Interlock Patch Panel Configuration

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Introduction

Interlock[1]

The interlock, designed by Zhicai Zhang, is composed of three sections:

1. The sensor input
2. The threshold potientiometers
3. The monitoring output

Two interlock boards are utilized for a single chiller, light tower, etc. since there are two crates attached.

The sensor input

The three analog sensors the interlock board uses as input are NTC thermistor sensors, relative humidity sensors, and airflow sensors.

NTC thermistor

It is arbitrary which lead of the NTC is GND and which is Out.

To measure the NTC voltage, place the red lead of the multimeter on the NTC1/NTC2/NTC3 port's metal screw, and place the black lead of the multimeter on any GND screw on the board. This voltage can be converted to a temperature using the equation

$$V_T = \frac{129356.944 \exp(\frac{3665.546}{T+273.15} - \frac{3665.546}{298.15})}{50000 + 9356.944 \exp(\frac{3665.546}{T+273.15} - \frac{3665.546}{298.15})},$$

where V_T is the voltage read from the NTC1, NTC2, NTC3, or NTC4 ports on J5 in volts and T is the temperature measured by the NTC in degrees Celsius.

Why is this equation non-linear? While the interlock board measures a voltage-type value for temperature, the NTC actually provides a resistor-type value, in contrast to the humidity and air flow sensors that provide voltage-type values in alignment with the interlock board readings. For most NTC thermistors, the Steinhart-Hart equation can be used to convert a resistance-type value to a voltage-type value, and the NTCs used for the interlock are no exception.

Relative humidity

When looking at the side of humidity sensor with the circle on it, from left to right, the pins are GND (which goes to the GND port on J7), OUT (which goes to the HUM port on J7), and VDD (which goes to the 5V port on J7). NTC4 has also been repurposed as a HUM channel, and the pins for that sensor from left to right are GND (which goes to the GND port on J5), OUT (which goes to the NTC4 port on J5), and VDD (which goes to the 5V port on J7, sharing it with another humidity sensor).

To measure the humidity sensor voltage, place the red lead of the multimeter on the HUM port's metal screw, and place the black lead of the multimeter to any GND screw on the baord. This voltage can be converted to a relative humidity percentage using the equation

$$V_H = 0.0308P_{RH} + 0.8254,$$

where V_H is the voltage read from the HUM1 or HUM2 ports on J7 in volts and P_{RH} is the relative humidity measured by the humidity sensor in percent.

Airflow

When looking at the flow meter sensor pins, orient the arrow so that it's below the pins. From left to right (tail of arrow to tip of arrow), the pins are NC (a cable going nowhere, covering the end with tape), AOut (which goes to the FLOW port on J7), GND (which goes to the GND port on J7), and VDD (which goes to the 5V port on J7). The connections to J7 are made with wires, and the portion of the wire connecting to the flow meter should be attached to a connector. To connect any cable to the interlock, take a flattop screwdriver and unscrew the port you want to connect to. Then, insert the cable into the side of the port, and screw the port back down; this should hold the cable in place, while connecting it to the board.

To measure the flow meter voltage, place the red lead of the multimeter on the FLOW port's metal screw, and place the black lead of the multimeter on any GND screw on the board. This voltage can be converted to a flow rate using the equation

$$V_F = 1.0088R_F + 0.5725,$$

where V_F is the voltage read from the FLOW port on J7 in volts and R_F is the flow rate measured by the flow meter in cubic feet per minute.

The threshold potentiometers

With the exception of S1, all switches on the interlock board (S2-S20) correspond to a potentiometer threshold. When the switch is turned on, if the voltage of a channel is lower than the Low threshold or higher than the High threshold, the interlock is activated and all corresponding electronics are shut off. Using the equations for the different sensor types, Low and High thresholds can be determined for the different sensors as needed.

All HUM sensors have a High threshold of 1.5 V (21% RH). Since the ideal humidity is 0% RH, there is no Low threshold.

NTC sensors on the passive side of the crate have a High threshold of 0.884-0.885 V (47.25 °C). Since the Low threshold is outside the range of temperatures the NTCs can read, there is no Low threshold.

NTC sensors on the active side of the crate have a High threshold of 0.89 V (47.1 °C) and a Low threshold of 4.8 V (-3 °C).

The FLOW sensor has a Low threshold of 1.5 V (1.15 CFM). Since the ideal air flow rate is as high as possible, there is no High threshold.

The threshold for LV0-2 is 3 V.

The threshold for the connection between multiple interlock boards is 10 V, assuming $\overline{12V}$ is the output connection of the first interlock board.

The monitoring output

The interlock board is able to control the HV power, LV power, and chiller using barred output voltages (e.g. $\overline{5V}$). These voltages are their nominal value if the board is green (meaning all conditions are acceptable), but switch to 0 V if the board is red (one of the thresholds has been tripped). Intermediary connections are used to allow the interlock to control and monitor in the form of a patch panel and a relay.

Patch Panel[2]

The patch panel, designed by Timon Heim, is the intermediary board between the interlock and the supplies the crate runs on: chiller, LV power, and HV power. It is in charge of shutting down the power supplies and chiller if the conditions in the crate become dangerous. On the right side of the panel, a pin connector is attached to the interlock board and power supplies. This is how the interlock controls the supplies. It is worth noting that there are cables to the active boards in the crate, but these do not pertain to the interlock.

Configuration

There are six primary connections that the various boards are making:

1. Connecting J52 (patch panel[2]) to J2, J3, and J10 (interlock[1])
2. Connecting J21 and J22 (patch panel[2]) to the INTERLOCK connector (A1538D HV[4])
3. Connecting J2 (interlock[1]) to the EMO Interlock (cooler[5]) through the relay[10]
4. Connecting J25, J28, and J31 (patch panell[2]) to the Service connector (A2519 LV[3])
5. Connecting J5 and J7 (interlock[1]) to the analog sensors in the crate[6][7][8]

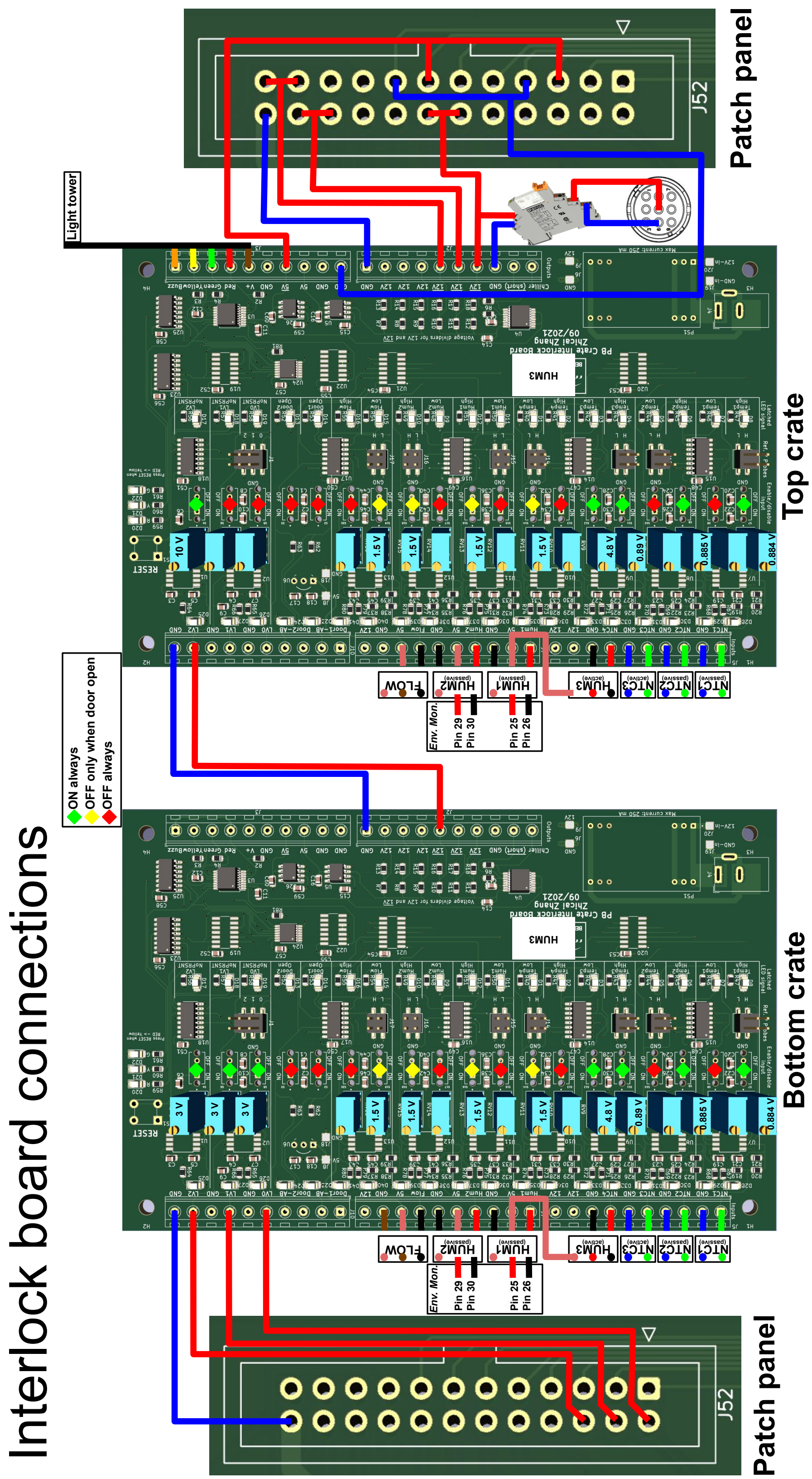

Figure 1: Connections to interlock board[11]

6. Connecting J3 (interlock[1]) to the light tower[9]

0.1 Two Interlocks?

Because we're using two crates, two interlock systems are required. You can think of these as Board 1 and Board 2. Board 1 will receive all the "inputs" (that is, every connection on the left of the board, J5/7/10) that aren't sensors, specifically the LV0-2 PRESENT connections. The only "outputs" (J2/3) of Board 1 will be $\overline{12V}$ and GND going directly to the "inputs" of Board 2, a vacant LV PRESENT channel (in Figure 1, we use the LV0 PRESENT ports). Since only Board 1 receives the LV0-2 PRESENT connections, you can re-purpose an LV PRESENT port on Board 2 for this connection. Make sure to tune that potentiometer to 10V. Board 2 only has "inputs" for the connection with Board 1 and the sensors for Board 2. Board 2 has all the interlock "outputs" except the connection between the two interlock boards. Board 2 talks to the light tower, chille (via relay), and patch panel.

Why does this work? If a board is RED, all barred output channels (e.g. $\overline{12V}$) will be 0V. Assume Board 1 is RED. If the threshold potentiometer value where Board 1 is connected to Board 2 is not met (which, 0V is not greater than 10V), then Board 2 will become RED. Now assume Board 2 is RED. This means all outputs from Board 2 to the patch panel become 0V. The patch panel then connects to Board 1's input via the LV PRESENT connections. Since there is no voltage at any pin on the patch panel, the LV PRESENT channels will not receive 3V or more, making Board 1 RED. Thus, the interlock boards can shut one another down no matter what occurs, protecting our double system.

1 Connecting J52 (patch panel[2]) to J2, J3, and J10 (interlock[1])

J2 and J3 are on the output side of the interlock board (denoted with ^{I_O}). The connections to J52 (denoted with ^{P}) are as follows:

1. $\overline{5V}^{I_O}$ connects to SIG_P_0 $(5)^P$ and SIG_P_1 $(13)^P$
2. $\overline{12V}^{I_O}$ connects to $\overline{IT03\_0}$ $(21)^P$, $\overline{IT47\_0}$ $(23)^P$, $\overline{IT03\_1}$ $(12)^P$, $\overline{IT47\_1}$ $(14)^P$, $\overline{IT03\_2}$ $(20)^P$, and $\overline{IT47\_2}$ $(22)^P$
3. GND^{I_O} connects to SIG_N_0 $(7)^P$, SIG_N_1 $(15)^P$, and GND $(24)^P$

J10 is on the input side of the interlock (denoted with ^{I_I}). The connections to J52 are as follows:

1. LV0^{I_I} connects to LV_PRSNT_0 $(2)^P$
2. LV1^{I_I} connects to LV_PRSNT_1 $(4)^P$
3. LV2^{I_I} connects to LV_PRSNT_2 $(6)^P$
4. GND^{I_I} below LV0-2^{I_I} connects to GND $(24)^P$

2 Connecting J21 and J22 (patch panel[2]) to the INTERLOCK connector (A1538D HV[4])

J21 and J22 are below J52 on the patch panel (denoted with ^{P}). Assign the pins closest to the _0/_1 side 1, and assign the pin closest to the HV side 4. If there is only one crate, only J21 is used. For a rack with two crates, both J21 and J22 are used.

On page 10 of the A1538D HV manual, the INTERLOCK connector is displayed. Assign the pin closest to the SIG side 1, and assign the pin closest to the PAS side 4.

The connections to the INTERLOCK connector (denoted with ^{HV}) are as follows:

1. J21 Pin 3^P connects to Pin 1^{HV}
2. J21 Pin 4^P connects to Pin 2^{HV}
3. When using two crates on one rack, connect the same pins from J22 to the same INTERLOCK connector pins on an additional HV power supply

3 Connecting J2 (interlock[1]) to the EMO Interlock (cooler[5]) through the relay[10]

On the first page of the relay manual, the physical relay is displayed. Assign the lower port on the side of the relay with two ports 1, the higher port on the two port side 2, the higher port on the orange side of the relay (the side with three ports) 3, and the lower port on the orange side 5.

The connections from $J2^{Io}$ to the relay (denoted with ^{R}) are as follows:

1. GND^{Io} connects to Pin 1^R
2. $\overline{12V}^{Io}$ connects to Pin 2^R

The relay then connects to the CPC connector of the EMO interlock[5]. The CPC connector has 9 labeled pins (denoted with ^{C}), and the connections from the relay are as follows:

1. Pin 4^R connects to Pin 5^C
2. Pin 5^R connects to Pin 6^C

Don't let the port labeled Chiller on $J2^{Io}$ fool you; it is unused.

4 Connecting J25, J28, and J31 (patch panell[2]) to the Service connector (A2519 LV[3]))

These connections are fairly simple: there are 3 LV cables that connect the patch panel to the LV power supply. To connect the LV cables, you will need to place the connector into the pins, and then twist the knobs to the left and right of the connector until they're tight. To remove the LV cables, you will need to untwist the two knobs before removing the connector head.

5 Connecting J5 and J7 (interlock[1]) to the analog sensors in the crate[6][7][8]

This is a brief summary of the analog sensor information provided in the Sensor Input section of the Introduction.

NTC thermistor

It is arbitrary which lead of the NTC is GND and which is Out. One lead goes to the NTC port on J7, and one lead goes to the GND port on J7.

The NTC thermistors are affixed to the inside of the crate on both sides. Try to evenly distribute them, with any extras on the passive side in case of an uneven split (e.g. 2 on passive, 1 on active).

Relative humidity

When looking at the side of humidity sensor with the circle on it, from left to right, the pins are GND (which goes to the GND port on J7), OUT (which goes to the HUM port on J7), and VDD (which goes to the 5V port on J7). NTC4 has also been repurposed as a HUM channel, and the pins for that sensor from left to right are GND (which goes to the GND port on J5), OUT (which goes to the NTC4 port on J5), and VDD (which goes to the 5V port on J7, sharing it with another humidity sensor).

The relative humidity sensors are affixed to the inside of the crate on both sides. Try to evenly distribute them, with any extras on the passive side in case of an uneven split (e.g. 2 on passive, 1 on active).

Airflow

When looking at the flow meter sensor pins, orient the arrow so that it's below the pins. From left to right (tail of arrow to tip of arrow), the pins are NC (a cable going nowhere, covering the end with tape), AOut (which goes to the FLOW port on J7), GND (which goes to the GND port on J7), and VDD (which goes to the 5V port on J7). The connections to J7 are made with wires, and the portion of the wire connecting to the flow meter should be attached to a connector. To connect any cable to the interlock, take a flattop screwdriver and unscrew the port you want to connect to. Then, insert the cable into the side of the port, and screw the port back down; this should hold the cable in place, while connecting it to the board.

The airflow sensor sits outside the crate, attached to the dry air supply.

6 Connecting J3 (interlock[1]) to the light tower[9]

The light tower has five coloured cables: red, orange, yellow, green, and brown. The red cable connects to the Red port on J3. The orange cable connects to the Buzz port on J3. The yellow cable connects to the Yellow port on J3. The green cable connects to the Green port on J3. The brown cable connects to the V+ port on J3.

7 Links

1. https://gitlab.cern.ch/zhicaiz/pb_crate_interlock/-/blob/master/schematic.pdf
2. https://gitlab.cern.ch/berkeleylab/pbv3_test_adapter/pb_masstest_patchpanel/-/blob/master/pb_masstest_patchpanel.pdf
3. https://www.caen.it/?downloadfile=6026 (found by clicking Manuals on https://www.caen.it/products/a2518/ while signed in)
4. https://www.caen.it/?downloadfile=5702 (found by clicking Manuals on https://www.caen.it/products/a1538d/ while signed in)
5. https://twiki.cern.ch/twiki/pub/Sandbox/EquipmentAndInstallationThermalImagingSetUp/Manual_RC211_MNL-011-A_RC211_Rev006_0412.pdf
6. https://prod-edam.honeywell.com/content/dam/honeywell-edam/sps/siot/en-us/products/sensors/humidity-with-temperature-sensors/hih-4010-4020-4021-series/documents/sps-siot-hih4010-4020-4021-s pdf
7. https://www.vishay.com/docs/29092/ntcalug01a.pdf
8. https://www.sensirion.com/media/documents/3CBC9FC5/616683BB/Sensirion_Mass_Flow_Meters_SFM3020_Datasheet.pdf
9. https://www.adafruit.com/product/2993#technical-details
10. https://www.phoenixcontact.com/product/pdf/api/v1/MjkwMzM3MQ?_realm=us&_locale=en-US&blocks=commercial-data%2Ctechnical-data%2Cdrawings%2Capprovals%2Cclassifications%2Cenvironmental-compliance-data
11. https://docs.google.com/presentation/d/1S380VxdQm-G5sv445VK1gH6q3tGxK_7NvrFI6IePhL8/edit?usp=sharing

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