

(Un)Common™ – HMT

HUMIDITY • MOISTURE • TEMPERATURE

MAKE YOUR OWN GRAIN BIN MONITORING SYSTEM

Project Ideas and Programming Code by

The Computer Connectors LLC



WHY SPEND THOUSANDS WHEN YOU COULD SPEND JUST A FEW HUNDRED?!

- Know the condition of your grain as you place it into your bin
 - HMT – Humidity, Moisture, Temperature
- Know the condition of your grain for the duration of its storage in your bin
- Minimize spoilage
- Avoid losing money by over drying your grain
- Make more money by (legally) re-hydrating your grain to (near) industry standards
- (Hopefully) Minimize the need to enter your bin to remove/breakup spoilage
- (And, did we mention)... **Make More Money**

Getting Started

If you are reading this, you are probably a farmer.

Be proud of that!

Nobody feeds and fuels the world like you.

There are a lot of people who are secretly jealous of you. Yes - Seriously!

Why else would they spend so much time and effort trying to tear us down?

Ok, We know...

Nobody likes to read instruction manuals. We feel the same way.

In this case, however, we strongly recommend reading this manual in its entirety – at least once prior to beginning the build process.

Reading this manual will help you get a good feel for:

- Where you are starting from
- A realistic goal
- The tools you will need
- The project parts you will need to order
- The building process
- And finally, what to expect at the end of the build.

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(Un)Common – HMT

Make Your Own Grain Bin Monitoring System

THEORY OF OPERATION

Theory of Operation

Introduction

Throughout this document, you will find references to:

- Grain types
- Temperature
- Humidity
- Moisture
- Equilibrium
- Grain marketing standards
- Etc.

As a farmer, you may have any number of reasons for growing your crops. Yet, regardless of your reason(s), one of your goals is to preserve the quality of that crop for as long as necessary. That may be days, weeks, or even years.

This project is intended to help you with that goal. We cannot **prevent** quality degradation or even outright spoilage. However, we can provide you with information to help you minimize your risk.

With that said, **YOU** need to be the subject matter expert here! Chances are that you have been farming for a long time. **How have you minimized your crop storage losses in the past?**

Use our HMT device (the one you are building) as a supplement to and **NOT a replacement for the knowledge that you have built up over the years.**

Grain spoilage is, in many cases, the result of too much moisture (a.k.a water) in the grain. That moisture combined with oxygen and other components in the environment is all we need for bacteria, fungi, and even pests to thrive in, on, and around your grain. In theory then, we want to minimize the amount of moisture contained within your grain. Yet, we don't want to remove so much water as to then miss out on additional profits that would have resulted from the additional "water weight."

So, you can see... It's a [water] balancing act.

In general, you can "get away with" more moisture if you will be storing your grain for very short periods of time and/or in cold environments. For longer periods of time or in warm environments, you may have to sacrifice some of the additional "water weight" profit to ensure that you maintain your grains quality.

But, How Can You Know your grain's moisture content?!

What This Device Does

In very simple terms, our HMT device uses Temperature and Humidity sensors connected to a miniature computer. That computer reads those sensors and calculates the [estimated] amount of moisture (as a percentage) in your grain.

On the following pages, we will discuss this device in two different contexts: The “FREE” version and the “PRO” version. We will discuss the differences between the FREE and PRO versions in more depth later in this document.

Briefly, the first difference between the versions is the ability to read more sensors. With the FREE version, you have the ability to read two sensors. We will call the first sensor the “Weather” sensor. Its purpose is to sense the outdoor air conditions and report those values to the computer. The second sensor is installed inside the grain bin. Its purpose is to sense the temperature and humidity within [one portion of] the grain pile and report those values to the computer. The computer then uses two mathematical formulas to compute and estimate your grain’s moisture content. The computer also uses those same formulas to compute an “Equilibrium Moisture Content” of the outside air from the Weather sensor.

With the PRO version, you have the ability to add two additional grain sensors inside your bin. Advantage example: Know the condition of your grain in three locations (ex. Top, Middle, and Bottom).

Additionally, with the PRO version, the device has four “Outputs.” Two of the outputs are designed to power LED lights which can quickly and visually help you determine what the effect will be on your grain if you run your bin’s fan. The third and fourth outputs are designed to provide control signals to external, third-party equipment.

Equilibrium Moisture Content

You are probably wondering what an “Equilibrium Moisture Content” is. While the term sounds technical, think of it like this...

If you left your grain out in the field, its moisture content would fluctuate based upon the weather conditions. If the air is cool and humid, the grain may absorb moisture from the air. If the air is hot and dry, the grain may lose moisture to the air.

The same is true inside your grain bin. If you use the fan to pull outside cool and humid air through the grain in your bin, the grain inside your bin may take on moisture from that outside air. If you use the fan to pull outside hot and dry air through the grain in your bin, the grain may lose moisture to that exhausted outside air.

So, if we use the aforementioned mathematical equations to calculate what moisture content your grain would “Equalize” to when out in the field, we will then also know what moisture content your grain would “Equalize” to when your bin fan pulls this outside air through the grain in your bin.

You just need to ask three questions:

- 1) What is the current moisture content of the grain in my bin?
- 2) Do I want to DRY the grain in my bin?
 - a. Turn the fan on when the outside air is hot and dry.
- 3) Do I want to REHYDRATE the grain in my bin?
 - a. Turn the fan on when the outside air is cool and humid.

This device helps you determine the answers to those questions.

Moisture Calculation

Decades ago, scientists realized the benefit of this moisture “balancing act.” They then proceeded to create mathematical formulas that now help us to estimate grain moisture content. Our HMT device uses the equations from two different scientists: Henderson [Modified] and Chung-Pfost. The equations look substantially different, but their end results are remarkably similar.

NOTE: To learn more about “equilibrium moisture” and these two scientists, simply search the Internet for their names. There are literally thousands of documents that make great bedtime reading.

ALSO NOTE: The aforementioned equations ARE NOT and CANNOT be 100% accurate. The “equilibrium moisture” is not only dependent upon temperature and humidity. It is also dependent upon the physical makeup of the grain: Starches, cell structures, etc. Even differences in grain hybrids will cause differences in the equilibrium moisture content. Thus, the bottom line: Use the moisture values calculated by Henderson and Chung-Pfost as an ESTIMATE of the real moisture content in your grain.

LEGAL STUFF

Legal Stuff

Here is the legal stuff you should know about this project...

Copyrights, Licenses, and Trademarks

This project is the result of years of work to create, gather, and test both the concepts and the components. The hardware parts are basic, “off the shelf” parts that anyone can buy. The firmware code is a culmination of our (The Computer Connectors LLC) ideas and various hardware vendor computer code. In the following paragraphs, we will attempt to present you with an authentic representation of the work accomplished by and the legal requirements imposed by those vendors.

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Arduino



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AM2302 Sensor

[The AM2305 sensor uses the same code as the AM2302]

Avoid the temptation to use the cheaper AM2302. Yes, they are cheaper, but they are also less reliable and a lot more work to implement.

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The FCC

You have probably noticed all the small print that comes with the products you buy. You find everything from safety information to EMF noise/interference compliance statements. We mention those two topics because we need to make some statements about them here.

FCC – Federal Communications Commission

<https://www.fcc.gov/>

From their website:

“The Federal Communications Commission regulates interstate and international communications by radio, television, wire, satellite and cable in all 50 states, the District of Columbia and U.S. territories. An independent U.S. government agency overseen by Congress, the commission is the United States' primary authority for communications law, regulation and technological innovation. In its work facing economic opportunities and challenges associated with rapidly evolving advances in global communications, the agency capitalizes on its competencies in:

- *Promoting competition, innovation and investment in broadband services and facilities*
- *Supporting the nation's economy by ensuring an appropriate competitive framework for the unfolding of the communications revolution*
- *Encouraging the highest and best use of spectrum domestically and internationally*
- *Revising media regulations so that new technologies flourish alongside diversity and localism*
- *Providing leadership in strengthening the defense of the nation's communications infrastructure”*

The first statement relates to our motivation in establishing this project/product.

- **Promoting competition:** You have seen the advertisements... A company offers a product to accomplish all of the objects as outlined on this document's title page. All while only spending \$\$\$\$,\$\$\$,\$\$ (basically all of your profit) per bin on their product. Now, don't get us wrong. We do believe in profits. However, we also believe in a competitive marketplace along with a “fair profit.” There are too many monopolistic companies in too many industries. Effectively none of those monopolies has your wellbeing in mind. Thus, at least in this small project, **we believe that you should have the knowledge and tools to build your own system.**
- **Encouraging the highest and best use of [the] spectrum:** You can't see it, but all around you are packets of radiation from everywhere (including outer space). In fact, if it weren't for our atmosphere's ability to filter out a lot of those cosmic rays from all corners of the universe, we... wouldn't/couldn't exist.

Regarding **man-made** radiation, every electrical source/product produces some sort of radiation. Even your own body produces electrical impulses to energize your heart and other muscles. For this project, we will be using two potential sources of radiation. The first device is the “Arduino” processor board [a.k.a. Computer]. You should consider it the brains of this device. The memory components on this board store the firmware code while the processor and other components follow the instructions provided by the code.

*Side Note: If you want to learn more about how computers work, have a look at our book: “**How Computers Work.**”*

<https://author.amazon.com/claim/join?query=ronald+lind>

The second potential radiator is the LCD screen. It doesn't produce any power of its own, but it **may** have the potential to be a “secondary” radiator.

Now, you don't need to worry about the “radiation.” You would get a higher dose sitting in front of your TV in the evening than you would from being near these two devices. Plus, the radiation frequency is “non-ionizing.” https://en.wikipedia.org/wiki/Non-ionizing_radiation So, other than raising your body temperature by an immeasurable fraction of a degree, there is no threat to your body.

Regardless, when you buy these components, it is important to buy them: A) from a reputable vendor and B) that they have an FCC certification. Normally, I wouldn't do any vendor recommendations, but we rely heavily on Adafruit (www.adafruit.com) and Arduino (www.arduino.cc) for this project. So, hint: buy from them. 😊

Terms of Use

Please see our website (www.thecomputerconnectors.com/client-resources.html) for the latest version of our “Terms of Use.” It governs our relationship.

Privacy Policy

Please see our website (www.thecomputerconnectors.com/client-resources.html) for the latest version of our “Privacy Policy.”

Suitability of Purpose

As mentioned above, you need to be the subject matter expert regarding your grain storage. Continue to use your accumulated knowledge and expertise. This device simply gives you additional information upon which to base your decisions. The information this device provides, may or may not be useful in your specific situation.

Warranty

This project uses components that are sourced from various vendors. Each component may or may not have its own, vendor-backed warranty. Please check each of those vendors for any warranty coverage.

Any specific component that we may provide, will come with a warranty as described on our website (www.thecomputerconnectors.com/client-resources.html).

Acknowledgements

The Computer Connectors LLC would like to thank all those people and organizations that contributed to the success of this project. Without you, this project and the resulting device would not exist.

Safety

Everyone knows, and no one knows better than a farmer, that farming is a DANGEROUS occupation. According to the CDC, “...the agriculture industry is consistently at the highest risk for occupational injuries and fatalities, with 453 fatalities in 2021, or an equivalent of 19.5 deaths per 100,000 workers.”

Learn more on the CDC website at: www.cdc.gov/niosh/newsroom/feature/national-farm-safety-and-health.html

In everything that you do:

- Slow down!
- Evaluate what you are about to do!
- Ask yourself, what risk will my actions expose me to?
- How can I minimize those risks?
- Do NOT think that “An injury cannot or will not happen to me.” It definitely CAN!

We would encourage you to learn more about your risks. The CDC link above is one resource. Here is another: www.uaex.uada.edu/publications/pdf/FSA-1062.pdf.

As the old saying goes: **Safety is Priority ONE!**

(Un)Common – HMT

Make Your Own Grain Bin Monitoring System

USER'S MANUAL

User's Manual

Powering the Device

NOTE: We STRONGLY advise you to use the USB port to power this device. The other power connections on the circuit board are NOT adequately protected.

When you purchase the device, it normally comes with a USB cable – ensure that it does. We recommend connecting the USB cable to the following power sources:

- Wall charger: The kind you use to charge your phone.



- A portable battery specifically for charging/powering mobile devices (ex. Your phone)



Technically, you could use any power source that produces the same kind of power you use to charge your phone. Just make sure that it produces a steady, reliable +5 volts and can deliver at least 1.5amps. A surge protector would also be a great idea.

Using Portable Batteries

These batteries (mentioned above) come in all kinds of shapes and sizes. The commonalities that you must look for are:

- They will have one or more USB charging ports
- They will have a mAH (milli-Amp-Hour) rating.
 - Think of this rating as “The amount of energy it can hold.”
- You will also need to look for portable batteries that don’t turn themselves off.
 - We found that a really nice 17,000mAH pack would turn itself off automatically because it didn’t recognize any significant power draw from our HMT device.

We have done some **very minimal** testing with a couple of these devices. Here is what we have learned:

- They are super convenient
 - Take them anywhere

- For us, a 17,000mAH battery pack powered our HMT device for about 24 hours in a warm environment. Your experience will differ, AND in a cold environment, you should expect the battery pack to provide about ¼ to ½ less operational time.

Device Longevity

Theoretically, the device (sensors and cabling excluded) should last indefinitely. On our own farm and during development, we have left our system out in subzero cold for extended periods of time without damage. The thing we have noticed: In really cold weather, the LCD and its touch functions seem “sluggish.”

[See “Sensor Longevity” below.]

FREE Version

You are invited and encouraged to build and use as many “FREE” versions of this device as you want. There is no limitation on the number of devices you may build. HOWEVER, this product is copyright and trademark protected. Thus, **YOU MAY NOT SELL THE DEVICES YOU BUILD!**

A primary difference between the FREE and PRO versions is the number of allowed sensors. The FREE version allows you two sensors. One [the “Weather Sensor”] for monitoring the outside air, and one sensor for monitoring the grain inside your bin.

PRO Version

The PRO version has a few additional capabilities.

- It provides you with the ability to add two more sensors to the system for a total of four.
 - One for monitoring the outside air’s temperature and humidity
 - Three for monitoring the temperature and humidity of the grain inside your bin.
- It has the ability to power four **“Outputs”**
 - A **“Fan On Recommendation” LED** that lights up when the device determines that it may be beneficial to run your bin fan.
 - A **“Fan Off Recommendation” LED** that lights up when the device determines that you should not need to run your bin fan.
 - Two **“ACCESSORY” outputs that can provide control signals to external, third-party equipment.** This ACCESSORY port generally follows the same fan operation recommendation pattern as the “Fan On” LED mentioned above. The difference is simply that this output has a built-in OFF → ON delay of approximately 20 minutes to prevent the “quick cycling” of any external, third-party equipment.
- Grain industry standard moisture values are programmed into the PRO version’s recommendation LEDs and ACCESSORY port. Thus, the PRO version will not light up the green

LED (telling you to run the fan) if the device determines that the weather sensor's calculated equilibrium will take your grains moisture content further from the industry standard.

“PRO” License Number

When building and operating the PRO version, you will see references to a “License Number.” We will provide you with one or more add-on components that are necessary to convert your FREE version to a PRO version. Those add-on components will come with a unique “License Number” that you will use to pair the component(s) with the device you built.

With the FREE version, the “License Number” will usually display as “0.” However, not all MEGA devices are identical, and some may display numbers other than 0. This is not something to be concerned with. In the FREE version, the license number is irrelevant to its operation.

Sensors

Sensor Longevity

Unlike the HMT device itself, the sensors will have a limited life. After all, like you, they must do their job in a cold/hot, wet/dry, dusty/dirty environment. Even the manufacturer(s) tell you in the documentation that they will “drift” (become less accurate) over time. There is no one set timeline for replacing the sensors, but **we would strongly suggest replacing the sensors prior to grain fill EVERY YEAR.** After all, **they really are very cheap compared to the value of the job they do!**

An additional caution: The humidity portion of these sensors is sensitive to water immersion. Do not immerse your sensors in water.

Calibrating the System's Sensors

The other thing that the manufacturers tell us in the documentation is that no two sensors will read identically. Example, one may read 65 degrees while another may read 64 or 66.

That is why we designed the system to accommodate these differences by allowing you to set “calibration biases” for each sensor.

We will discuss the “Calibration” process a little later.

Using the System

NOTE: The system is designed to accommodate almost any grain type. In this release however, we only support Corn and Soybeans. In future releases, we will be adding support for numerous other grains. The current challenge is finding verifiable Equilibrium Moisture charts for those additional grains. If you grow crops other than corn and soybeans, let us know where we can find and verify Temperature/Humidity/Moisture equilibrium values for your grain type. As a reward, we will provide you with a free PRO license.

IMPORTANT NOTE: Much of the work done to create the equilibrium moisture values presented by this device was completed in the 80's and 90's. Since that time, plant hybridization has dramatically changed the characteristics for nearly all commonly grown crops. Thus, the "Moisture" values that this device provides should only be used as a GUIDELINE for your grain conditioning efforts. In fact, we compared charts from two popular, commercially sold bin management systems [competitors to this device] and found that the grain's moisture value readings were typically about 1% (ex. 13% vs. 14%) different (sometimes even more). Bottom line: **treat the Moisture readings only as reasonable ESTIMATES.**

ALSO: The moisture readings are highly dependent upon the accuracy of the sensors! We designed this system to allow for easy sensor replacement. Replace your sensors OFTEN!

Supported Grain Types

For this release, the HMT device supports both CORN and SOYBEANS. In the following table, we provide a roadmap to additional grains that we plan to support. Compatibility for additional grains will require a simple firmware update which will, when completed, be available for free on our website.

GRAIN	COMPATIBILITY
Corn	via Modified-Henderson equation
Soybeans	via an average of both the Modified-Henderson and Chung Pfof equations
<i>Barley</i>	<i>[Planned future compatibility]</i>
<i>Canola</i>	<i>[Planned future compatibility]</i>
<i>Edible Bean</i>	<i>[Planned future compatibility]</i>
<i>Flax</i>	<i>[Planned future compatibility]</i>
<i>Lentils</i>	<i>[Planned future compatibility for several varieties of Lentils]</i>
<i>Oats</i>	<i>[Planned future compatibility]</i>
<i>Peanut</i>	<i>[Planned future compatibility for several peanut components]</i>
<i>Peas</i>	<i>[Planned future compatibility]</i>
<i>Rice</i>	<i>[Planned future compatibility for several varieties of Rice]</i>
<i>Sorghum</i>	<i>[Planned future compatibility]</i>
<i>Sunflower</i>	<i>[Planned future compatibility for several peanut components]</i>
<i>Wheat</i>	<i>[Planned future compatibility for several varieties of wheat]</i>

As mentioned above, if you grow crops other than corn and soybeans, let us know where we can find **and verify** Temperature/Humidity/Moisture equilibrium values for your grain type(s). As a reward, we will provide you with a free PRO license.

The “Dashboard” Screen



This is where you will find:

- The Moisture, Temperature, and Humidity values for each installed sensor
- The “Secret” spot where you can touch to change the grain type
 - Example: Corn → Soybeans → (back to) Corn
- The “Secret” spot where you view or add the FREE → PRO license codes
- The “Fan Effect”
- The “Fan” setup” button
- The “Sensor” setup buton

Let’s first start our “Dashboard” discussion with the “Secret Spots.”

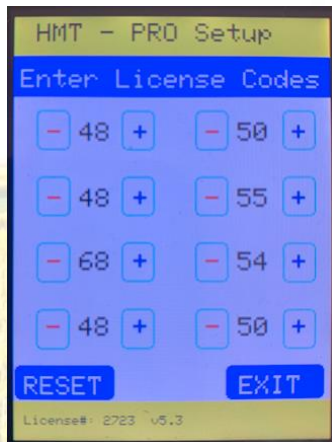
The “Licensing” Secret Spot

In the image above, notice the “HMT – PRO Edition” header.

If you haven’t already upgraded to PRO, you will see an “HMT – FREE Edition” header.

After you order and receive (from us) the PRO version upgrade component(s) and instructions, simply touch that header to access the Licensing Screen.

When you order the PRO version license, we will send you the necessary component(s), specific instructions on how to install the component(s), and the license numbers to configure in the License Screen (below).



The "Grain Type" Secret Spot

As mentioned previously, until we can find equilibrium moisture values for additional grains, our device simply supports Corn and Soybeans. In the Dashboard image above, you will notice the "Corn" reference.

If you touch the word "Corn," the system will switch over to the next grain – Soybeans.

If you then touch the word "Soybeans," the system will switch back to Corn.

Sensor Data

On the Dashboard image, notice the W, 1, 2, and 3 rows. Each of those rows represents the data read and calculated from an individual sensor.

The Grain Type

In the Dashboard image above, notice that there is a "[15.5]" after the word "CORN." This is telling you that the industry standard moisture for corn is 15.5%. If you cycle to "SOYBEAN" as your grain type, the device will tell you that the industry standard moisture for soybeans is 13%.

This industry standard is programmed into the PRO version's recommendation LEDs and ACCESSORY port. Thus, the PRO version will not light up the green LED (telling you to run the fan) if the device determines that the weather sensor's calculated equilibrium will take your grains moisture content further from the industry standard.

Lastly, notice that there is a small "[H]" after the word "CORN." This is telling you that the HMT device is using the "Modified Henderson" equation to calculate the Equilibrium Moisture value. If you cycle to "SOYBEAN" as your grain type, you will notice that there is a small "[B]" after the word "CORN." This is telling you that the HMT device is using an average of both the "Modified Henderson" and "Chung-Pfost" equations to calculate the Equilibrium Moisture value.

Weather Sensor

In the Dashboard image, sensor “W” (the Weather sensor) is reading 69° Fahrenheit, 20° Celsius, and 39% humidity. The device is using that data to calculate an equilibrium moisture content of 10.6% for Corn.

Equilibrium Moisture

Remember our previous discussion on “Equilibrium Moisture”?

Simply put, the Equilibrium Moisture calculation, is the moisture content your grain will “equalize” to when subjected to the outside air.

Let’s run through an **example**.

- When you put your corn in the bin at harvest, it was testing 18% moisture.
- You plan to use your bin’s fan to draw air through the corn to dry it down to the 15.5% industry standard.
 - [Chances are that you’ve been doing this for a lot of years].

But, how do you know that running the fan will help?

And, how do you know when to stop running the fan?

The HMT device you are building will help you answer those two questions.

If the outside air Weather sensor tells you that the current air condition is 68°F and 34% humidity, that means that the bin fan will eventually dry your corn to 9.9% moisture. Obviously, that is WAY below the industry standard of 15.5% for CORN. However, if you run the fan for a limited amount of time under these conditions, it will have the benefit of drying your 18% corn until you turn it off when sensor #1 tells you that your corn has reached the industry standard 15.5% moisture.

Additionally, the PRO version will light up the green LED to tell you when it recommends running the bin fan. Similarly, it will light up the red LED to tell you when it recommends turning off the bin fan.

It should probably go without saying that the outside air conditions will change throughout the day and night. Thus, keep an eye out for these weather changes and adjust your fan operation decisions accordingly. For instance, if you are trying to dry your grain, you probably won’t be running your fan at night and sucking in all that dew to be absorbed by your grain.

Grain Sensors

In the Dashboard image, sensor 1’s purpose is to measure the Temperature and Humidity in the grain. The device then calculates the “Equilibrium Moisture” for the selected grain type (in this case – Corn).



Sensors 2 and 3 are not being read: A) Because we don't have those two sensors connected, and B) Because we wanted to demonstrate what the "Free" version of this device would look like. The "Pro" version is designed to accommodate two additional grain sensors that would be placed in different parts of your bin (ex. Bottom, Middle, and Top).

The Fan Effect

Just to the left of the Setup button, you will notice a message that will help you understand what effect the grain bin fan will have on your grain. There are four possible messages here:

1. DRY
2. REHYDRATE
3. EQUALIZE
4. N/A

DRY

This message is telling you that the outside air will DRY your grain if the bin fan is left to run. This “DRY” message appears if:

- The average of three grain sensors' (1 – 3) moisture content values is greater than 1 point higher than the Weather sensor's calculated moisture.

REHYDRATE

This message is telling you that the outside air will REHYDRATE (add moisture to) your grain if the bin fan is left to run. This “REHYDRATE” message appears if:

- The average of three grain sensors' (1 – 3) moisture content values is less than 1 point lower than the Weather sensor's calculated moisture.

EQUALIZE

You have probably learned over the years that your grain's condition can vary from location to location within your bin. This message is telling you that the outside air will work to EQUALIZE the temperature and moisture of your grain if the bin fan is left to run.

NOTE: Recall how we previously explained that the moisture calculations provided by this (and all grain bin monitoring systems) should be considered an ESTIMATE of the grain's actual moisture. This “EQUALIZE” message appears if:

- The average of three grain sensors (1 – 3) moisture values is within 1 point (higher or lower) of the Weather sensor's calculated moisture.
 - Recall that the FREE version only has one grain sensor.

Touching Anywhere Else On The Dashboard Screen

If you find yourself impatient and want the device to do an immediate sensor read, simply touch anywhere on the Dashboard screen **other than** the two “secret” spots or the FAN and SENSORS buttons.

The “Fan Setup” Screen

From the “Dashboard” screen, a touch on the “Fan” button will take you to the setup screen for the Fan’s Min/Max Limits for Temperature and Humidity. This is where you set the limits for:

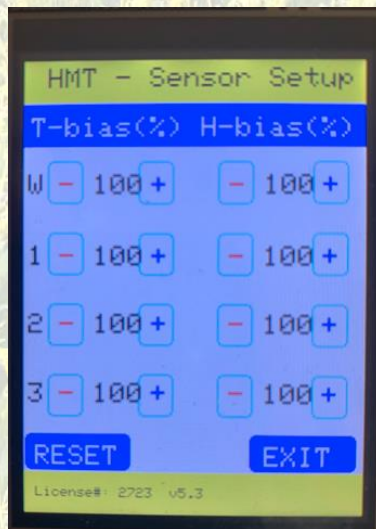
- The MINIMUM Temperature at which you want the HMT device to recommend running the bin fan.
- The MAXIMUM Temperature at which you want the HMT device to recommend running the bin fan.
- The MINIMUM Humidity at which you want the HMT device to recommend running the bin fan.
- The MAXIMUM Humidity at which you want the HMT device to recommend running the bin fan.

Just like the calibration settings (discussed below), it is important that you verify these numbers prior to each harvest season and then regularly adjust them throughout the storage season.

The “Sensor Setup” Screen

The Setup Button

From the “Dashboard” screen, a touch on the “Sensor” button will take you to the Sensor Setup screen.



Just as on the Dashboard screen, we have 4 rows to notice here. Each of those rows represent the “bias” setting for the respective sensor.

Allow us to provide an example...

Notice in row W that our “H” (humidity) bias is set to 100%. If that was set, for example, to 92%, that simply would mean that we had previously determined that our Weather sensor normally reads the humidity a few percentage points above reality. Thus, we would set the bias down to 92% to accommodate that inaccuracy. The HMT device then uses that adjusted sensor humidity value to make its moisture computations.

Similarly, if we had previously determined that our sensor 3 reads low on our grain's temperature, we would bump up the "T" (temperature) bias setting on sensor 3 to accommodate that inaccuracy.

Sensor Calibration

Before you install the sensors in your bin, you will need to "calibrate" your sensors.

We also recommend testing and setting your sensors bias settings as often as you can – yes, even after installation.

Examples: If a sensor normally reads high on temperature, you need to reduce its bias (< 100%) setting. If a sensor reads low on humidity, you need to increase its bias (> 100%) setting.

To accomplish this:

1. Find yourself a reliable temperature and humidity sensing device.
 - a. **Suggestion: Build yourself a separate FREE unit that will always contain a new sensor and to which you can compare the previously installed production sensor values.**
2. One by one, bring this separate reference device and its sensor near each of the production sensors.
3. Pause for several minutes for the reference device to acclimate to the environment near the production sensor.
4. Now read the Temperature and Humidity from both the production and reference sensors
5. In the Setup screen of the production HMT device, adjust the "Bias" for the installed, production sensor up or down as necessary so that the adjusted Temperature and Humidity match that of the reference sensor.
6. Repeat the process for each installed, production sensor.

When you are done adjusting the sensor bias settings, simply press the "EXIT" button. The device will resume its normal operation (with the newly calibrated sensor data).

Lastly, at the bottom, you may notice a couple of system related pieces of information: 1) The firmware version number, and 2) The system's License number.

BUILDING THE DEVICE

Building the Device

A Word of Encouragement

We know – this document looks daunting. You might as well go climb Everest. 😊

However, the reason it looks so difficult is because we have tried to think of and include every bit of detail to help you prepare and complete the build.

Trust us – you can do it!

You may even find it enjoyable.

Our Objective

Our goal is to provide you with the information you need to successfully build your own grain monitoring system. On the pages that follow, we will work you through the process we used to build our systems, including: Some of the lessons we learned along the way, the parts we used, the assembly process, loading the firmware, and the bin installation.

Please note: Below are the instructions to build a PRO version of our HMT device. Realistically, we know that you will probably build the FREE version first as your own “proof of concept.” But, **if you build the system to accommodate the PRO version now**, you may purchase a PRO license and upgrade the FREE version at any time.

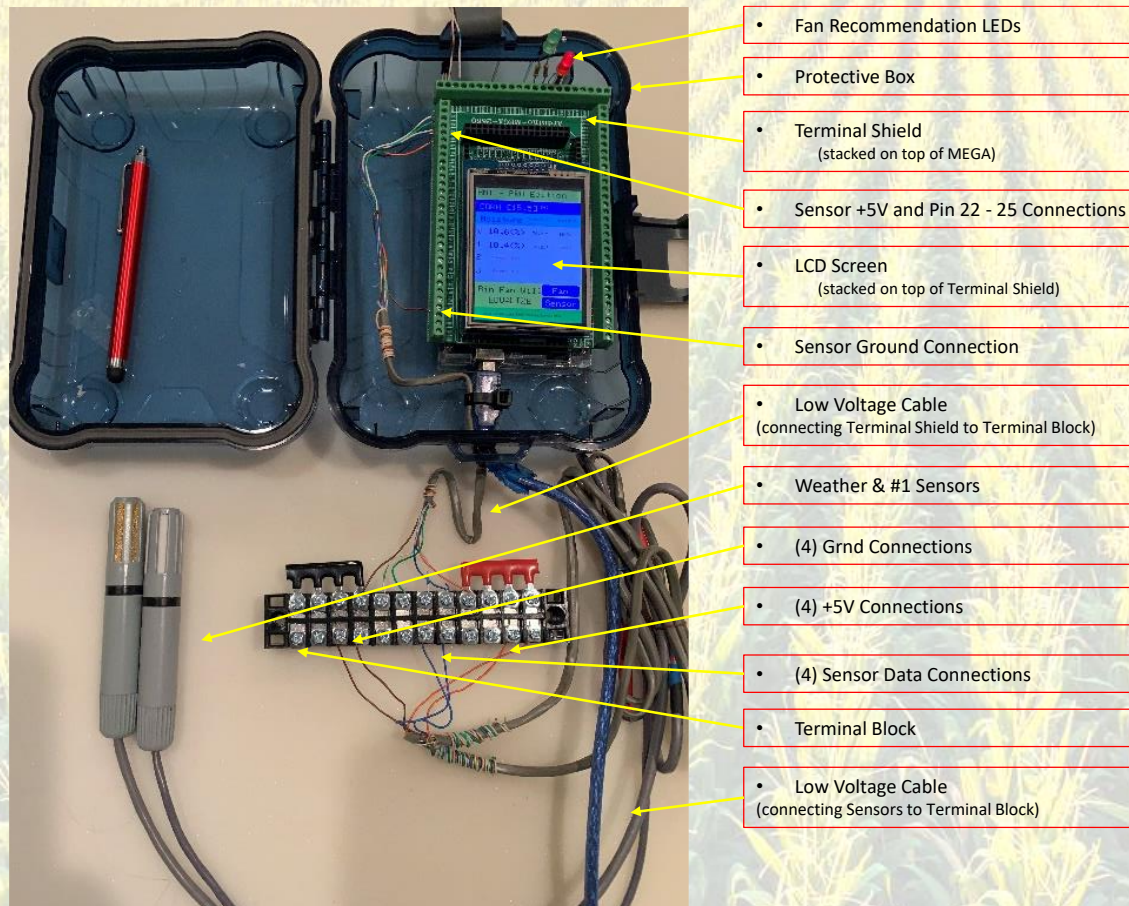
A Request

As you evaluate the instructions and your particular grain bin setups, you will undoubtedly think of better ways to complete the build and/or installation. Please feel free to share those ideas. We may even incorporate those ideas in future documentation.

Your Goal

A Few Pictures

If you are like us, you like pictures. One picture can make a whole lot more sense than even a few thousand words. Thus, we are including the following picture so that you may gain a mental image of the end goal.



Please visit Appendix C near the end of this document for more build and installation pictures.

Time Necessary to Build the Device

We would expect that, after gathering your parts, you could build and test the functionality of this device in less than one or two days. (Makes a great rainy/snowy day project!)

For the most part, building the device is minimally difficult. The most difficult part may be hanging the PVC pipe and sensors inside your bin. However, the device does contain some very small components.

Thus, please be patient and use a gentle hand!

Parts You Will Need

- Arduino MEGA 2560 Rev3
- MEGA 2560 Enclosure Case (Optional, but recommended)
- “Prototype Screw Terminal Block Shield”
- Arduino MEGA compatible 2.8” TFT LCD touch screen
- AM2305 Temperature and Humidity Sensors
- LEDs and Resistors [PRO Version (optional)]
 - (1) Green LED and (1) Red LED
 - (2) 330 Ohm Resistors
- PRO Version Enablement Components [PRO Version (Required)]
- Small box that you can use to protect and mount the Arduino, LCD, and one AM2305 sensor
- Electrical Box
- Lengths of landscape, CAT5, or other type of low-voltage wire
- Wire splice connectors
- 1” PVC pipe
- Stainless steel cable
- Hardware to hang the PVC pipe
- Junction box
- 12 position terminal block

Arduino MEGA 2560 Rev3 (with USB cable)



- Arduino.cc online store
- SKU A000067 / Barcode 7630049200067
 - <https://store-usa.arduino.cc/products/arduino-mega-2560-rev3?queryID=c6c29eb83a9ad4d733b9ffa8a0f1b326&selectedStore=us>

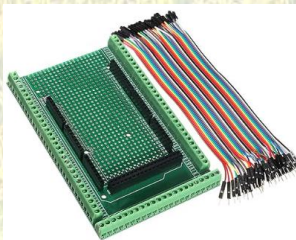
MEGA 2560 Enclosure Case (Optional, but recommended)



- Amazon.com: Search for “HiLetgo 5pcs MEGA 2560 Enclosure Case Kits Transparent Acrylic Enclosure Case MEGA 2560 Case Enclosure Box for Arduino MEGA 2560 R3 Pack of 5”.
- This case will help protect the MEGA circuit board.

NOTE: The acrylic is a little bit brittle, and the case does require patience and hand dexterity during assembly. So again, bring your patience and a gentle hand.

“Prototype Screw Terminal Block Shield”



- This will make your data wiring job WAY easier and more reliable.
- Amazon.com: Search for “ALAMSCN MEGA2560 PCB Prototype Screw Terminal Block Shield Board for Arduino MEGA 2560 Expansion with 40P Connect Wires”.

Arduino MEGA compatible 2.8” TFT LCD touch screen



NOTE: You may also find it helpful to have a “Touch Screen Pen.” You may even have a few of these lying around the house.



- Adafruit online store (Product ID: 376)

- <https://www.adafruit.com/product/376>

IMPORTANT NOTE: It has recently come to our attention that Adafruit is selling an updated version of this touch screen. We have not tested that newer version. For now, if Adafruit is out of stock, please find and purchase the older version from another source (ex. Amazon). You will notice the difference by one of the description items. **Look for “8 bit digital interface, plus 4 control lines”.**

DO NOT ORDER the newer version identified by “*The display uses digital pins 9, 10 and SPI. Touchscreen controller requires I2C and pin #2 optional IRQ. microSD pin requires digital #4*” in the description.

Even though Adafruit has stopped manufacturing the older version, its functionality in the context of this device is nearly identical.

We will update and release our device firmware as soon as we are able to source and complete the testing necessary for the new version.

AM2305 Temperature and Humidity Sensors



- (Quantity 2) When building the FREE version
- (Quantity 4) When building the PRO version

Note: Sometimes, these sensors come without any documentation. But, all you really need is the wire color code. All of the sensors we have ordered came with the following cable colors:

Red: +5V

White (or perhaps, Black): Ground

Yellow (or perhaps, Blue): Data

PRO Version Enablement Components [PRO Version (Required)]

If you chose to purchase a license to upgrade your device to the PRO version, simply order the upgrade from our website: www.TheComputerConnectors.com . We will then send you the necessary component(s) and the instructions for installing them.



LEDs and Resistors [PRO Version (Optional)]



(330 Ohm Resistor quantity: 2)

As mentioned in the “PRO Features” section, the PRO version of this device has the ability to power four “outputs.” Two of those outputs are designed for LEDs (a.k.a. Diodes).

Just for fun: During our research and development, we simply found some old electronics that we were going to recycle and that had the LEDs and resistors we want above. We then desoldered the LEDs and resistors from those old circuits and used them for this device. You may do the same.

You may purchase those components from your favorite electronics store. Or, you may order those components from us during the PRO version order checkout process.

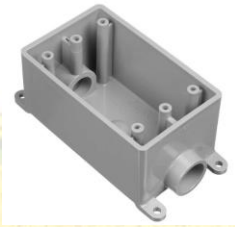
Small box that you can use to protect and mount the Arduino, LCD, and one AM2305 sensor



- We used a simple box from Walmart, but you can use any box you like as long as it protects the components from rain and direct sunlight and it allows you to view the LCD screen without opening the box.
 - Additionally, always mount the device in a location that does NOT receive direct sunlight.
- <https://www.walmart.com/ip/Outdoor-Products-Small-Watertight-Dry-Box-Blue-Polycarbonate/50109790?athbdg=L1600&from=/search>
 - NOTE: There is a larger (deeper) version of this box if you prefer to have more room.

Make Your Own Grain Bin Monitoring System

Electrical Box



- This will be used to protect the “Weather” sensor.
- More on this later.

Lengths of landscape or other type of low-voltage wire (length depends upon bin size)

Wire splice connectors

- You have options here!
- We typically use “Outdoor” rated CAT3, CAT5e, or CAT6 cable because it is both super easy to work with and cheap.



- Outdoor landscape cable may also be an option as long as it has 4 or more conductors.
- You could also use something like 4 conductor thermostat wire. HOWEVER, thermostat wire is typically NOT outdoor/UV resistant. Thus, it will not last very long outdoors.
- The quantity you need will be at least 10% to 20% more than the length of PVC you calculate (below).

1” PVC pipe (length depends upon bin size)

- We will be using this to protect our wiring both inside and outside the bin.
- You basically have two options here.
- Basic Schedule 40 PVC or PVC Conduit.
 - The conduit type will probably last longer, but even in full-sun outside the bin, the Schedule 40 should be just fine.

Make Your Own Grain Bin Monitoring System



- The amount you need will depend upon your individual installation. To get an estimate, measure from the floor sump of your bin to the roof and then to the outside and down to the location where you will put the HMT device. Then add (maybe) 20% to the length.
 - If you will be using the PRO version, you will need to do this for each sensor.
- Also, don't forget the pipe couplers and PVC glue



Stainless steel cable to hang the sensor end of the PVC pipe inside the bin.

- Something like "1/8 in. x 250 ft. Galvanized Aircraft Cable, 7x7 Construction - 340 lbs Safe Work Load - Reeled"



- Don't forget the cable clamps

You will also need the necessary hardware to hang the PVC at the top of the bin and along the side going down to the HMT device's mounting location.

- Bolts/Nuts, Eye Bolts, Washers, etc.
- We will talk more about and share some pictures of that later.

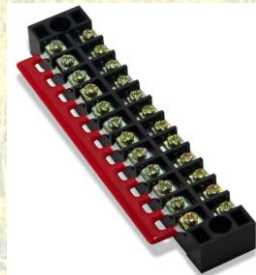
Make Your Own Grain Bin Monitoring System

Junction box



You'll use this to house the Terminal Block (below).

12 position terminal block



Amazon.com item number: B07CLW5FPS

Make Your Own Grain Bin Monitoring System

Tools You Will Need

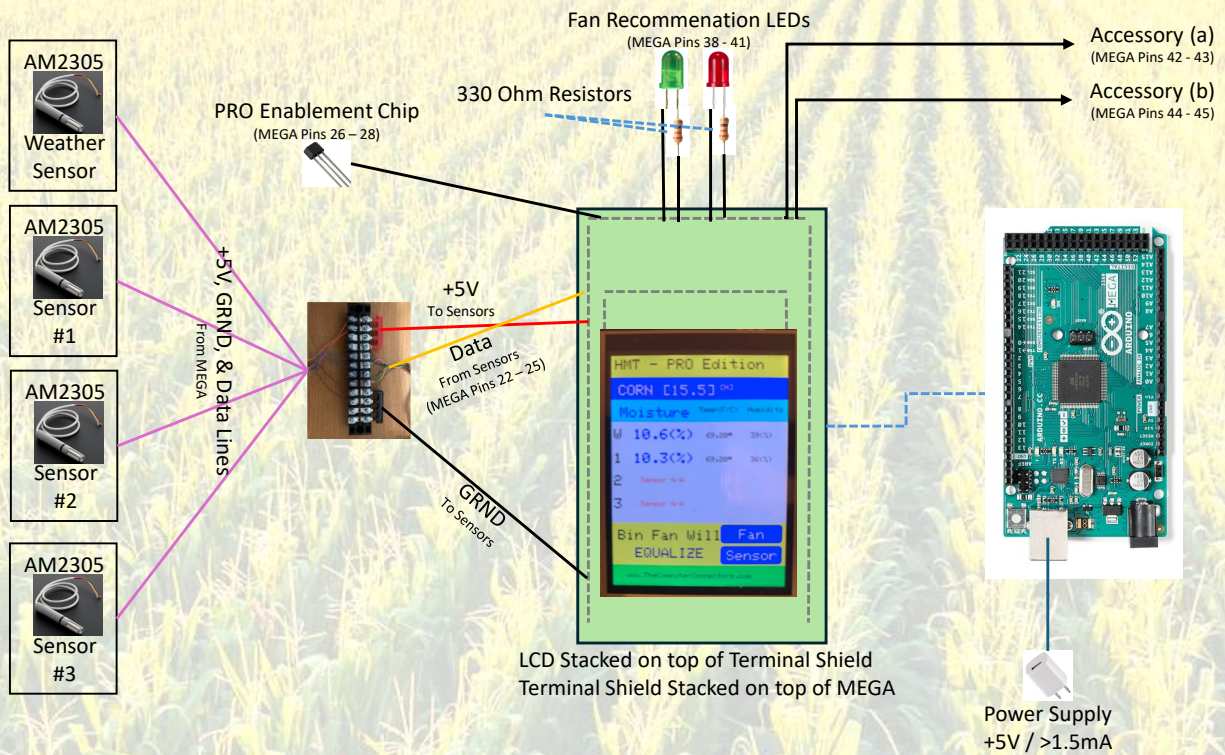
- Your reading glasses
- A flashlight
- Ladder & Harness
 - It'd be a REALLY good idea to wear a harness while climbing on the bin.
- Soldering iron and solder



- Drill and various bits
- A variety of screws (for hanging the unit & the junction box)
- Needle nose pliers
- Wire stripper/cutter
- Knife
- Electrical tape
- Shrink tubing (optional)
- Hot glue gun (optional – to help secure the device's components and wiring)
- Caulk - (optional – to help secure and protect the device's components and wiring)
- Various sized wrenches
- Screw drivers
 - Including a really small, "jewelry type" flat blade
 - Necessary to assemble the MEGA's acrylic case
- Plastic pull-ties

Assembling the Device

Schematic



Assembling the MEGA 2560 Enclosure Case Around the MEGA Circuit Board

USING EXTREME PATIENCE...

- Remove the protective paper from the case's acrylic pieces.
- Using about 5 hands and 25 fingers, use the provided screws to assemble and secure the acrylic case around the MEGA circuit board.

NOTE: Be very careful with the case. The acrylic can be a little fragile.

NOTE2: We have noticed that some MEGA circuit boards have their mounting holes drilled in differing locations. Usually, the holes near the USB connection fit the case just fine. However, the holes at the other end of the board don't always match the holes in the case. You may just need to forgo securing that end of the board. We would NOT recommend trying to drill additional mounting holes in the acrylic case.

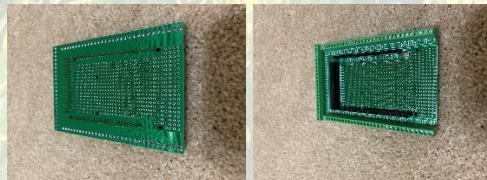
Assembling the Pieces and Placing Them in the Box

Start with the MEGA circuit board and case combination you assembled above.



CAREFULLY, layer the terminal shield on top of the MEGA circuit board.

DO NOT FORCE these two items together! There are LOTS of pins that need to line up exactly before the entire board can be fully inserted onto the MEGA. If you use too much force, you may bend or even break the pins on the terminal shield. It took us a while. Thus, we know it can be done! Just be gentil and use lots of patience.



Layer the LCD on top of the terminal shield.

Regarding the LCDs orientation on top of the terminal shield, ensure that the SD card slot on the bottom of the LCD is located near the USB connection on the MEGA board.

Just like the terminal block's mounting on top of the MEGA, DO NOT FORCE these two items together! Even though there are less pins that need to line up, you don't want to bend or break any.

IMPORTANT NOTE: NEVER ever, NEVER ever press on the glass portion of the LCD. It will break! If you look closely at our picture, we made that mistake and cracked the screen. Luckily, for us, it still works except that the touch features are finicky. You may not be that lucky! Again, don't make the mistake that we made! Just use a gentil hand and lots of patience.



- VERY CAREFULLY, drill a hole at the bottom of your outer case.
 - Use a bit that is just large enough to fit the USB cable's rounded end.
- Insert the USB cable through the box hole and connect it to the Mega circuit board.
- Use the hot glue gun (or other method) to secure MEGA circuit board (in its case) to the outer case.
- Those three things layered together and inserted into the box result in this:



PRO Features

PRO Version Enablement Components

Upon ordering your PRO upgrade, we will send you the necessary component(s) and the specific instructions for installing those component(s).

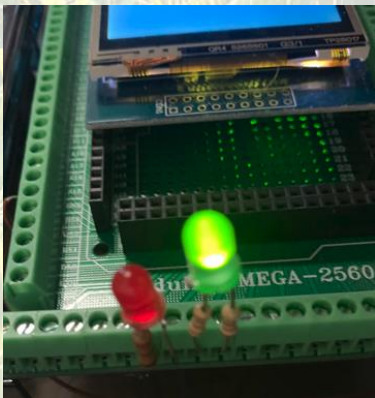


LEDs and Resistors [Optional]

If you are adding the LED features to your PRO version build, you will be soldering one resistor to each LED. It doesn't matter which "leg" of the LED you solder it to. You will then connect the LED-resistor combination to the terminal board.

1. Using a wire cutter, shorten the length of one of the LED's legs – leaving about ½ inch.
2. Using a wire cutter, shorten the length of one of the resistor's legs – leaving about ½ inch.
3. Using your soldering iron, solder the shortened legs together.
 - a. **IMPORTANT: The LEDs are heat sensitive! Do not touch the soldering iron to the LED's legs any longer than is absolutely necessary.**
4. Using a wire cutter, shorten the other resistor's leg to match the length of the un-shortened LED leg.

You have a choice to make here. Do you want to mount the LEDs directly and close to the terminal shield? Or, do you want to mount the LEDs somewhere else?



5. Connect the LED-resistor combination to the terminal shield.

NOTE: The LED may appear to be perfectly round. BUT, if you look closely, you will see that the edge of the LED is flattened slightly near one leg. This leg will get connected to the Ground connection on the terminal shield.

- a. The green LED gets connected to ports 38 and 39 on the terminal shield.
 - i. Connect the Ground leg to port 39.
- b. The red LED gets connected to ports 40 and 41 on the terminal shield.
 - i. Connect the Ground leg to port 41.

NOTE: You may be wondering why we have two resistors on one of the LEDs in the picture. If you don't have two 330 ohm resistors, you may add two, smaller ohm resistors in series to accomplish 330 ohms (ex. One 110 ohm + one 220 ohm).

If you wish to mount the LEDs anywhere else, simply add additional wire lengths to the LED leads and mount them wherever you deem appropriate.

Accessory Outputs

While we are on the topic of connecting things to the terminal shield, the device's ACCESSORY outputs come from pins 42 through 45 on the terminal shield.

Pin 42 will deliver roughly +3.7v to whatever it is connected to when the HMT device recommends running the fan. To use this connection, connect your external equipment's input connection to pin 42 and its GRND connection to pin 43.

Pin 44 takes the opposite approach. It will tie to GRND whatever it is connected to when the HMT device recommends running the fan. It will deliver roughly +3.7v to whatever it is connected to when the HMT device recommends **NOT** running the fan. To use this connection, connect your external equipment's input connection to pin 44 and its GRND connection to pin 45.

IMPORTANT: You may be tempted to connect one of these accessory outputs to a relay that can power your bin's fan contactor. However, the MEGA board has a limited amount of electrical current (amperage) that it can deliver. Thus, do not connect pins 42 – 45 to external equipment that will draw anything more than a few milli-Amperes (mA).

Sensor Placement Decisions

1. Determine the number of sensors you will install in your bin.
 - a. If you are using the FREE version, you will have just one sensor in the bin.
 - b. If you plan to purchase the PRO version, you will have up to three sensors in the bin.
2. Determine where in the bin you would like your sensors.
 - a. Near bottom (center), near middle (slightly outward), and near top (closer to sidewall) was our choice.

Assembling the Interior PVC Pipes

You may find this part of the device construction project the most time-consuming. It involves (for EACH sensor):

For each sensor inside the bin...

1. Determine the length of the PVC pipe you will need inside the bin. You may hang the pipe any way you deem best.

IMPORTANT NOTE: When determining your sensor placement, be mindful of the potential data cable length necessary to reach the HMT device. We tested our devices with data cable lengths up to about 100 feet. At that length, the sensor still worked for us, but we would not suggest using a sensor cable with a length beyond 50 to 70 feet.

- a. When we installed our sensors, we measured a straight line from the “man hole” entrance at the top of the bin’s sidewall to the middle of the bin just a few feet above the floor sump.
 - i. **Our theory is:** Since when we unload a bin, the grain flows down from the top first but then quickly begins pulling at an angle from the side to the middle. If the PVC pipe is angled roughly in-line with the pull of the grain, we will have less of a chance of the grain flow forces damaging the installation.
 - ii. Thus, if we angle the PVC from the “man hole” to the middle of the bin, the grain’s horizontal flow forces during bin unloading will be minimized.
 1. The vertical flow forces will still be considerable.
 - iii. **DON’T UNDERESTIMATE** the force of the grain pulling on the PVC. You wouldn’t believe it if we told you.
2. Now, determine how your sensor cable will exit the bin.
3. Determine the length of the PVC pipe necessary to protect the cable from the “man hole” to the exit point. *In some cases, you may not even need this piece.*
4. Construct these PVC pipes using PVC couplers and PVC glue.
5. **For the PRO version, REPEAT the process for each sensor.**

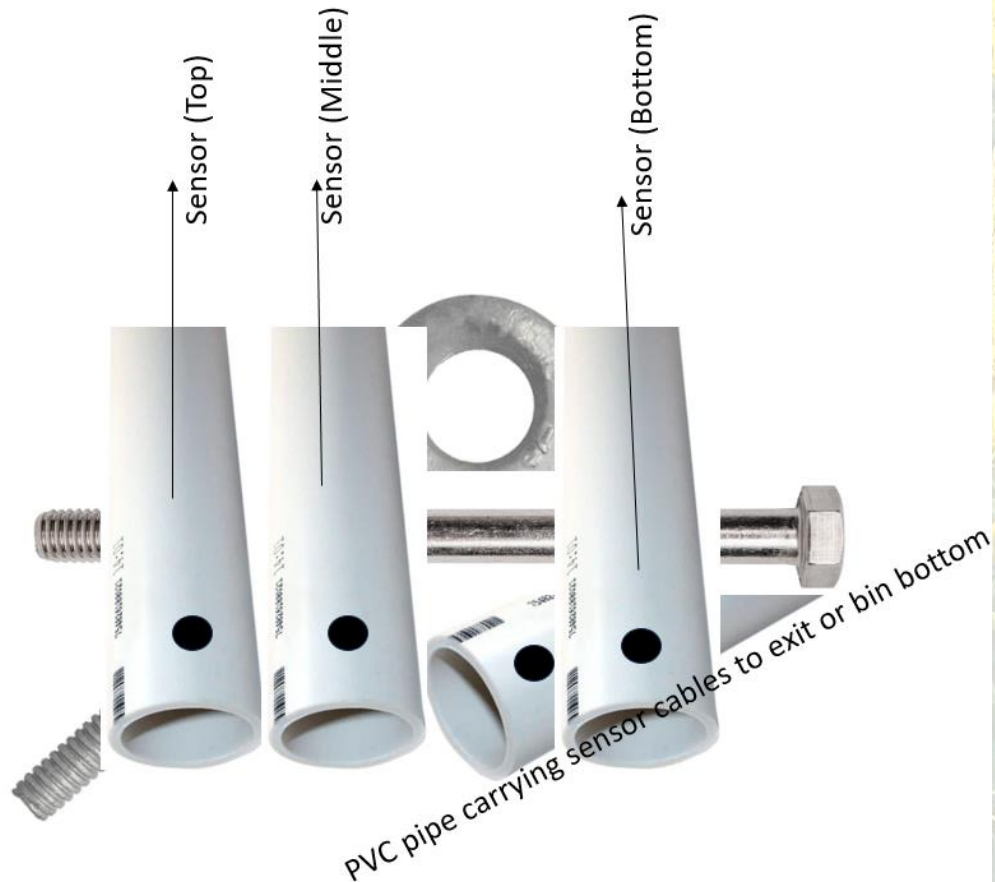
When you have completed the PVC pipes, connect them together.

6. Drill holes through each end of each pipe
7. Use a long bolt to connect all of the pipes and the eye bolt.
 - a. See the following image.
8. Plastic tie the sensor PVC pipes together.
 - a. We are assuming that you made them three different lengths
 - b. This provides additional strength to the assembly.

In our case [PRO version], we used three PVC pipes inside the bin. [In this mock-up] The three similarly oriented PVC pipes carry individual, low-voltage, sensor cables. The other pipe carries all three cables to the bin exit.

We drilled holes through BOTH ends of all of the PVC pipes. The “holes” you see in this mock-up, are used along with a long bolt to connect them together.

The long bolt is also inserted through an eye bolt which is used to attach the entire assembly to a reinforced part of the bin near the side man-hole.



Assembling the Exterior PVC Pipes

1. On the outside of the bin, determine the path and PVC pipe length necessary to protect the cable from the bin's exit point to the point where you will hang the HMT device.
 - a. **Keep in mind that you should hang the device out of direct sunlight.**
2. Add up all of those PVC pipe lengths.
 - a. The sum **(plus a several extra feet)** will roughly represent the length of cable you will need for this sensor.
3. Construct the necessary PVC pipes using PVC couplers and PVC glue.

Connecting the Sensors to the Low-Voltage Cable & PVC Pipe Assembly

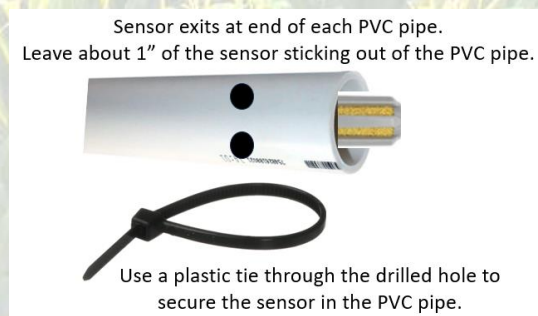
For each PVC pipe and sensor...

1. Using the PVC pipe and low-voltage cable measurements from above, cut the appropriate length of low-voltage cable to reach all the way through both the interior and exterior PVC pipes **PLUS** whatever you will need at the end of the exterior pipe to connect to the HMT device box.
 - a. In other words, you want a piece of data cable with a length **NO LESS THAN** what you measure from the sensor hanging in the bin, up to the roof, over to the man-hole, exiting the bin, down the side of the bin, and over to the HMT mounting point.
2. From the top end of the **internal** PVC pipe, thread the low-voltage cable down through the PVC pipe.
3. When the cable exits the bottom of the PVC pipe, use a wire splice connector to connect the sensor's +5V, Ground, and Data conductors to the low-voltage cable.
 - a. CAT5 (or similar) cable typically has 8 color coded conductors.
 - b. Technically, you may use any of those 8 colored conductors. Just be consistent – and **DOCUMENT what you did**.
 - c. Use electrical tape or shrink tubing to protect the soldered connections.
 - d. **Tip:** Your installation will look more professional if you are consistent with the colors you use. **Perhaps:**

Function	Sensor Cable Color	Data Cable Color
+5V	RED	ORANGE
Ground	WHITE	BROWN
SENSOR DATA	YELLOW	BLUE



4. At the end of the PVC pipe, secure the sensor into the pipe with a pull-tie.
 - a. Leave about 1" of the sensor sticking out of the pipe.
 - b. See the following image.



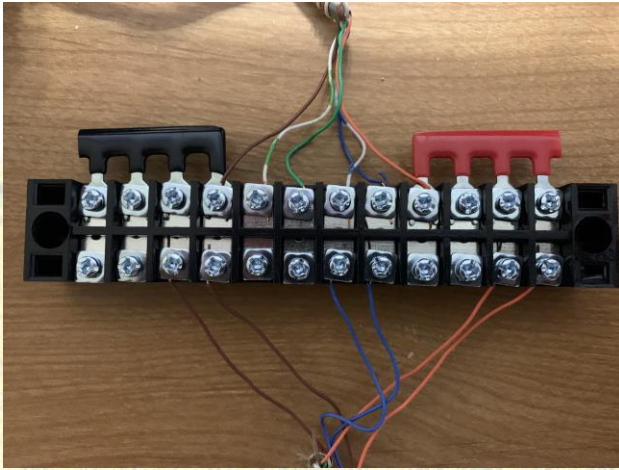
5. Thread the other end of the low-voltage cable through the PVC that runs from the mounting point to the bin exit.

NOTE: You should now have an assembly consisting of three interior sensor cable pipes (Pro version) and one (or more) interior sensor cable pipes all connected using a long bolt (see mock-up image above).

6. Hang the assembly using the eye bolt to a reinforced area on the bin near the man-hole.
7. Measure the distance from the top of the bin to the point above the floor where the sensor will hang within the PVC pipe.
8. Using that measurement, cut a length of stainless-steel cable.
9. Carefully hang the sensor end of the PVC from the top of the bin.
 - a. Remember – you have a data cable and a sensor running through the PVC. You don't want to damage them in any way!
 - b. Ensure that the stainless steel cable does not interfere with anything else (ex. Your bin's fill Spreader)
 - c. The PVC should now be hanging more/less diagonally from the top man-hole to the sensor's final location within the bin.
10. Label the data cables with something that is at least semi-permanent to indicate their sensor's location within the bin. **Don't overlook this step! You'll thank us later.**
11. Thread the remaining data cable through the bin exit and down to the ground.

Connecting the HMT Device to the 12 Position Terminal Block

1. Cut a piece of data cable that is long enough to reach from the HMT device to the junction box (plus a little extra).
2. Mount the terminal block inside of the junction box.
3. Strip several inches of the data cable's insulation from one end of the cable.
4. Untwist the 8 revealed data cable conductors.
5. Connect the ORANGE wire to one of the +5V terminals on the HMT device's terminal shield.
6. Connect the BROWN wire to one of the Ground terminals on the HMT device's terminal shield.
7. Connect the BLUE wire to the HMT device's terminal shield D22 terminal.
8. Connect the BLUE/WHITE wire to the HMT device's terminal shield D23 terminal.
9. Connect the GREEN wire to the HMT device's terminal shield D24 terminal.
10. Connect the GREEN/WHITE wire to the HMT device's terminal shield D25 terminal.
11. Strip several inches of the data cable's insulation from the other end of the cable.
12. Untwist the 8 revealed data cable conductors.
13. Connect the ORANGE wire to FOUR of the terminal block's connectors. (See picture.)
 - a. Yup, FOUR
 - b. These four connectors on the terminal block will power the four sensors.
14. Connect the BROWN wire to FOUR of the terminal block's connectors. (See picture.)
 - a. Yup, FOUR
 - b. These four connectors on the terminal block will provide a Ground connection for the four sensors.
15. Connect the BLUE wire to one of the terminal block's connectors.
 - a. This connection will connect to the "Weather" sensor's data wire.
16. Connect the BLUE/WHITE wire to one of the terminal block's connectors.
 - a. This connection will connect to sensor 1's data wire.
17. Connect the GREEN wire to one of the terminal block's connectors.
 - a. This connection will connect to sensor 2's data wire.
18. Connect the GREEN/WHITE wire to one of the terminal block's connectors.
 - a. This connection will connect to sensor 3's data wire.



- Notice how we have connected the HMT's +5V wire (orange) to four posts in the block and how we have connected the HMT's Ground wire to four posts in the block.
- The sensors' +5V and Ground wires get connected individually in the block.
- In this picture, the two sensors' data wires are connected to the two blue conductors in the block.
 - In this picture, the green conductors are unused and reserved for sensors 3 and 4.

Connecting the Sensors to the 12 Position Terminal Block

Connecting the Weather Sensor to the Terminal Block

1. Cut a piece of data cable that is long enough to reach from the Weather sensor's mounting location to the junction box (plus a little extra).
2. Strip several inches of the data cable's insulation from both ends of the cable.
3. Untwist the 8 revealed data cable conductors.
4. Solder the RED wire from the Weather sensor to the data cable's ORANGE wire.
5. Solder the WHITE wire from the Weather sensor to the data cable's BROWN wire.
6. Solder the YELLOW wire from the Weather sensor to the data cable's BLUE wire.

At the other end of the data cable:

7. Connect the ORANGE wire to one of the +5V connections on the terminal block.
8. Connect the BROWN wire to one of the Ground connections on the terminal block.
9. Connect the BLUE wire to the BLUE wire that you already connected to the terminal block.

Connecting Sensors 1 – 3 to the 12 Position Terminal Block

For each of the three sensors:

1. Strip several inches of the data cable's insulation from both ends of the cable.
2. Untwist the 8 revealed data cable conductors.
3. Solder the RED wire from the sensor to the data cable's ORANGE wire.
4. Solder the WHITE wire from the sensor to the data cable's BROWN wire.
5. Solder each sensor's data connection to the terminal block.
 - a. BLUE wire from sensor 1 to the BLUE/WHITE connection on the terminal block.
 - b. BLUE wire from sensor 2 to the GREEN connection on the terminal block.
 - c. BLUE wire from sensor 3 to the GREEN/WHITE connection on the terminal block

Admiring What You Have Accomplished

Your device should look a little bit like our unfinished device image below.

Verify that you have all the wires connected securely and correctly.

Theoretically, your device should now be assembled to the point where it would work – except that we haven't loaded the firmware yet.

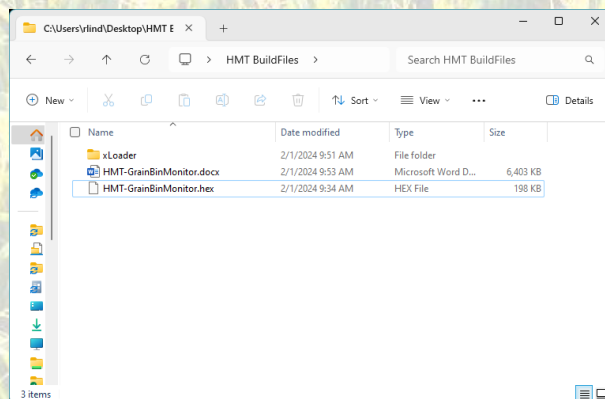


Installing the Firmware

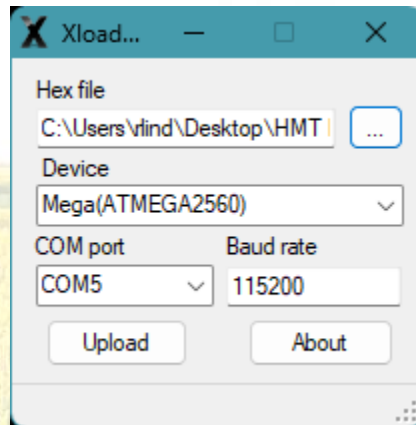
NOTE: If you are not comfortable using a computer, just take these instructions and your previously built HMT device to your local computer shop. They should be able to get everything working for you.

The steps to installing the firmware are:

1. Build a FREE version by following the steps above.
2. Using a PC computer, download firmware from our website
 - a. www.TheComputerConnectors.com
3. The download will be in the form of a .ZIP which will include several files.
 - a. The software (Xloader) you will use to load the firmware on to the MEGA processor board
 - b. The latest firmware (.HEX file)
 - c. The then current version of this document
4. Using the USB cable, connect the HMT device to one of your computer's USB ports.
5. Create a folder on your computer to store the .ZIP file's contents.
 - a. Using your mouse, right-click any open (not occupied by an icon) spot on your computer's desktop.
 - b. Select NEW and Folder
 - c. Give the new folder a name (whatever you want)
 - i. We will call it "HMT BuildFiles"
6. Open the .ZIP file you downloaded above.
7. Copy the files from inside the .ZIP file to the new folder you created above.



8. Open the xLoader folder.
9. Double-click the "XLoader.exe" file to run the XLoader program.



a.

In the XLoader software:

10. Under the “Hex File” label, find the .HEX file you extracted from the downloaded .ZIP file and saved to your computer.
11. Under the “Device” label, select “MEGA (ATMEGA2560).
12. Under the “COM port” label, select the COM port that your computer assigned to the HMT device.
 - a. It may be different than what you see in the image above.
13. Under the “Baud Rate” label, set the program to use “115200” baud.
14. Click “Upload”
 - a. The upload process should take about a minute.
15. When the upload is complete, you should see the message “xxxxxx bytes uploaded” at the bottom of the XLoader window.
16. **CONGRATULATIONS!**
 - a. **You have successfully loaded the firmware for your new HMT device.**



Installing the “Pro” Version License (optional)

Why are we selling the PRO version?

Honestly, we are just hoping to sell some PRO licenses to help offset the research and development costs that went into designing and distributing this device.

The steps to installing the PRO license are:

1. Build a FREE version and verify that it is fully operational.
 - a. You may upgrade to PRO at any time. Even after installation.
2. Order a PRO License from our website: www.TheComputerConnectors.com
 - a. If you wish to source the LEDs and resistors (see the build instructions above) from us, please include that option during your order checkout process.
 - b. Ensure that you provide us with a valid email and mailing address.
3. If you ordered the LED and resistor components from us, follow the instructions provided in the “PRO Features” section above.
4. We will send you an email to verify your order, and we will mail you (most likely via USPS) the additional components and instructions necessary to upgrade to PRO.

Preliminary Testing

If all has gone well, the HMT device should be reading the sensors now.



If it is not, check all your wiring and refer to the “Troubleshooting” section at the end of this document.

Finalizing the Installation

1. If you haven't already, finished hanging the exterior PVC pipe from the bin exit to the HMT mounting location.
2. Mount the HMT device in its permanent location.
3. Mount the Electrical Box near the HMT device - Upside down.
4. Place and secure the weather sensor in the Electrical Box.
 - a. The electrical box's purpose is to protect the sensor while still allowing it full access to the outside air.
5. Remove and label sensors 1 - 3 cables from the terminal block.
 - a. Trim the ends of those cables to remove the portions that were connected to the terminal block.
6. Thread the remaining low-voltage sensor cable(s) from the bin exit through the **exterior** PVC pipe section(s) that lead to the HMT device's mounting location.
7. Reconnect the sensor cables to the terminal block.
 - a. Use the same instructions as detailed above in the "Connecting Sensors 1 – 3 to the 12 Position Terminal Block" section.
8. Use the hot glue gun, caulk, pull ties, or whatever is necessary to secure all the assembled components.
9. Visually inspect everything.
10. Fix anything that "doesn't look right."

Final Testing

1. Connect your new HMT device to a power source.
2. Is the device reading all the installed sensors and displaying Moisture, Temperature, and Humidity values for each sensor?
 - a. See the Troubleshooting section if something isn't working.
 - b. If yes, you are ready to build additional devices for your other bins.
 - c. If no, our strategy is to:
 - i. Take a coffee break.
 - ii. Verify all the wiring.
 - iii. Work through the Troubleshooting section.

Congratulations on a job well done!

NOW – Go brag about your successful project to all your friends and neighbors!

APPENDICES

Appendix A: Troubleshooting

SYMPTOM	Possible Cause	Possible Solution	Additional Note
No sign of life	USB power supply failure	Try a different USB power supply	Some older, cheap cell phone chargers simply cannot supply enough amperage. Try a newer power supply.
		Try a different USB cable	
The LED on the MEGA board lights up but the LCD does not	Programming failed	Try to reload the device firmware	If the device was not successfully programmed, the LCD has nothing to display.
	Bent or broken pin connecting either the terminal board or the LCD to the MEGA board	During and after the build process, ensure that there are no bent or broken pins	
	The LCD was incorrectly layered on top of the terminal board	Ensure that the SD card slot on the bottom of the LCD is located near the USB connection on the MEGA board	
	The LCD is broken	Try replacing the LCD	After all, they are pretty cheap
The LCD works but is very dim	The MEGA board is broken	Try replacing the MEGA board	When operating correctly, the LED on the MEGA board will turn ON→OFF→ON every 30-60 seconds. (During the sensor read cycle.)
	Power issue	Try a different USB power supply	Some older, cheap cell phone chargers simply cannot supply enough amperage. Try a newer power supply that can deliver >1.5mA.
	[On PRO version] The “ACCESSORY” and LED ports are drawing too much power	Determine which component is drawing too much power.	One at a time, try disconnecting the LEDs and ACCESSORY connections
		Find a way to draw less power from the ACCESSORY ports.	Ex. Use a different external control circuit.

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		Add larger resistors to the LED connections	This may decrease the brightness of the LEDs but it could also brighten the LCD.
The touch functions on the SETUP and LICENSING screens do not work	Bent or broken pin connecting either the terminal board or the LCD to the MEGA board	During and after the build process, ensure that there are no bent or broken pins	
	The LCD is broken or cracked	Try replacing the LCD	Even a small crack in the screen can impact the touch features.
Sensor Read Failure	<i>MOST COMMON:</i> Wiring issue	Verify all of the sensor wire connections	
		Sensor not receiving +5V power or proper Ground	Measure the +5V and Ground wire connections at the sensor.
		Sensor data wire not properly connected to terminal block	Use Ohm meter to ensure that the data wire between the sensor and the terminal block has continuity.
		The sensor cable is too long	We have tested sensors with cables up to 100'. However, we do not recommend cables over 50 – 70 feet. When the cable gets too long and/or is routed near electrical power lines, the data signal becomes inconsistent.
	Bent or broken pin connecting either the terminal board to the MEGA board	During and after the build process, ensure that there are no bent or broken pins	
	The sensor is broken	Try replacing the sensor	
The sensor is reading incorrectly	The sensor bias settings need to be updated	See the “Calibration” section in this document	

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	The sensor is broken	Try replacing the sensor	
The Green LED is lit	This means that the HMT device believes that your grain could benefit from running your bin's fan.	Consider your experience and common sense... Decide whether you want to run the fan.	
The Red LED is lit	This means that the HMT device believes that there would be no benefit from running your bin's fan.	Consider your experience and common sense... Decide whether you want to run the fan.	
	The weather sensor's MIN and MAX settings for temperature and humidity are outside of your set ranges.	Change the MIN and MAX temperature and humidity in the SETUP2 screen.	
	"Out of Range" displayed on screen because the air temperature and/or humidity are out of range.	Adjust the range of allowed temperature and humidity values in the SETUP2 screen.	
Both the Green and the Red LEDs are lit up	<p>This means that the HMT device believes that your grain could benefit from running your bin's fan.</p> <p>HOWEVER, if you are using one of the HMT device's ACCESSORY ports, there is an approximately 20 minute delay between when the device lights up the Green LED and when it energizes the ACCESSORY port.</p>	Consider your experience and common sense... Decide whether you want to run the fan.	
None of the LEDs are lit	The LEDs only operate in the PRO version.	Upgrade to the PRO version if you haven't already.	
	One or more of the LEDs is broken.	Use a volt meter to check the voltage on pins 38, 40, and 42.	

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		If you receive > +3.5v on either of those pins, replace the LED connected to that pin.	
	You don't receive > +3.5v on any of the LED pins.	Try a different USB power supply	
		During and after the build process, ensure that there are no bent or broken pins	

Appendix B: Grain Moisture Equilibrium Charts

Corn

Temperature (°F)	CORN															
	Humidity															
35	9.3	10.3	11.2	12.1	13	13.9	14.8	15.7	16.6	17.6	18.7	19.8	21.2	22.9		
40	9.1	10	10.9	11.8	12.7	13.5	14.4	15.3	16.2	17.1	18.2	19.3	20.7	22.3		
45	8.8	9.8	10.6	11.5	12.3	13.2	14	14.9	15.8	16.7	17.7	18.9	20.2	21.8		
50	8.6	9.5	10.4	11.2	12	12.9	13.7	14.5	15.4	16.3	17.3	18.5	19.8	21.4		
55	8.4	9.3	10.1	11	11.8	12.6	13.4	14.2	15.1	16	17	18.1	19.3	20.9		
60	8.2	9.1	9.9	10.7	11.5	12.3	13.1	13.9	14.8	15.7	16.6	17.7	18.9	20.5		
65	8	8.9	9.7	10.5	11.3	12	12.8	13.6	14.5	15.3	16.3	17.4	18.6	20.1		
70	7.9	8.7	9.5	10.3	11	11.8	12.6	13.4	14.2	15	16	17	18.2	19.8		
75	7.7	8.5	9.3	10.1	10.8	11.6	12.3	13.1	13.9	14.8	15.7	16.7	17.9	19.4		
80	7.6	8.4	9.1	9.9	10.6	11.4	12.1	12.9	13.7	14.5	15.4	16.4	17.6	19.1		
85	7.4	8.2	9	9.7	10.4	11.2	11.9	12.6	13.4	14.3	15.2	16.2	17.3	18.8		
90	7.3	8.1	8.8	9.5	10.3	11	11.7	12.4	13.2	14	14.9	15.9	17	18.5		
95	7.2	7.9	8.7	9.4	10.1	10.8	11.5	12.2	13	13.8	14.7	15.6	16.8	18.2		
100	7.1	7.8	8.5	9.2	9.9	10.6	11.3	12	12.8	13.6	14.5	15.4	16.5	17.9		

Source: University of Arkansas, FSA1074

https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/Grain_drying_and_storage/Docs/FSA_1074_Grain_Drying_Tools_Equilibrium_Moisture_Content_Tables_and_Psychrometric_Charts.pdf

Note: As mentioned elsewhere, the HMT device uses the "Modified Henderson" and "Chung-Pfost" equations to calculate equilibrium moisture values.

The Univ. of Arkansas uses an unknown equation to populate this chart. Thus, this chart varies slightly from the HMT device calculations.

Soybeans

		SOYBEANS													
Humidity		25	30	35	40	45	50	55	60	65	70	75	80	85	90
Temperature (°F)	35	5.9	6.5	7.1	7.8	8.6	9.4	10.3	11.5	12.8	14.4	16.4	19.1	22.9	28.9
	40	5.8	6.4	7.1	7.7	8.5	9.3	10.2	11.3	12.6	14.2	16.2	18.9	22.7	28.7
	45	5.8	6.4	7	7.7	8.4	9.2	10.1	11.2	12.5	14.1	16.1	18.7	22.5	28.4
	50	5.7	6.3	6.9	7.6	8.3	9.1	10	11.1	12.4	14	16	18.6	22.3	28.2
	55	5.7	6.2	6.8	7.5	8.2	9	10	11	12.3	13.8	15.8	18.4	22.1	28
	60	5.6	6.2	6.8	7.4	8.1	8.9	9.9	10.9	12.2	13.7	15.7	18.3	21.9	27.8
	65	5.6	6.1	6.7	7.4	8.1	8.9	9.8	10.8	12.1	13.6	15.5	18.1	21.7	27.6
	70	5.5	6.1	6.6	7.3	8	8.8	9.7	10.7	11.9	13.5	15.4	17.9	21.6	27.3
	75	5.4	6	6.6	7.2	7.9	8.7	9.6	10.6	11.8	13.3	15.2	17.8	21.4	27.1
	80	5.4	5.9	6.5	7.1	7.8	8.6	9.5	10.5	11.7	13.2	15.1	17.6	21.2	26.9
	85	5.3	5.9	6.4	7.1	7.7	8.5	9.4	10.4	11.6	13.1	15	17.5	21	26.7
	90	5.3	5.8	6.4	7	7.7	8.4	9.3	10.3	11.5	13	14.8	17.3	20.8	26.5
	95	5.2	5.7	6.3	6.9	7.6	8.3	9.2	10.2	11.4	12.8	14.7	17.1	20.7	26.3
	100	5.2	5.7	6.2	6.9	7.5	8.3	9.1	10.1	11.3	12.7	14.5	17	20.5	26.1

Source: University of Arkansas, FSA1074

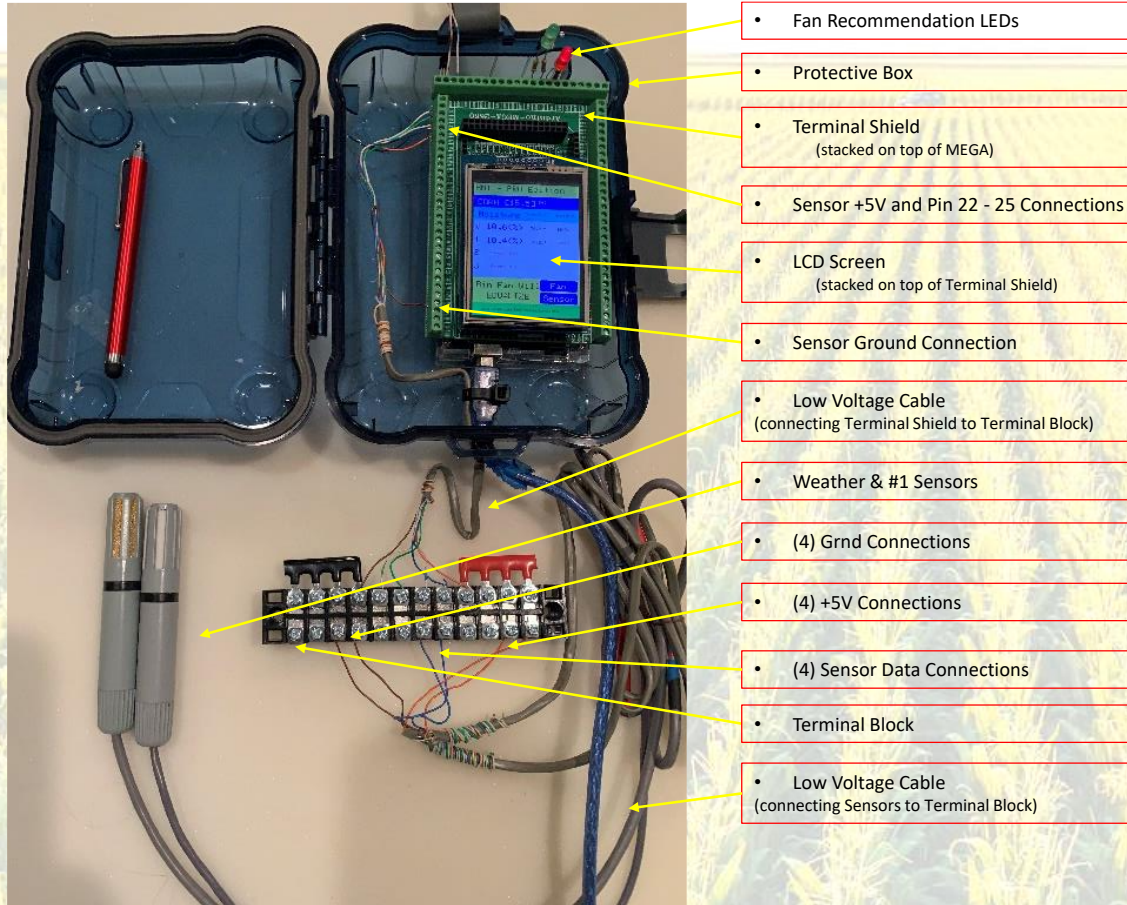
https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/Grain_drying_and_storage/Docs/FSA_1074_Grain_Drying_Tools_Equilibrium_Moisture_Content_Tables_and_Psychrometric_Charts.pdf

Note: As mentioned elsewhere, the HMT device uses the "Modified Henderson" and "Chung-Pfost" equations to calculate equilibrium moisture values.

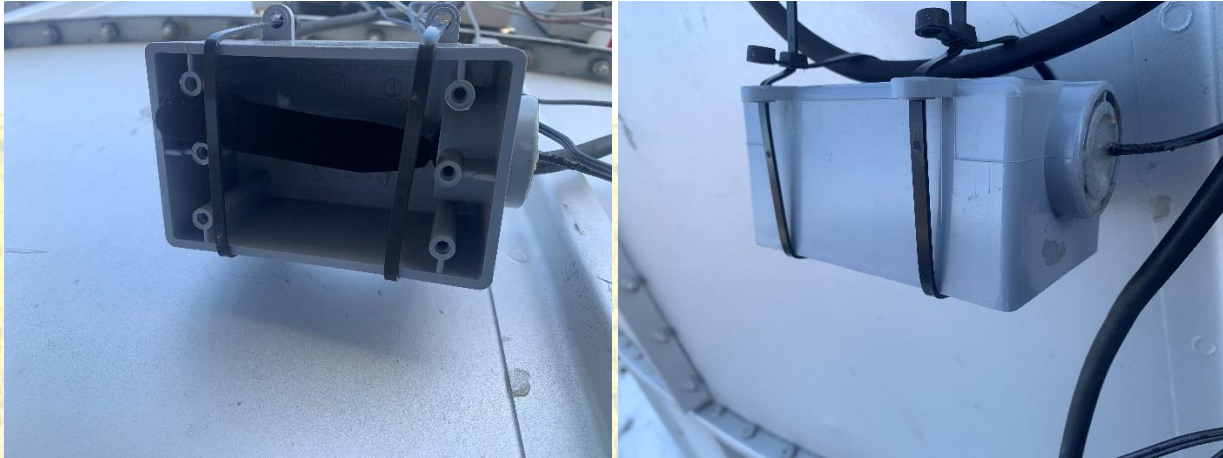
The Univ. of Arkansas uses an unknown equation to populate this chart. Thus, this chart varies slightly from the HMT device calculations.

Appendix C: Our Build and Installation Pictures

The HMT Device



Weather Sensor – Protected by Electrical Box



In the above two pictures, we are showing you the Electrical Box that we are using to protect the AM2305 Weather Sensor. A few things to notice:

- The box is hung so that the opening is facing down. In this example, we simply used plastic pull ties to hang it from a cable.
- We placed the sensor in the box through the hole that, normally, an electrical conduit would connect.
- We then sealed the hole with silicone caulk.
- You may also notice that we added a sleeve over the sensor. The sleeve is just a piece of breathable fabric. We believe that this simple piece of fabric will help keep the sensor clean, and thus, extend its life.

Hanging the Sensor PVC Pipes



Sensor exits at end of each PVC pipe.
Leave about 1" of the sensor sticking out of the PVC pipe.



Use a plastic tie through the drilled hole to
secure the sensor in the PVC pipe.

In the above two pictures, we are showing you the interior PVC pipes that we are using to protect the AM2305 Sensor cables. A few things to notice:

- In this bin, we are using two sensors. One located near the floor sump. The second located about 2/3 of the way up from the floor.
- The third PVC pipe is carrying (protecting) both sensor cables down to the bin exit. That bin exit is located near the bottom of the bin. Depending upon how you decide to exit the bin, you may or may not need a similar PVC pipe.
- Notice how we are using a long bolt to secure all three pipes and an eye bolt together.
- In this bin, the eye bolt is securing the sensor pipes to the frame of the bin's side man-hole.
- Since the bin is about half full of soybeans, you can't see that we have plastic pull-tied the two sensor PVC pipes together at a couple places along their lengths. We believe that this simple act of connecting them together will help provide additional support.
- Since the bin is about half full of soybeans, you also cannot see that there is a stainless steel cable hanging from the bin's top man-hole down to the end of the bottom sensor's PVC pipe. We are using that cable to hang and better secure the end of the bottom sensor's PVC pipe near the floor sump.
- In the third [mockup] picture, we are using two holes and a plastic pull-tie at the end of the sensors' PVC pipes to secure the sensors in the pipes. Leave about an inch of the sensor sticking out of the pipe.
 - Just like we did with the Weather Sensor in the above picture, you may wish to cover the sensor with a piece of breathable fabric to help keep it clean and extend its life.
 - Remember!... Replace and Calibrate the sensors often!

Protecting Some of the Outside Equipment



Ok – don't laugh. We finished this installation about a week before harvest. So, we were in a bit of a rush. We intend to come back and "re-engineer" this outside portion of our installation sometime soon. Anyway...

We used a simple "battery box" to store several items:

- Surge protector
- Excess wire
- Power supply.

Knowing that a little moisture (snow or rain) could find its way into the box, we also drilled a hole in the bottom of the box.

A Word From Our Sponsor

A Word From Our Sponsor

Thank you for your interest in this project. Even though (or perhaps because) a lot of time and money went into the research and development, it is very rewarding to see it come to fruition.

We hope that you had some fun building this device. We certainly did!

Tell all your friends and neighbors!

Please let us know about any challenges or ideas you have. We are always looking for ways to improve. As such, we do plan on occasionally releasing new firmware updates. And, in a lot of cases, those firmware updates will add new features. And of course, the firmware updates are FREE. So, visit our website (www.TheComputerConnectors.com) often.

Our Other Products and Services

Also on our website, you will find links to our other products and services. You will find:

- Technology Services
- Business Consulting Services
- Training Services
- Drone Services (Certified FAA Unmanned Pilot)
- Software Products
- Technology Books such as:
 - How Computer Work
 - Microsoft Word
 - Microsoft Excel
 - Microsoft Windows
 - See them at: <http://amazon.com/author/ronaldind>.
- We even have a New Zealand travel book available.