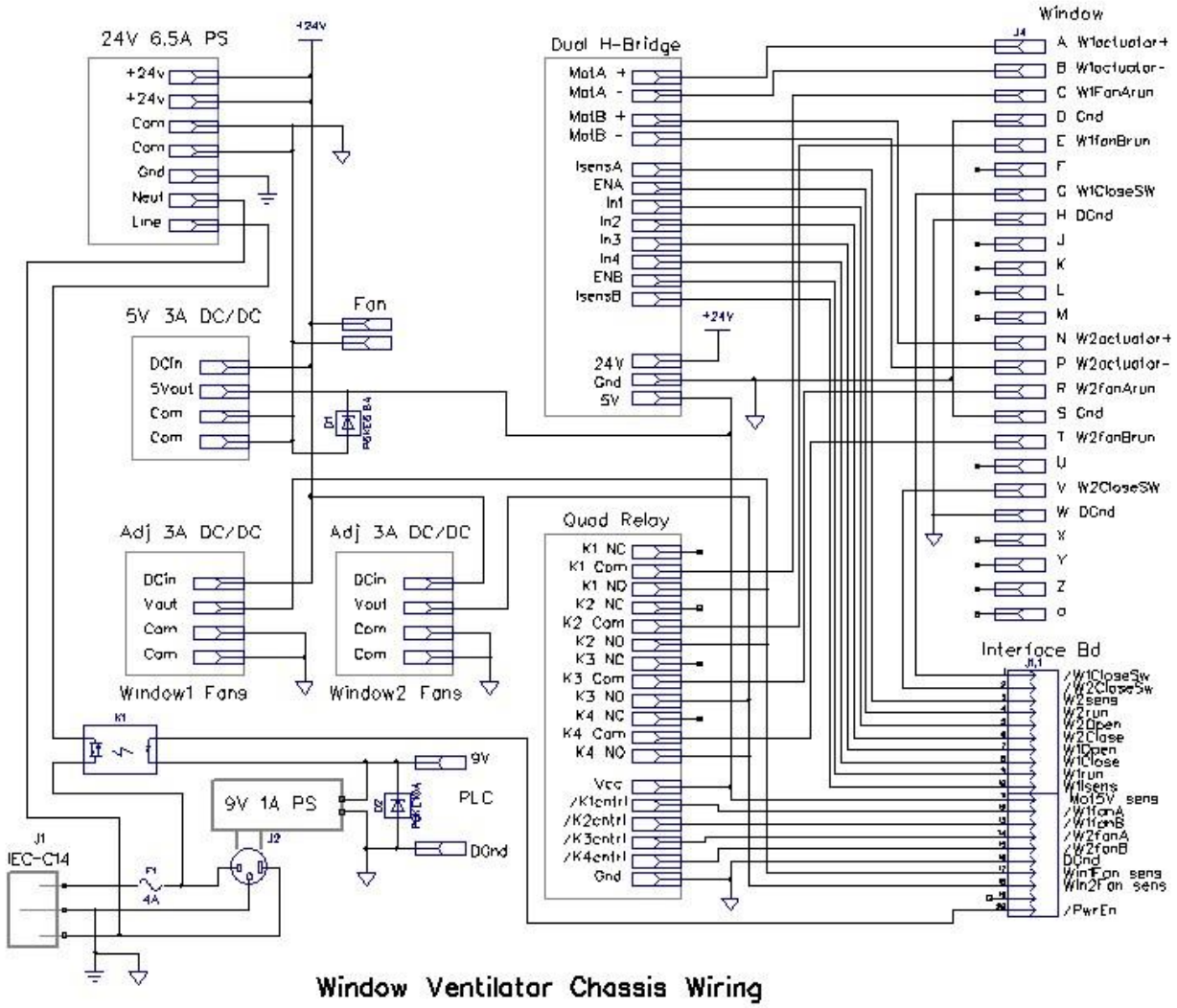
I originally added debug code to send an email whenever the window is open or closed. It turned out to be pretty useful so I left it in.

Appendix A – Schematic

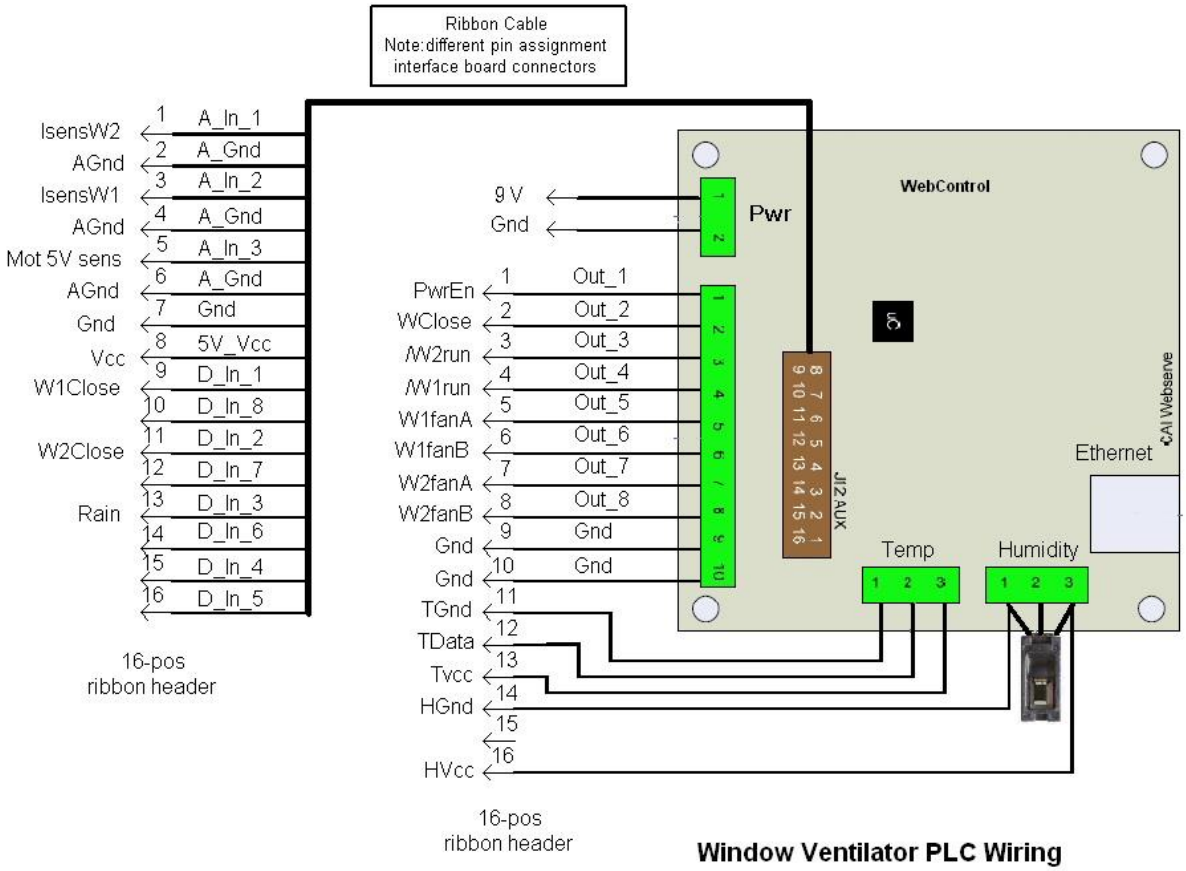
Like many of my other home automation projects I used an old TiVo Series 2 chassis to house the electronics. A small 24V fan replaced the original 12V TiVo fan to provide cooling whenever the 24V supply is turned on.

The controller is positioned vertically under the window on what was the front of the TiVo. The plastic TiVo bezel was removed and I attached four rubber feet to that side of the chassis.

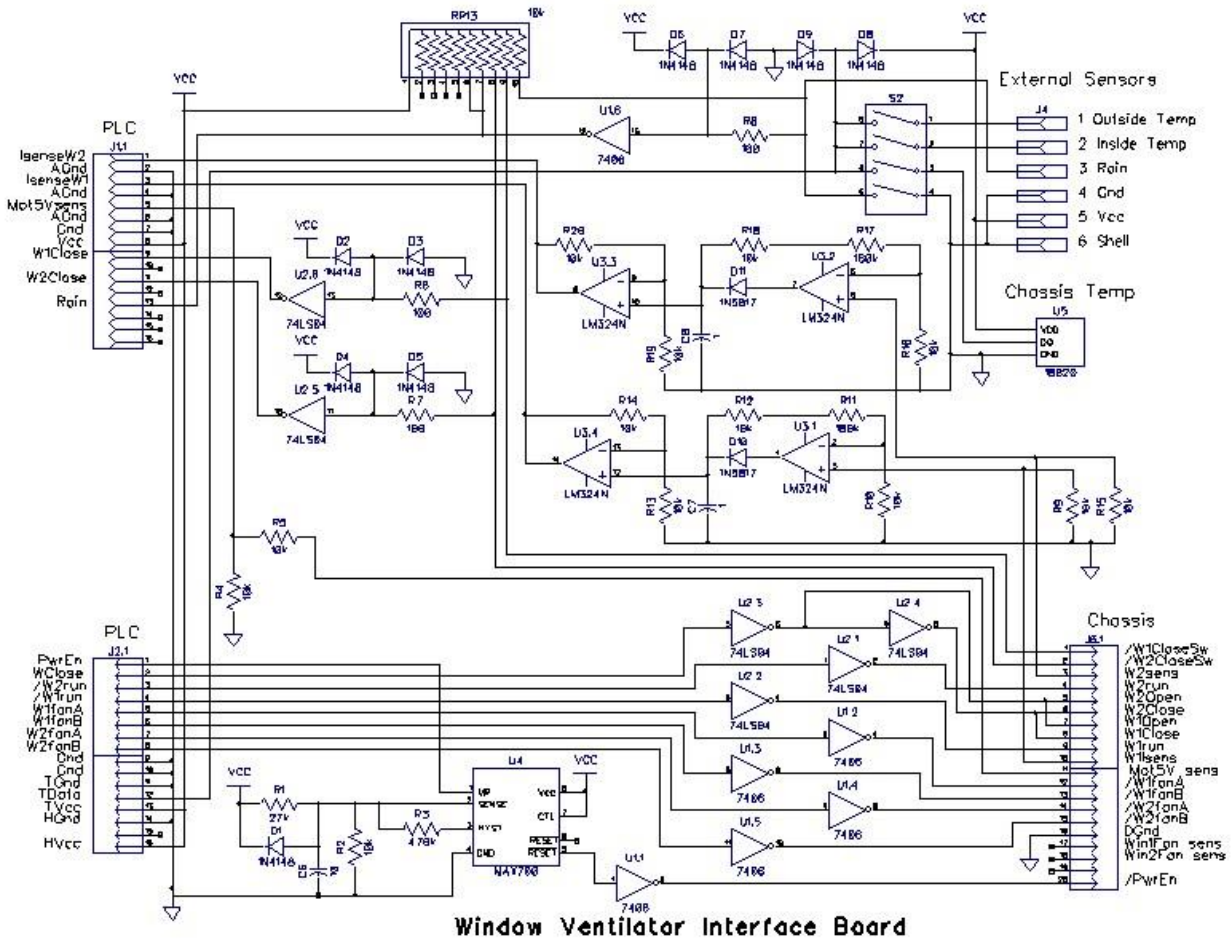




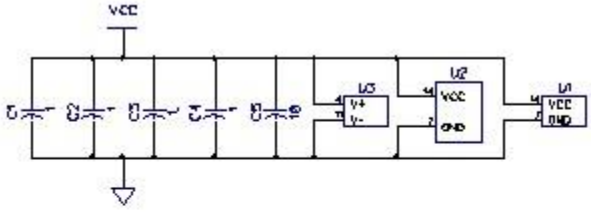
Window Ventilator Chassis Wiring



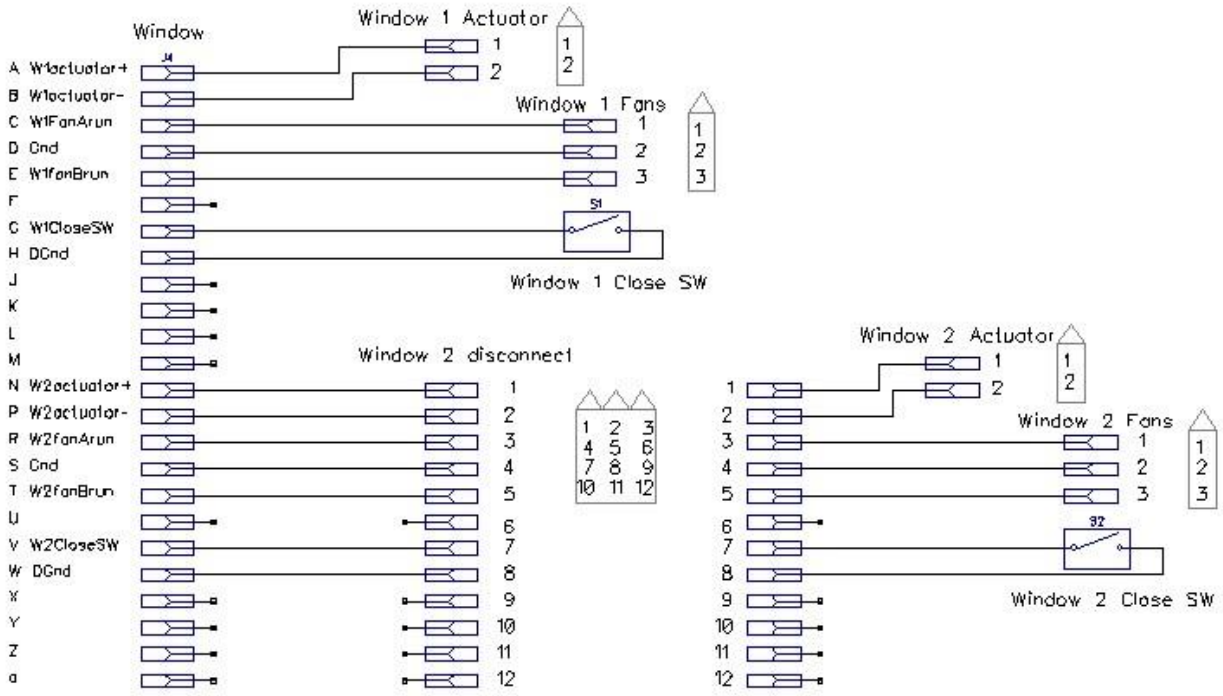
Window Ventilator PLC Wiring



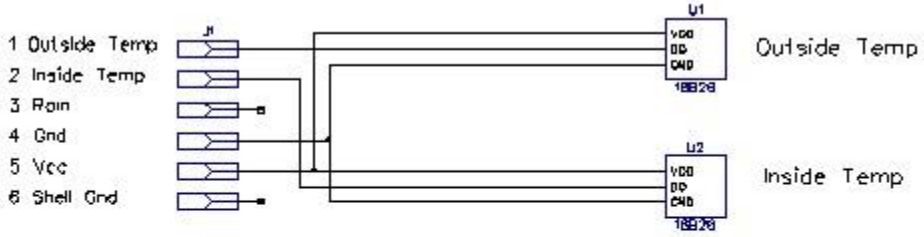
Window Ventilator Interface Board



Window Ventilator Interface Board - Spares



Window Ventilator - Actuator/Fan Cable



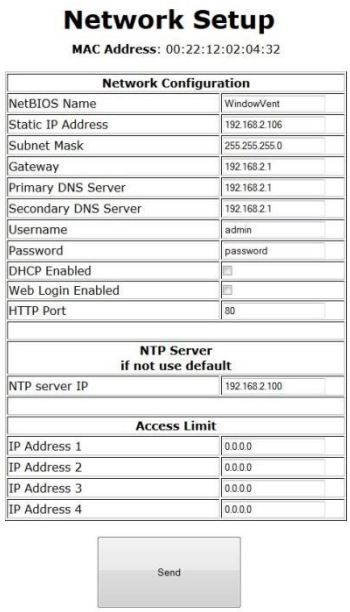
Note: Rain sensor not installed.

Window Ventilator - Temperature Sensors

Appendix B – WebControl Configuration Pages

There are several web based configuration pages that determine system operation.

Network Setup



Network Setup

MAC Address: 00:22:12:02:04:32

Network Configuration	
NetBIOS Name	WindowVent
Static IP Address	192.168.2.106
Subnet Mask	255.255.255.0
Gateway	192.168.2.1
Primary DNS Server	192.168.2.1
Secondary DNS Server	192.168.2.1
Username	admin
Password	password
DHCP Enabled	☐
Web Login Enabled	☐
HTTP Port	80
NTP Server if not use default	
NTP server IP	192.168.2.100
Access Limit	
IP Address 1	0.0.0.0
IP Address 2	0.0.0.0
IP Address 3	0.0.0.0
IP Address 4	0.0.0.0

Send

This page selects DHCP or static configuration. It also allows setting the NetBIOS name. Web access to the controller can be unrestricted or require username/password login.

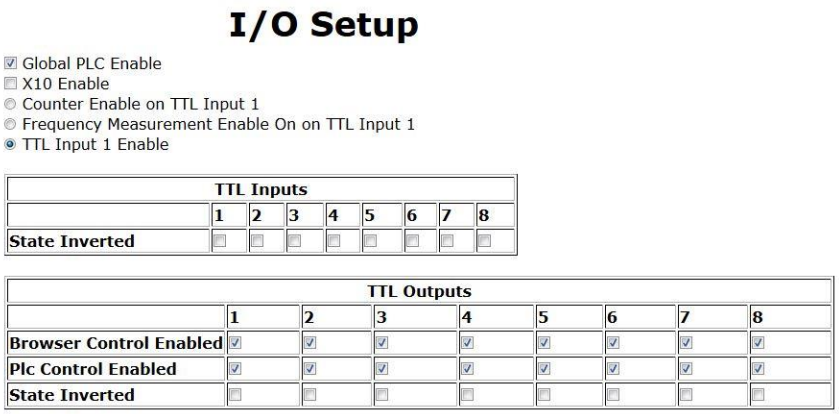
WebControl time can be set automatically via NTP or manually. The controller does not have a built in battery backed real time clock, time must be set each time controller is powered up or it is set to firmware default date/time. I run my own LAN based NTP time server so point the controller at that time server rather than one on the Internet.

Pressing “Send” updates network settings and reboots the PLC. This is a handy way to reset the PLC remotely even when not making any changes to network settings.

I/O Setup

Individual outputs can be configured to allow PLC control and direct browser control. In most cases PLC code will eventually force the output to correct value even if web browser attempts to set or reset it. For critical outputs the browser interface can be disabled.

The active polarity of the outputs is set from this page.



I/O Setup

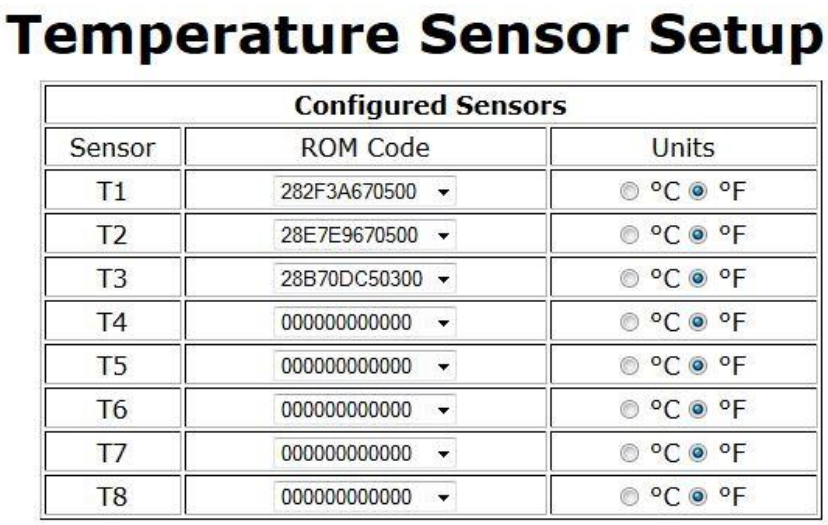
☑ Global PLC Enable
☐ X10 Enable
○ Counter Enable on TTL Input 1
○ Frequency Measurement Enable On on TTL Input 1
◉ TTL Input 1 Enable

TTL Inputs								
	1	2	3	4	5	6	7	8
State Inverted	☐	☐	☐	☐	☐	☐	☐	☐

TTL Outputs								
	1	2	3	4	5	6	7	8
Browser Control Enabled	☑	☑	☑	☑	☑	☑	☑	☑
Plc Control Enabled	☑	☑	☑	☑	☑	☑	☑	☑
State Inverted	☐	☐	☐	☐	☐	☐	☐	☐

Temperature Sensor Setup

18B20 1-wire temperature sensors are individually serialized. The controller detects attached temperature sensors at power up but they must be manually assigned to a particular sensor ID and units of measure specified.



Notify Setup

Email can be set up to use any TCP/IP port but the unit does not support SSL. In addition to email this page also configures HTTP GETs (not used in this example).

Up to eight email messages may be configured and each may be sent to a different email address. In addition to the user defined subject line and message body System Status page information is automatically appended.

I noticed a problem setting message body text with some web browsers (Firefox, chrome, IE10) the second character of each line after the first is lost. Setting message body works fine using IE8.

EMAIL Messages

Message ID	To Address	Message Subject	Message Body	
EM1	tom@tschmidt.com	Ventilator Powerup		Test
EM2				Test
EM3	tom@tschmidt.com	Ventilator Fail	VAR1 System 1 Normal 2 PS fail 3 Temp fail VAR2/3 Window1/2	Test
EM4	tom@tschmidt.com	Ventilator UROM setpoint out of range	UROM1/2 Window1/2 0 Close 1 No fan 2 Lo fan 3 Hi fan	Test
EM5	tom@tschmidt.com	Ventilator UROM setpoint OK		Test
EM6				Test
EM7	tom@tschmidt.com	Ventilator Close		Test
EM8	tom@tschmidt.com	Ventilator Open		Test

Appendix C – WebControl PLC Code

Window Ventilator Controller
T. Schmidt

********** Change Log **********

6/15/2015 Reduced opening hysteresis to 1F in auto mode to speed up window opening at night. South facing outside temp sensor takes a long time too cool off.

5/30/2015 Installed pair of adjustable DC/DC buck converters, one for each window. Running fans at lower voltage (18V) dramatically reduced noise. Fan power consumption reduced to about 1/3 compared 24v, 6w vs 18W, with commensurate reduction of CFM. Voltage change is transparent to software.

Solved problem of bad info in email notifications. Reduce size of total email ASCII so text does not get cut off. This solved the problem of corrupt output and temp data. Curiously WC saved the extra data and did not complain about the size but it must have corrupted something internally.

5/23/2015 Added Hysteresis to manual mode to prevent short cycling if inside or outside temp is near minimum. Added delay for fan high mode to turn on each pair separately to reduce current surge.

5/22/2015 Fan were pretty loud. Used EDPM weather stripping to create a resilient mount between polycarbonate panel and fan body. Added aluminum angle stiffener above the four fans. Fans still fairly loud but drumming sound has been eliminated.

5/13/2015 Window actuator and fans installed. Added debug code to send email each time window opens or closes. Firmware appears to be operating properly, time will tell.

Window flexes if attempt to open when locked. Added code to reclose window against stop if locked to reduce stress on glass.

5/10/2015 Changed automatic mode. UROM3 sets min outside temp (T1 same as

before) UROM4 sets inside threshold temp. When outside (T1) and inside (T2) are 2F higher than UROM setpoints and inside exceeds outside by 2F window opens. When inside equal/less than outside or outside too low window closed.

In manual mode inside/outside temp tested for hard coded min UROM3/4 values to force close. High temp not verified.

2/7/2015 Taped over PLC heartbeat LED, flashing was distracting at night. Deleted soft reset code, easier to just hit Network update. Added dummy Window 2 code to set VAR3 to no current.

1/28/2015 Mag reed closed position switch sensing too sloppy - replaced with microswitch.

1/25/2015 Rewrote open/close code to take advantage of new actuator current sensing.

9/4/2014 Changed OP amp to peak detector, increased gain to 40x from 10. Actuator jam shuts down too quickly for WC to detect peak current spike.

3/20/2014 Added pinch recovery

3/17/2014 Added actuator code

3/5/2014 Code complete for Window 1 except control of window actuator. Waiting on delivery.

3/3/2014 Built dummy window test jig for code development.

2/28/2014 Code start

2/28/2014 Hardware complete

1/6/2014 Project start

********** PCB Hardware/Firmware version **********

Hardware: 2.2.2
Firmware: 3.2.17d

Customer loop executed every ~50ms (minimal test code) 65ms-ish (real code)

VAR and RAM initialized to 0 by system at power up
To reset PLC to power up state - update network settings (Send)
RAM location reset to 0 on code upload, VAR not affected
WebControl takes about 400ms to init I/O at power up
Per CAI Support Temp sensors take up to 2 sec to stabilize at power up
Email takes about 1.5 sec to send, no timeout if SMTP server does not respond
TTL inputs have 10k pulldown
Output buffers 10mA per output, 30mA total
A/D 10V full scale 10-bits

9V Power consumption (PS 9V @1A)

175ma PLC only (Live Ethernet serving web page)
215ma PLC and interface board
14ma 24v power control SSR

24V Power consumption (PS 24V @6.5A)

Idle
22ma Idle - DC/DC down converter, H-bridge, relay logic, chassis fan (low speed) actuator and window fans off.

Fan current draw
620ma Rotron fan @24V 240CFM
780ma Papst fan @24V 240CFM
345ma Papst fan @18V

Actuator run time (unloaded)
27 seconds open
27 seconds close

Actuator run time (installed)
33 seconds open
33 seconds close

Open
80-100ma Start surge (very short)
90ma Run
90ma End of travel peak
>365ma Jam surge (very short)
10ma Full open idle current

Close

80-100ma Start surge (very short)
80ma Run
>421ma End of travel peak
>470ma Jam surge (very short)
10ma Full close idle current

Actuator A/D current sensing
.1 ohm Isens 100mv per amp
Opamp 40x gain (20x peak det, 2X buffer)
Single ended 5V
Peak detector saturates at 3.72V output into WC A/D

<.360v No connection (worst case 9mv offset 40x gain) (155mv typ)
>1.500v Open/close jam

Temperature rise
Ambient temp 72F, chassis vertical orientation, 24V off
24V PS heatsink 73F
Interface board 77F

Ambient temp 72F, chassis vertical orientation, 4 fans running
24V PS heatsink 87F
Interface board 75F

********** I/O Defs **********

Analog Inputs

AIP1 - Window 2 I sense (4V per amp, saturates at 3.7V)
AIP2 - Window 1 I sense (4V per amp, saturates at 3.7V)
AIP3 - 1/2 5 volt motor supply sense

Digital Inputs

IP1 - Window 1 close sw
IP2 - Window 2 close sw
IP3 - Rain Sensor (not installed)
IP4 -
IP5 -
IP6 -
IP7 -
IP8 -

Digital Outputs

OP1 - 24v power supply enable
OP2 - Window actuator close direction (high to close)
OP3 - /Window 2 actuator run
OP4 - /Window 1 actuator run
OP5 - Window 1 Fan group A
OP6 - Window 1 Fan group B
OP7 - Window 2 Fan group A
OP8 - Window 2 Fan group B

Temperature Sensors

T1 - Outside
T2 - Inside
T3 - Chassis
T4 - Not used
T5 - Not used
T6 - Not used
T7 - Not Used
T8 - Not used

Temp Sensor status (1 = OK)

TS1
TS2
TS3
TS4
TS5
TS6
TS7
TS8

Humidity Sensor

H1 - Display only

Email message Identifiers

EM1 - Wakeup email at power up
EM2 -

EM3 - System Fault status code in VAR1 or VAR2/3 if actuator fault
EM4 - UROM setpoint out range
EM5 - UROM setpoint OK
EM6 -
EM7 - Window Close
EM8 - Window Open

Variables

VAR1 - System Status:
0=Power up
1=Normal operation
2=24volt or 5volt motor power supply failure
3=Temp sensor fail

Temp sensor fail cleared automatically on status OK, other faults reboot.

VAR2 - Window 1 most recent open/close cycle status code
0= Nop
1= Successful operation
2= Jam - window recycled to start position
3= No actuator current
4= Window closed switch failure
5= Window locked (Open cycle only)
6= Unable to recover from jam
7= Operation took too long watchdog expired

VAR3 - Window 2 most recent open/close cycle status code (not installed)
0= Nop
1= Successful operation
2= Jam - window recycled to start position
3= No actuator current
4= Window closed switch failure
5= Window locked (Open cycle only)
6= Unable to recover from jam
7= Operation took too long watchdog expired
VAR4 -
VAR5 - Elapsed seconds counter during open/close cycle
VAR6 - actuator operating current
0 = no current
1 = normal run current
2 = Jam current

VAR7 - HWfail email sent flag, 0 normal, 1 email has been sent.
VAR8 - Sum of current UROM values

RAM

RAM1 - Scratch
RAM2 - UROM1/2 state cache during operation
RAM3 -
RAM4 -
RAM5 -
RAM6 -
RAM7 -
RAM8 - Actuator duty cycle flag, forces a 30 idle delay after use.

Web Settings

UROM1 - Window 1 mode
0=close window
1=open no fan
2=open low fan
3=open hi fan
4=auto no fan
5=auto low fan
6=auto hi fan
UROM2 - Window 2 mode (same as window 1)
UROM3 - Minimum outside temp in auto mode to open (55-85F)
UROM4 - Inside temp open setpoint in auto mode (65-85F)

********** Modules **********
PUINIT
Power up init, sets default reg values and cycles 24volt supply for go/nogo test. 1/2 5V DC/DC down converter voltage measured by A/D. If that is OK both it and 24v supply assumed to be OK. TVS limits fault voltage to <10V to protect analog front end.

TSENSOR
Verifies T1-3 temp status flag. If fail delay 3seconds and try again. If bad set VAR1 status to 3 indicating temp sensor failure. This is the only error that clears itself automatically, all others need reboot.

UROMCHG
Sums all four UROM registers to detect change. When change occurs RANGECHK

verifies each value in range. Email sent whenever UROM value is changed and also at power up if any are out of out of range. Change detection is a simply a summation, will miss event if two values changed in same but opposite values.

WINDOWx

Determines open/close operating mode for each window. Rain forces window closed. In manual mode window closed if inside/outside temperature drops mim acceptable UROM values.

CLOSEWx

Turns fans off at start of cycle.

High level routine to close window, WINxRUN does the heavy lifting in both directions. If WINxRUN reports jam attempts to recover, does open, than close. Updates VAR2/3 with status. During any error event EM3 sent. If unable to recover from jam second EM3 sent with VAR2/3 status of 6.

OPENWx

Same as CLOSEWx except if jam, attempts to close, then open and close.

If cycle successful calls WINxFANS. If UROMx set to high both fans turned on. If fans set to low current seconds since 1/1/2000 (CTS) used as pseudo random number to toggle which pair of fans to turn on.

WINxRUN

Direction set by CLOSEWx/OPENWx. Time synchronized to current second, this delays operation up to a minute but since this is normally an automatic operation not a big deal. During first 5 seconds of operation verifies actuator is running, sets VAR6 1. After 5 seconds, 1) detects jam, high current sets VAR6 2, 2) Detects end of actuator travel, low current or 3) excessive cycle time, watch dog timeout.

At end of cycle evaluates: run time, current detection, and window switch position to set VAR2/3 completion status. If locked in open direction reverses direction to reseat window in fully closed position to reduce glass stress due to jam flexing. If close jam detected immediately runs actuator in open direction for a few seconds to remove pressure on obstruction.

PWRCHK

If none of the fans are turned on switches 24 volt supply off to save power.

If 24V supply is on voltage verified. Powerchk enforces a 30 second delay to insure actuator duty cycle limit is not exceeded.

HWFAIL

If VAR1 is other than normal (1) hardware fail email sent. VAR7 is flag used to send a single email. If temp sensors fail and recover VAR7 flag reset automatically. All other errors require hardware reboot.

********** Code **********

```
START
        CALLSUB     PUINIT
        CALLSUB     TSENSOR
        CALLSUB     UROMCHG
        CALLSUB     WINDOW1
        CALLSUB     WINDOW2
        CALLSUB     PWRCHK
        CALLSUB     HWFAIL
END

PUINIT:
        TSTNE       VAR1 0
        RET

        EMAIL       EM1
        SET         OP2 1
        SET         OP3 1
        SET         OP4 1
        SET         OP5 0
        SET         OP6 0
        SET         OP7 0
        SET         OP8 0
        SET         VAR1 1
        SET         VAR2 0
        SET         VAR3 0
        SET         VAR7 0
        SET         VAR8 UROM1
        ADD         UROM2 VAR8 VAR8
        ADD         UROM3 VAR8 VAR8
        ADD         UROM4 VAR8 VAR8
        CALLSUB     RANGECHK
        BZ          RANGEOK
```

```
        EMAIL       EM4
RANGEOK:
        SET         OP1 1
        DELAY       3000
        CALLSUB     VOLTCHK
        SET         OP2 1
        CALLSUB     WIN1RUN
        CALLSUB     WIN2RUN
        SET         OP1 0
        RET

TSENSOR:
        TSTEQ       VAR1 2
        RET

        AND         TS1 TS2 RAM1
        AND         TS3 RAM1 RAM1
        BZ          BADSENSOR
GOODTEMP:
        TSTNE       VAR1 3
        RET

        SET         VAR1 1
        SET         VAR7 0
        RET

BADSENSOR:
        DELAY       3000
        AND         TS1 TS2 RAM1
        AND         TS3 RAM1 RAM1
        BNZ         GOODTEMP
        SET         VAR1 3
        RET

UROMCHG:
        SET         RAM1 UROM1
        ADD         UROM2 RAM1 RAM1
        ADD         UROM3 RAM1 RAM1
        ADD         UROM4 RAM1 RAM1
        TSTEQ       RAM1 VAR8
        RET
```

```
        SET         VAR8 RAM1
        CALLSUB     CLOSEW1
        CALLSUB     CLOSEW2
        CALLSUB     RANGECHK
        BZ          UROMOK
        EMAIL       EM4
        RET

UROMOK:
        EMAIL       EM5
        RET

RANGECHK:
        TSTLT       UROM1 0
        RET
        TSTGT       UROM1 6
        RET
        TSTLT       UROM2 0
        RET
        TSTGT       UROM2 6
        RET
        TSTLT       UROM3 55
        RET
        TSTGT       UROM3 85
        RET
        TSTLT       UROM4 65
        RET
        TSTGT       UROM4 85
        RET
        RET

WINDOW1:
        TSTNE       VAR1 1
        RET

        TSTEQ       IP3 1
        GOTO        CLOSEW1
        TSTLT       T1 550
        GOTO        CLOSEW1
        TSTLT       T2 650
        GOTO        CLOSEW1
        SET         RAM2 UROM1
```

```
        TSTGT   RAM2 6
        GOTO    CLOSEW1
        TSTEQ   RAM2 0
        GOTO    CLOSEW1
        TSTGT   RAM2 3
        GOTO    WINDOW1A
        TSTLE   T1 570
        RET

        TSTLE   T2 670
        RET

        GOTO    OPENW1

WINDOW1A:
        MUL     UROM3 10 RAM1
        TSTLT   T1 RAM1
        GOTO    CLOSEW1
        MUL     UROM4 10 RAM1
        TSTLT   T2 RAM1
        GOTO    CLOSEW1
        TSTLE   T2 T1
        GOTO    CLOSEW1
        ADD     UROM3 1 RAM1
        MUL     RAM1 10 RAM1
        TSTLT   T1 RAM1
        RET

        ADD     UROM4 1 RAM1
        MUL     RAM1 10 RAM1
        TSTLT   T2 RAM1
        RET

        ADD     T1 10 RAM1
        TSTGT   T2 RAM1
        GOTO    OPENW1
        RET

CLOSEW1:
        SET     OP5 0
        SET     OP6 0
        TSTGT   VAR2 1
```

```
        RET

        TSTEQ       IP1 1
        RET

        EMAIL       EM7
        DELAY       3000
        SET         VAR2 0
        SET         OP2 1
        CALLSUB     WIN1RUN
        TSTLE       VAR2 1
        RET

        EMAIL       EM3
        DELAY       3000
        TSTNE       VAR2 2
        RET
        SET         OP2 0
        CALLSUB     WIN1RUN
        TSTGT       VAR2 1
        RET

        SET         OP2 1
        CALLSUB     WIN1RUN
        TSTLE       VAR2 1
        RET

        SET         VAR2 6
        EMAIL       EM3
        DELAY       3000
        RET

OPENW1:
        TSTGT       VAR2 1
        RET

        TSTEQ       IP1 0
        RET

        EMAIL       EM8
        DELAY       3000
        SET         VAR2 0
```

```
        SET         OP2 0
        CALLSUB     WIN1RUN
        TSTLE       VAR2 1
        GOTO        WIN1FANS
        EMAIL       EM3
        DELAY       3000
        TSTNE       VAR2 2
        RET

        SET         OP2 1
        CALLSUB     WIN1RUN
        TSTGT       VAR2 1
        RET

        SET         OP2 0
        CALLSUB     WIN1RUN
        TSTLE       VAR2 1
        GOTO        WIN1FANS
        SET         OP2 1
        CALLSUB     WIN1RUN
        SET         VAR2 6
        DELAY       3000
        EMAIL       EM3
        RET

WIN1RUN:
        SET         OP1 1
        SET         RAM8 1
        SET         VAR6 0
        SET         VAR5 1
WIN1SYNC:
        TSTNE       CS 0
        GOTO        WIN1SYNC
        SET         OP4 0
        DELAY       100
WIN1BGN:
        TSTGT       AIP2 20
        SET         VAR6 1
        TSTNE       CS VAR5
        GOTO        WIN1BGN
        INC         VAR5
        TSTLT       VAR5 5
```

```
        GOTO        WIN1BGN
WIN1OPR:
        TSTGT       AIP2 150
        SET         VAR6 2
        TSTEQ       VAR6 2
        GOTO        WIN1DONE
        TSTLT       AIP2 20
        GOTO        WIN1DONE
        TSTNE       CS VAR5
        GOTO        WIN1OPR
        INC         VAR5
        TSTLT       VAR5 45
        GOTO        WIN1OPR
WIN1DONE:
        SET         OP4 1
        SET         VAR2 3
        TSTEQ       VAR6 0
        RET

        SET         VAR2 7
        TSTEQ       VAR5 45
        RET

        TSTEQ       OP2 0
        GOTO        WIN1OPEN
        SET         VAR2 1
        TSTEQ       IP1 1
        RET

        SET         OP2 0
        SET         OP4 0
        DELAY       3000
        SET         OP4 1
        SET         VAR2 2
        RET

WIN1OPEN:
        SET         VAR2 5
        TSTEQ       VAR5 5
        GOTO        WIN1LOCK

        SET         VAR2 2
```

```
        TSTEQ       VAR6 2
        RET

        SET         VAR2 1
        TSTEQ       IP1 0
        RET

        SET         VAR2 4
        RET

WIN1LOCK:
        SET         OP2 1
        SET         OP4 0
        DELAY       5000
        SET         OP4 1
        RET

WIN1FANS:
        TSTEQ       RAM2 1
        RET

        TSTEQ       RAM2 4
        RET

        TSTEQ       RAM2 3
        GOTO        W1FANHI
        TSTEQ       RAM2 6
        GOTO        W1FANHI
        ANDB        CTS 1 OP5
        XOR         OP5 1 OP6
        RET

W1FANHI:
        SET         OP5 1
        DELAY       3000
        SET         OP6 1
        RET

WINDOW2:
        NOP
        RET
```

```
OPENW2:
        NOP
        RET

CLOSEW2:
        NOP
        SET         VAR3 3
        RET

WIN2RUN:
        NOP
        SET         VAR3 3
        RET

PWRCHK:
        TSTEQ       RAM8 1
        DELAY       30000
        SET         RAM8 0
        TSTEQ       OP1 1
        CALLSUB     VOLTCHK
        CALLSUB     SYSSTATUS
        TSTEQ       OP5 1
        RET
        TSTEQ       OP6 1
        RET
        TSTEQ       OP7 1
        RET
        TSTEQ       OP8 1
        RET
        SET         OP1 0
        RET

SYSSTATUS:
        TSTEQ       VAR1 1
        RET
        SET         OP5 0
        SET         OP6 0
        SET         OP7 0
        SET         OP8 0
        RET
```

```
VOLTCHK:
        TSTLT       AIP3 225
        GOTO        VCHK2
        TSTGT       AIP3 275
        GOTO        VCHK2
        RET

VCHK2:
        DELAY       1000
        TSTLT       AIP3 225
        SET         VAR1 2
        TSTGT       AIP3 275
        SET         VAR1 2
        RET

HWFAIL:
        TSTEQ       VAR1 1
        RET

        TSTEQ       VAR7 1
        RET

        EMAIL       EM3
        DELAY       3000
        SET         VAR7 1
        RET

********** End **********
```