Mycodo Manual

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About Mycodo

Mycodo is a remote monitoring and automated regulation system with a focus on modulating environmental conditions. It was built to run on the Raspberry Pi (versions Zero, 1, 2, and 3) and aims to be easy to install and set up.

The core system coordinates a diverse set of responses to sensor measurements, including actions such as camera captures, email notifications, relay activation/deactivation, regulation with PID control, and more. Mycodo has been used for cultivating gourmet mushrooms, cultivating plants, culturing microorganisms, maintaining honey bee apiary homeostasis, incubating snake eggs and young animals, aging cheeses, fermenting foods, maintaining aquatic systems, and more.

A proportional-derivative-integral (PID) controller is a control loop feedback mechanism used throughout industry for controlling systems. It efficiently brings a measurable condition, such as the temperature, to a desired state and maintains it there with little overshoot and oscillation. A well-tuned PID controller will raise to the setpoint quickly, have minimal overshoot, and maintain the setpoint with little oscillation.

Frequently Asked Questions

Where do I even begin?

Here is how I generally set up Mycodo to monitor and regulate:

1. Determine what environmental condition you want to measure or regulate. Consider the devices that must be coupled to achieve this. For instance, temperature regulation require a temperature sensor and an electric heater and/or electric air conditioner.
2. Determine what relays you will need to power your electric devices. The Raspberry Pi is capable of directly switching relays (using a 3.3-volt signal), although opto-isolating the circuit is advisable. Be careful when selecting a relay not to exceed the current draw of the Raspberry Pi's PGIO.
3. See the Device Specific Information for information about what sensors are supported. Acquire one or more of these sensors and relays and connect them to the Raspberry Pi according to the manufacturer's instructions.
4. On the `Sensors` page, create a new sensor, using the dropdown to select the correct sensor. Configure the sensor with the correct communication pins, etc. and save. Activate the sensor to begin recording measurements.
5. Go to the `Data -> Live Measurements` page to ensure there is recent data being acquired from the sensor.

6. On the `Relay -> Relays` page, add a relay and configure the GPIO pin that switches it, whether the relay switches On when the signal is HIGH or LOW, and what state (On or Off) to set the relay when Mycodo starts.
7. Test the relay by switching it On and Off from the `Relay -> Relays` page and make sure the device connected to the relay turns On when you select "On", and Off when you select "Off".
8. On the `PID -> PID Controllers` page, create a PID controller with the appropriate sensor, measurement, relay, and other parameters. Refer to the Quick Setup Examples for setting up and tuning a PID controller.
9. On the `Data -> Live Graphs` page, create a graph that includes the sensor measurement, the relay that is being used by the PID, and the PID setpoint. This provides a good visualization for tuning and adjusting the system.

Why is there only one FAQ?

Good question.

Upgrading

If you already have Mycodo installed (version >= 4.0.0), you can perform an upgrade to the latest release on github by either using the Upgrade option in the web UI (recommended) or by issuing the following command in a terminal. A log of the upgrade process is created at `/var/log/mycodo/mycodoupgrade.log`

```
sudo /bin/bash ~/Mycodo/mycodo/scripts/upgrade_commands.sh upgrade
```

Settings

The settings menu, accessed by selecting the gear icon in the top-right, then the Configure link, is a general area for various system-wide configuration options.

General Settings

Setting	Description
Language	Set the language that will be displayed in the web user interface.
Force HTTPS	Require web browsers to use SSL/HTTPS. Any request to http:// will be redirected to https://.

Setting	Description
Hide success alerts	Hide all success alert boxes that appear at the top of the page.
Hide info alerts	Hide all info alert boxes that appear at the top of the page.
Hide warning alerts	Hide all warning alert boxes that appear at the top of the page.
Opt-out of statistics	Turn off sending anonymous usage statistics. Please consider that this helps the development to leave on.

Relay Usage Settings

In order to calculate accurate relay usage statistics, a few characteristics of your electrical system needs to be know. These variables should describe the characteristics of the electrical system being used by the relays to operate electrical devices. Note: Proper relay usage calculations also rely on the correct current draw to be set for each relay (see Relay Settings).

Setting	Description
Voltage	Alternating current (AC) voltage that is switched by the relays. This is usually 120 or 240.
Cost per kWh	This is how much you pay per kWh.
Currency Unit	This is the unit used for the currency that pays for electricity.
Day of Month	This is the day of the month (1-30) that the electricity meter is read (which will correspond to the electrical bill).

Users

Mycodo requires at least one Admin user for the login system to be enabled. If there isn't an Admin user, the web server will redirect to an Admin Creation Form. This is the first page you see when starting Mycodo for the first time. After an Admin user has been created, additional users may be created from the User Settings page.

Setting	Description
Username	Choose a user name that is between 2 and 64 characters. The user name is case insensitive (all user names are converted to lowercase).
Email	The email associated with the new account.
Password/Repeat	Choose a password that is between 6 and 64 characters and only contain letters, numbers, and symbols.

Setting	Description
Role	Roles are a way of imposing access restrictions on users, to either allow or deny actions. See the table below for explanations of the four default Roles.

User Roles

Roles define the permissions of each user. There are 4 default roles that determine if a user can view or edit particular areas of Mycodo. Custom roles may be created, but these four roles may not be modified or deleted.

Role	Admin	Editor	Monitor	Guest
Edit Users	X			
Edit Controllers	X	X		
Edit Settings	X	X		
View Settings	X	X	X	
View Camera	X	X	X	
View Stats	X	X	X	
View Logs	X	X	X	

1The `Edit Controllers` permission protects the editing of Graphs, LCDs, Methods, PIDs, Relays, Sensors, and Timers.

2The `View Stats` permission protects the viewing of usage statistics and the System Info and Relay Usage pages.

Alert Settings

Alert settings set up the credentials for sending email notifications.

Setting	Description
SMTP Host	The SMTP server to use to send emails from.
SMTP Port	Port to communicate with the SMTP server (465 for SSL, 587 for TSL).
Enable SSL	Check to emable SSL, uncheck to enable TSL.
SMTP User	The user name to send the email from. This can be just a name or the entire email address.
SMTP Password	The password for the user.

Setting	Description
From Email	What the from email address be set as. This should be the actual email address for this user.
Max emails (per hour)	Set the maximum number of emails that can be sent per hour. If more notifications are triggered within the hour and this number has been reached, the notifications will be discarded.

Camera Settings

Many cameras can be used simultaneously with Mycodo. Each camera needs to be set up in the camera settings, then may be used throughout the software. Note that not every option (such as Hue or White Balance) may be able to be used with your particular camera, due to manufacturer differences in hardware and software.

Setting	Description
Type	Select whether the camera is a Raspberry Pi Camera or a USB camera.
Library	Select which library to use to communicate with the camera. The Raspberry Pi Camera uses picamera (and potentially opencv), and USB cameras should be set to opencv.

Setting	Description
OpenCV Device	Any devices detected by opencv will populate this drop-down list. If there are no values in this list, none were detected. If you have multiple opencv devices detected, try setting the camera to each device and take a photo to determine which camera is associated with which device.

Setting	Description
Relay ID	This relay will turn on during the capture of any still image (which includes time-lapses).
Rotate Image	The number of degrees to rotate the image.
...	Image Width, Image Height, Brightness, Contrast, Exposure, Gain, Hue, Saturation, White Balance. These options are self-explanatory. Not all options will work with all cameras.

Setting	Description
Pre Command	A command to execute (as user mycodo) before a still image is captured.
Post Command	A command to execute (as user mycodo) after a still image is captured.
Flip horizontally	Flip, or mirror, the image horizontally.
Flip vertically	Flip, or mirror, the image vertically.

Controllers

Controllers are essentially modules that can be used to perform functions or communicate with other parts of Mycodo. Each controller performs a specific task or group of related tasks. There are also Controller Functions, which are larger functions of a controller or controllers and have been given their own sections.

Sensors

Sensors measure environmental conditions, which will be stored in an influx database. This database will provide recent measurement for Conditional Statements or PID Controllers to operate from, among other uses.

Setting	Description
Activate	After the sensor has been properly configured, activation begins acquiring measurements from the sensor. Any activated conditional statements will now being operating.
Deactivate	Deactivation stops measurements from being acquired from the sensor. All associated conditional statements will cease to operate.

Setting	Description
Save	Save the current configuration entered into the input boxes for a particular sensor.
Delete	Delete a particular sensor.
Up/Down	Move a particular sensor up or down in the order displayed.

Setting	Description
Location	Depending on what sensor is being used, you will need to either select a serial number (DS18B20 temperature sensor), a GPIO pin (in the case of sensors read by a GPIO), or an I2C address. and channel if using the TCA9548A I2C multiplexer.

Setting	Description
I2C Bus	The bus to be used to communicate with the I2C address. If you're using an I2C multiplexer that provides multiple buses, this allows you to select which bus the sensor is connected to.
Period	After the sensor is successfully read and a database entry is made, this is the duration of time waited until the sensor is measured again.

Setting	Description
Pre Relay	If you require a relay to be activated before a measurement is made (for instance, if you have a pump that extracts air to a chamber where the sensor resides), this is the relay number that will be activated. The relay will be activated for a duration defined by the Pre Duration, then once the relay turns off, a measurement by the sensor is made.

Setting	Description
Pre Relay Duration	This is the duration of time that the Pre Relay runs for before the sensor measurement is obtained.

Setting	Description
Edge	Edge sensors only: Select whether the Rising or Falling (or both) edges of a changing voltage are detected. A number of devices to do this when in-line with a circuit supplying a 3.3-volt input signal to a GPIO, such as simple mechanical switch, a button, a magnet (reed/hall) sensor, a PIR motion detector, and more.

Setting	Description
Bounce Time (ms)	Edge sensors only: This is the number of milliseconds to bounce the input signal. This is commonly called debouncing a signal. and may be necessary if using a mechanical circuit.

Setting	Description
Reset Period	Edge sensors only: This is the period of time after an edge detection that another edge will not be recorded. This enables devices such as PIR motion sensors that may stay activated for longer periods of time.
Multiplexer (MX)	If connected to the TCA9548A I2C multiplexer, select what the I2C address of the multiplexer is.

Setting	Description
Mx I2C Bus	If connected to the TCA9548A I2C multiplexer, select the I2C bus the multiplexer is connected to.
Mx Channel	If connected to the TCA9548A I2C multiplexer, select the channel of the multiplexer the device is connected to.

Setting	Description
Measurement	Analog-to-digital converter only: The type of measurement being acquired by the ADC. For instance, if the resistance of a photocell is being measured through a voltage divider, this measurement would be "light".

Setting	Description
Units	Analog-to-digital converter only: This is the unit of the measurement. With the above example of “light” as the measurement, the unit may be “lux” or “intensity”.
Channel	Analog-to-digital converter only: This is the channel to obtain the voltage measurement from the ADC.

Setting	Description
Gain	Analog-to-digital converter only: set the gain when acquiring the measurement.
Volts Min	Analog-to-digital converter only: What is the minimum voltage to use when scaling to produce the unit value for the database. For instance, if your ADC is not expected to measure below 0.2 volts for your particular circuit, set this to “0.2”.

Setting	Description
Volts Max	Analog-to-digital converter only: This is similar to the Min option above, however it is setting the ceiling to the voltage range. Units Min Analog-to-digital converter only: This value will be the lower value of a range that will use the Min and Max Voltages, above, to produce a unit output. For instance, if your voltage range is 0.0 - 1.0 volts, and the unit range

Setting	Description
Units Max	Analog-to-digital converter only: This is similar to the Min option above, however it is setting the ceiling to the unit range.

Sensor Verification

Sensor verification was introduced in an earlier version and was broken when the system moved to its new software framework. It was a great feature, and it's planned to be integrated into the latest version.

This allows the verification of a sensor's measurement with another sensor's measurement. This feature is best utilized when you have two sensors in the same location (ideally as close as possible). One sensor (host) should be set up to use the other sensor (slave) to verify. The host sensor should be used to operate the PID, as one feature of the verification is the ability to disable the PID if the difference between measurements is not within the range specified.

Setting	Description
GPIO	This is the sensor that will be used to verify the sensor measurement. The sensor will be read directly after the first sensor's measurement to verify whether the sensors have similar measurements.

Setting	Description
Difference	This is the maximum measured measurement difference between the two sensors before an action is triggered (either notify by email or prevent PID from operating; more below).
Notification	If the measurements of the two sensors differ by more than the set *Difference*, an email will be sent to the address in the *Notification* field.

Setting	Description
Stop PID	If the measurements of the two sensors differ by more than the set *Difference*, the PID controller will turn off.

Relays

Relays are electromechanical or solid-state devices that enable a small voltage signal (such as from a microprocessor) to activate a much larger voltage, without exposing the low -voltage system to the dangers of the higher voltage.

Relays must be properly set up before PID regulation can be achieved. Add and configure relays in the Relay tab. Set the "GPIO Pin" to the BCM GPIO number of each pin that activates each relay. *On Trigger* should be set to the signal that activates the relay (the device attached to the relay turns on). If your relay activates when the potential across the coil is 0-volts, set *On Trigger* to "Low", otherwise if your relay activates when the potential across the coil is 3.3-volts (or whatever switching voltage you are using, if not being driven by the GPIO pin), set it to "High".

When a relay is initially added, the background of the new relay will be yellow, indicating it is not configured. When properly configured, it will either turn green, indicating the relay is activated (device is on), or red, indicating the relay is inactivated (device is off).

Setting	Description
GPIO Pin	This is the GPIO that will be the signal to the relay.

Setting	Description
Current Draw (amps)	The is the amount of current the device powered by the relay draws. Note: this value should be calculated based on the voltage set in the Relay Usage Settings.

Setting	Description
On Trigger	This is the state of the GPIO to signal the relay to turn the device on. HIGH will send a 3.3-volt signal and LOW will send a 0-volt signal. If you relay completes the circuit (and the device powers on) when a 3.3-volt signal is sent, then set this to HIGH. If the device powers when a 0-volt signal is sent, set this to LOW.

Setting	Description
Start State	This specifies whether the relay should be ON or OFF when mycodo initially starts.
Seconds to turn On	This is a way to turn a relay on for a specific duration of time. This can be useful for testing the relays and powered devices or the measured effects a device may have on an environmental condition.

PIDs

A proportional-derivative-integral (PID) controller is a control loop feedback mechanism used throughout industry for controlling systems. It efficiently brings a measurable condition, such as the temperature, to a desired state and maintains it there with little overshoot and oscillation. A well-tuned PID controller will raise to the setpoint quickly, have minimal overshoot, and maintain the setpoint with little oscillation.

PID settings may be changed while the PID is activated and the new settings will take effect immediately. If settings are changed while the controller is paused, the values will be used once the controller resumes operation.

Setting	Description
Activate/Deactivate	Turn a particular PID controller on or off.
Pause	When paused, the PID will not turn on the associated relays, and settings can be changed without losing current PID output values.
Hold	When held, the PID will turn on the associated relays, and settings can be changed without losing current PID output values.

Setting	Description
Resume	Resume a PID controller from being held or paused.
Setpoint	This is the specific point you would like the environment to be regaulted at. For example, if you would like the humidity regulated to 60%, enter 60.

Setting	Description
Direction	This is the direction that you wish to regulate. For example, if you only require the temperature to be raised, set this to “Up,” but if you require regulation up and down, set this to “Both.”

Setting	Description
Period	This is the duration between when the PID relay turns off amd when the sensor takes another measurement, the PID is updated, and the relay is turned on again for another duration.

Setting	Description
Max Age	The time (in seconds) that the sensor measurement age is required to be less than. If the measurement is not younger than this age, the measurement is thrown out and the PID will not actuate the relay. This is a safety measure to ensure the PID is only using recent measurements.

Setting	Description
Raise Relay	This is the relay that will cause the particular environmental condition to rise. In the case of raising the temperature, this may be a heating pad or coil.

Setting	Description
Min Duration (raise)	This is the minimum that the PID output must be before the Up Relay turns on. If the PID output exceeds this minimum, the Up Relay will turn on for the PID output number of seconds.

Setting	Description
Max Duration (raise)	This is the maximum duration the Up Relay is allowed to turn on for. If the PID output exceeds this number, the Up Relay will turn on for no greater than this duration of time.
Lower Relay	This is the relay that will cause the particular environmental condition to lower. In the case of lowering the CO_2, this may be an exhaust fan.

Setting	Description
Min Duration (lower)	This is the minimum that the PID output must be before the Down Relay turns on. If the PID output exceeds this minimum, the Down Relay will turn on for the PID output number of seconds.

Setting	Description
Max Duration (lower)	This is the maximum duration the Down Relay is allowed to turn on for. if the PID output exceeds this number, the Down Relay will turn on for no greater than this duration of time.

Setting	Description
K_P	Proportional coefficient (non-negative). Accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive.

Setting	Description
K_I	Integral coefficient (non-negative). Accounts for past values of the error. For example, if the current output is not sufficiently strong, the integral of the error will accumulate over time, and the controller will respond by applying a stronger action.

Setting	Description
K_D	Derivative coefficient (non-negative). Accounts for predicted future values of the error, based on its current rate of change.
Integrator Min	The minimum allowed integrator value, for calculating Ki_total: (Ki_total = Ki * integrator; and PID output = Kp_total + Ki_total + Kd_total)

Setting	Description
Integrator Max	The maximum allowed integrator value, for calculating Ki_total: (Ki_total = Ki * integrator; and PID output = Kp_total + Ki_total + Kd_total)

Timers

Timers enable a relay to be manipulated after specific durations of time or at a specific times of the day. For *Duration Timers*, both the on duration and the off duration can be defined and the timer will be turned on and off for those durations until deactivated. For *Daily Timers*, the start hour:minute can be set to turn a specific relay on or off at the specific time of day.

LCDs

Data may be output to a liquid crystal display (LCD) for easy viewing. There are only a few number fo LCDs that are supported. Only 16x2 and 20x4 character LCD displays with I2C backpacks are supported. Please see the README for specific information regarding compatibility.

Setting	Description
Reset Flashing	If the LCD is flashing to alert you because it was instructed to do so by a triggered Conditional Statement, use this button to stop the flashing.
Type	Select either a 16x2 or 20x4 character LCD display.
I2C Address	Select the I2C to communicate with the LCD.
Multiplexer I2C Address	If the LCD is connected to a multiplexer, select the multiplexer I2C address.

Setting	Description
Multiplexer Channel	If the LCD is connected to a multiplexer, select the multiplexer channel the LCD is connected to.
Period	This is the period of time (in seconds) between redrawing the LCD with new data.
Display Line #	Select which measurement to display on each line of the LCD.

Controller Functions

Conditional Statements

A conditional statement is a way to perform certain actions based on whether a condition is true. Conditional statements can be created for both relays and sensors. Possible conditional statements include:

- If Relay #1 turns ON, turn Relay #3 ON
- If Relay #1 turns ON, turn Relay #4 ON for 40 seconds and notify critical-issue@domain.com
- If Relay #4 turns ON for 21 seconds, turn Relay #5 ON for 50 seconds
- If Relay #4 turns ON for 20 seconds, turn Relay #1 OFF
- If Humidity is Greater Than 80%, turn Relay #4 ON for 40 seconds
- If Humidity if Less Than 50%, turn Relay #1 ON for 21 seconds, execute '/usr/local/bin/myscript.sh', and notify email@domain.com
- If Temperature if Greater Than 35 C, deactivate PID #1

Before activating any conditional statements or PID controllers, it's advised to thoroughly explore all possible scenarios and plan a configuration that eliminates conflicts. Then, trial run your configuration before connecting devices to the relays. Some devices or relays may respond atypically or fail when switched on and off in rapid succession. Therefore, avoid creating an infinite loop with conditional statements.

Conditional Statement Actions

Setting	Description
Relay	Turn a relay on, off, or on for a duration of time.
Command	Execute a command in the linux shell (as user mycodo).
Activate PID	Activate a particular PID controller.
Deactivate PID	Deactivate a particular PID controller.

Setting	Description
Email	Send an email containing information about the current condition that triggered the conditional to send the email.
Flash LCD	Have an LCD screen begin flashing in order to alert.
Photo	Capture a photo with the selected camera.
Email Photo	Capture a photo and email it as an attachment to the an email address.

Setting	Description
Video	Capture a video of a set duration with the selected camera.
Email Video	Capture a video and email it as an attachment to the an email address.

Methods

Methods allow different types of setpoint tracking in PID controllers. Normally, a PID controller will regulate an environmental condition to a specific setpoint. If you would like the setpoint to change over time, this is called setpoint tracking. Setpoint tracking is useful for applications such as reflow ovens, thermal cyclers (DNA replication), mimicking natural daily cycles, and more.

Universal Options

These options are shared with several method types.

Setting	Description
Start Time/Date	This is the start time of a range of time.
End Time/Date	This is the end time of a range of time.
Start Setpoint	This is the start setpoint of a range of setpoints.
End Setpoint	This is the end setpoint of a range of setpoints.

Specific Method Options

Time/Date Method

A time/date method allows a specific time/date span to dictate the setpoint. This is useful for long-running methods, that may take place over the period of days, weeks, or months.

Duration Method

A duration method allows a specific durations of time to dictate the setpoint. This is useful for when short periods of time are required in a method, such as those that take place over the course of a few minutes or hours. Each duration will stack on the previous duration, meaning a newly-added start setpoint will begin from the previous entry's end setpoint.

Daily (Time-Based) Method

The daily time-based method is similar to the time/date method, however it will repeat every day. Therefore, it is essential that only the span of one day be set in this method. Begin with the start time at 00:00:00 and end at 23:59:59 (or 00:00:00, which would be 24 hours from the start). The start time must be equal or greater than the previous end time.

Daily (Sine Wave) Method

The daily sine wave method defines the setpoint over the day based on a sinusoidal wave. The sine wave is defined by y = [A * sin(B * x + C)] + D, where A is amplitude, B is frequency, C is the angle shift, and D is the y-axis shift. This method will repeat daily.

Daily (Bezier Curve) Method

A daily Bezier curve method define the setpoint over the day based on a cubic Bezier curve. If unfamiliar with a Bezier curve, it is recommended you use the graphical Bezier curve generator and use the 8 variables it creates for 4 points (each a set of x and y). The x-axis start (x3) and end (x0) will be automatically stretched or skewed to fit within a 24-hour period and this method will repeat daily.

PID Tuning

PID Control Theory

The PID controller is the most common regulatory controller found in industrial settings, for it“s ability to handle both simple and complex regulation. The PID controller has three paths, the proportional, integral, and derivative.

The **P**roportional takes the error and multiplies it by the constant $\mathrm{K_p}$, to yield an output value. When the error is large, there will be a large proportional output.

The **I**ntegral takes the error and multiplies it by $\mathrm{K_i}$, then integrates it ($\mathrm{K_i} \cdot 1/s$). As the error changes over time, the integral will continually sum it and multiply it by the constant $\mathrm{K_i}$. The integral is used to remove perpetual error in the control system. If using $\mathrm{K_p}$ alone produces an output that produces a perpetual error (i.e. if the sensor measurement never reaches the Set Point), the integral will increase the output until the error decreases and the Set Point is reached.

The **D**erivative multiplies the error by $\mathrm{K_d}$, then differentiates it ($\mathrm{K_d} \cdot s$). When the error rate changes over time, the output signal will change. The faster the change in error, the larger the derivative path becomes, decreasing the output rate of change. This has the effect of dampening overshoot and undershoot (oscillation) of the Set Point.

Using temperature as an example, the Process Variable (PV) is the measured temperature, the Setpoint (SP) is the desired temperature, and the Error (e) is the distance between the measured temperature and the desired temperature (indicating if the actual temperature is too hot or too cold and to what degree). The error is manipulated by each of the three PID components, producing an output, called the Manipulated Variable (MV) or Control Variable (CV). To allow control of how much each path contributes to the output value, each path is multiplied by a gain (represented by K_P, K_I, and K_D). By adjusting the gains, the sensitivity of the system to each path is affected. When all three paths are summed, the PID output is produced. If a gain is set to 0, that path does not contribute to the output and that path is essentially turned off.

The output can be used a number of ways, however this controller was designed to use the output to affect the measured value (PV). This feedback loop, with a *properly tuned* PID controller, can achieve a set point in a short period of time, maintain regulation with little oscillation, and respond quickly to disturbance.

Therefor, if one would be regulating temperature, the sensor would be a temperature sensor and the feedback device(s) would be able to heat and cool. If the temperature is lower than the Set Point, the output value would be positive and a heater would activate. The temperature would rise toward the desired temperature, causing the error to decrease and a lower output to be produced. This feedback loop would continue until the error reaches 0 (at which point the output would be 0). If the temperature continues to rise past the Set Point (this is may be acceptable, depending on the degree), the PID would produce a negative output, which could be used by the cooling device to bring the temperature back down, to reduce the error. If the temperature would normally lower without the aid of a cooling device, then the system can be simplified by omitting a cooler and allowing it to lower on its own.

Implementing a controller that effectively utilizes K_P, K_I, and K_D can be challenging. Furthermore, it is often unnecessary. For instance, the K_I and K_D can be set to 0, effectively turning them off and producing the very popular and simple P controller. Also popular is the PI controller. It is recommended to start with only K_P activated, then experiment with K_P and K_I, before finally using all three. Because systems will vary (e.g. airspace volume, degree of insulation, and the degree of impact from the connected device, etc.), each path will need to be adjusted through experimentation to produce an effective output.

Quick Setup Examples

These example setups are meant to illustrate how to configure regulation in particular directions, and not to achieve ideal values to configure your K_P, K_I, and K_D gains. There are a number of online resources that discuss techniques and methods that have been developed to determine ideal PID values (such as here, here, here, here, and here) and since there are no universal values that will work for every system, it is recommended to conduct your own research to understand the variables and essential to conduct your own experiments to effectively implement them.

Provided merely as an example of the variance of PID values, one of my setups had temperature PID values (up regulation) of $K_P = 30$, $K_I = 1.0$, and $K_D = 0.5$, and humidity PID values (up regulation) of $K_P = 1.0$, $K_I = 0.2$, and $K_D = 0.5$. Furthermore, these values may not have been optimal but they worked well for the conditions of my environmental chamber.

Exact Temperature Regulation

This will set up the system to raise and lower the temperature to a certain level with two regulatory devices (one that heats and one that cools).

Add a sensor, then save the proper device and pin/address for each sensor and activate the sensor.

Add two relays, then save each GPIO and On Trigger state.

Add a PID, then select the newly-created sensor. Change *Setpoint* to the desired temperature, *Regulate Direction* to “Both”. Set *Raise Relay* to the relay attached to the heating device and the *Lower Relay* to the relay attached to the cooling device.

Set $K_P = 1$, $K_I = 0$, and $K_D = 0$, then activate the PID.

If the temperature is lower than the Set Point, the heater should activate at some interval determined by the PID controller until the temperature rises to the set point. If the temperature goes higher than the Set Point (or Set Point + Buffer), the cooling device will activate until the temperature returns to the set point. If the temperature is not reaching the Set Point after a reasonable amount of time, increase the K_P value and see how that affects the system. Experiment with different configurations involving only *Read Interval* and K_P to achieve a good regulation. Avoid changing the K_I and K_D from 0 until a working regulation is achieved with K_P alone.

View graphs in the 6 to 12 hour time span to identify how well the temperature is regulated to the Setpoint. What is meant by well-regulated will vary, depending on your specific application and tolerances. Most applications of a PID controller would like to see the proper temperature attained within a reasonable amount of time and with little oscillation around the Setpoint.

Once regulation is achieved, experiment by reducing K_P slightly (~25%) and increasing K_I by a low amount to start, such as 0.1 (or lower, 0.01), then start the PID and observe how well the controller regulates. Slowly increase K_I until regulation becomes both quick and with little oscillation. At this point, you should be fairly familiar with experimenting with the system and the K_D value can be experimented with once both K_P and K_I have been tuned.

High Temperature Regulation

Often the system can be simplified if two-way regulation is not needed. For instance, if cooling is unnecessary, this can be removed from the system and only up-regulation can be used.

Use the same configuration as the Exact Temperature Regulation example, except change *Regulate Direction* to “Raise” and do not touch the “Down Relay” section.

Miscellaneous

Graphs

There are two different types of graphs, Live and Asynchronous.

Live Graphs

A graphical data display that is useful for viewing data sets spanning relatively short periods of time (hours/days/weeks). Select a time frame to view data and continually updating data from new sensor measurements. Multiple graphs can be created on one page that enables a dashboard to be created of graphed sensor data. Each graphs may have one or more sensor measurement, relay duration, or PID setpoint rendered onto it. Several live graph options exist, such as the time period (x-axis) and line colors, as well as navigation and data/image export options. To edit graph options, select the plus sign on the top-right of a graph.

Asynchronous Graphs

A graphical data display that is useful for viewing data sets spanning relatively long periods of time (weeks/months/years), which could be very data- and processor-intensive to view as a Live Graph. Select a time frame and data will be loaded from that time span, if it exists. The first view will be of the entire selected data set. For every view/zoom, 700 data points will be loaded. If there are more than 700 data points recorded for the time span selected, 700 points will be created from an averaging of the points in that time span. This enables much less data to be used to navigate a large data set. For instance, 4 months of data may be 10 megabytes if all of it were downloaded. However, when viewing a 4 month span, it’s not possible to see every data point of that 10 megabytes, and aggregating of points is inevitable. With asynchronous loading of data, you only download what you see. So, instead of downloading 10 megabytes every graph load, only ~50kb will be downloaded until a new zoom level is selected, at which time only another ~50kb is downloaded.

Note: Live Graphs require measurements to be acquired, therefore at least one sensor needs to be added and activated in order to display live data.

Camera

Once a cameras has been set up (in the Camera Settings), it may be used to capture still images, create time-lapses, and stream video. Cameras may also be used with Conditional Statements to trigger a camera image or video capture (as well as the ability to email the image/video with a notification).

Relay Usage

Relay usage statistics are calculated for each relay, based on how long the relay has been powered, the current draw of the device connected to the relay, and other Relay Usage Settings.

System Backup

A backup is made to /var/Mycodo-backups when the system is upgraded through the web interface or the upgrade script.

System Restore

If you need to restore a backup, do the following, changing the appropriate directory names with these commands, changing 'user' to your user name:

```
sudo mv /home/user/Mycodo /home/user/Mycodo_old
sudo cp -a /var/Mycodo-backups/Mycodo-TIME-COMMIT /home/user/Mycodo
sudo /bin/bash ~/Mycodo/mycoco/scripts/upgrade_post.sh
```

Troubleshooting

Daemon Not Running

- Check the Logs: From the `[Gear Icon] -> Mycodo Logs` page, check the Daemon Log for any errors. If the issue began after an upgrade, also check the Upgrade Log for indications of an issue.
- Determine if the Daemon is Running: Execute `ps aux | grep '/var/www/mycodo/env/bin/python /var/www/mycodo/mycodo/` in a terminal and look for an entry to be returned. If nothing is returned, the daemon is not running.
- Daemon Lock File: If the daemon is not running, make sure the daemon lock file is deleted at `/var/lock/mycodo.pid`. The daemon cannot start if the lock file is present.
- If a solution could not be found after investigating the above suggestions, submit a New Mycodo Issue on github.

More

Check out the Diagnosing Mycodo Issues Wiki Page on github for more information about diagnosing issues.

Sensor and Device Setup

Certain sensors will require extra steps to be taken in order to set up the interface for communication. This includes I2C, one-wire, and UART.

Sensor Interfaces

Sensors are categorized below by their communication interface.

1-Wire

The 1-wire interface should be configured with these instructions.

DS18B20: Temperature link (Also works with: DS18S20, DS1822, DS28EA00, DS1825/MAX31850K)

GPIO

DHT11, DHT22/AM2302: Relative humidity and temperature link

SHT1x/SHT7x, SHT2x: Relative humidity and temperature link

UART

> Atlas Scientific pH: pH link K30: Carbon dioxide (CO2) in ppmv link

This documentation provides specific installation procedures for configuring UART for the K30 with the Raspberry Pi version 1 or 2. Once the K30 has been configured with this documentation, it can be tested whether the sensor is able to be read, by executing `~/Mycodo/mycodo/tests/manual_tests/test_uart_K30.py`

For Atlas Scientific sensors, this guide may be used, as well as the above K-30 guide, to set up UART on the Raspberry Pi 1 and 2. However, for Pi 3s, use the procedure below.

Because the UART is handled differently by the Raspberry Pi 3, from of the addition of bluetooth, there are a different set of instructions for getting the K30 working on the Raspberry Pi 3. If installing on a Raspberry Pi 3, you only need to perform these steps to get the K30 working:

Run raspi-config

`sudo raspi-config`

Go to `Advanced Options` -> `Serial` and disable. Then edit `/boot/config.txt`

`sudo vi /boot/config.txt`

Find the line "enable_uart=0" and change it to "enable_uart=1", then reboot.

I2C

The I2C interface should be enabled with `raspi-config`.

> AM2315: Relative humidity, temperature link
>
> Atlas Scientific PT-1000: Temperature link
>
> BH1750: Light link
>
> BME280: Barometric pressure, humidity, temperature link
>
> BMP085, BMP180: Barometric pressure, temperature link
>
> HTU21D: Relative humidity and temperature link
>
> TMP006, TMP007: Contactless temperature link
>
> TSL2561: Light link
>
> Chirp: link Moisture, light, and temperature

Edge Detection

The detection of a changing signal, for instance a simple switch completing a circuit, requires the use of edge detection. By detecting a rising edge (LOW to HIGH), a falling edge (HIGH to LOW), or both, actions or events can be triggered. The GPIO chosen to detect the signal should be equipped with an appropriate resistor that either pulls the GPIO up [to 5-volts] or down [to ground]. The option to enable the internal pull-up or pull-down resistors is not available for safety reasons. Use your own resistor to pull the GPIO high or low.

Examples of devices that can be used with edge detection: simple switches and buttons, PIR motion sensors, reed switches, hall effect sensors, float switches, and more.

Device Setup

I2C Multiplexers

All devices that connected to the Raspberry Pi by the I2C bus need to have a unique address in order to communicate. Some sensors may have the same address (such as the AM2315), which prevents more than one from being connected at the same time. Others may provide the ability to change the address, however the address range may be limited, which limits by how many you can use at the same time. I2C multiplexers are extremely clever and useful in these scenarios because they allow multiple sensors with the same I2C address to be connected.

> TCA9548A: I2C Multiplexer link (I2C): Has 8 selectable addresses, so 8 multiplexers can be connected to one Raspberry Pi. Each multiplexer has 8 channels, allowing up to 8 devices/sensors with the same address to be connected to each multiplexer. 8 multiplexers x 8 channels = 64 devices/sensors with the same I2C address.

TCA9545A: I2C Bus Multiplexer link (I2C): This board works a little differently than the TCA9548A, above. This board actually creates 4 new I2C busses, each with their own selectable voltage, either 3.3 or 5.0 volts. Instructions to enable the Device Tree Overlay are at https://github.com/camrex/i2c-mux-pca9545a. Nothing else needs to be done in Mycodo after that except to select the correct I2C bus when configuring a sensor.

Analog to Digital Converters

An analog to digital converter (ADC) allows the use of any analog sensor that outputs a variable voltage. A voltage divider may be necessary to attain your desired range.

ADS1x15 link ±4.096 (I2C)

MCP342x link ±2.048 (I2C)

Device Specific Information

Temperature Sensors

Raspberry Pi

The Raspberry Pi has an integrated temperature sensor on the BCM2835 SoC that measure the temperature of the CPU/GPU. This is the easiest sensor to set up in Mycodo, as it is immediately available to be used.

Atlas Scientific PT-1000

The PT1000 temperature probe is a resistance type thermometer. Where PT stands for platinum and 1000 is the measured resistance of the probe at 0°C in ohms (1k at 0°C).

Specifications

- Accuracy ±(0.15 + (0.002*t))
- Probe type: Class A Platinum, RTD (resistance temperature detector)
- Cable length: 81cm (32")
- Cable material: Silicone rubber
- 30mm sensing area (304 SS)
- 6mm Diameter
- BNC Connector
- Reaction Time: 90% value in 13 seconds
- Probe output: analog
- Full temperature sensing range: -200°C to 850°C
- Cable max temp 125°C
- Cable min temp -55°C

DS18B20

The DS18B20 is a 1-Wire digital temperature sensor from Maxim IC. Each sensor has a unique 64-Bit Serial number, allowing for a huge number of sensors to be used on one data bus (GPIO 4).

Specifications

- Usable temperature range: -55 to 125°C (-67°F to +257°F)
- 9 to 12 bit selectable resolution
- Uses 1-Wire interface- requires only one digital pin for communication
- Unique 64 bit ID burned into chip
- Multiple sensors can share one pin
- ±0.5°C Accuracy from -10°C to +85°C
- Temperature-limit alarm system
- Query time is less than 750ms
- Usable with 3.0V to 5.5V power/data

TMP006, TMP007

The TMP006 Breakout can measure the temperature of an object without making contact with it. By using a thermopile to detect and absorb the infrared energy an object is emitting, the TMP006 Breakout can determine how hot or cold the object is.

Specifications

- Usable temperature range: -40°C to 125°C
- Optimal operating voltage of 3.3V to 5V (tolerant up to 7V max)

Temperature, Humidity Sensors

AM2315

Specifications

- 0-100% humidity readings with 1% (10-90% RH) and 3% (0-10% RH and 90-100% RH) accuracy
- -20 to 80°C temperature readings ±0.1°C typical accuracy
- 3.5 to 5.5V power and I/O
- 10 mA max current use during conversion (while requesting data)
- No more than 0.5 Hz sampling rate (once every 2 seconds)

DHT11

Specifications

- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)
- 20-80% humidity readings with 5% accuracy
- 0-50°C temperature readings ±2°C accuracy
- No more than 1 Hz sampling rate (once every second)

DHT22, AM2302

Compared to the DHT11, this sensor is more precise, more accurate and works in a bigger range of temperature/humidity, but its larger and more expensive. The wiring is the same as the DHT11.

Specifications

- 0-100% humidity readings with 2% (10-90% RH) and 5% (0-10% RH and 90-100% RH) accuracy
- -40 to 80°C temperature readings ±0.5°C accuracy
- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)
- No more than 0.5 Hz sampling rate (once every 2 seconds)

HTU21D

Specifications

- 0-100% humidity readings with 2% (20-80% RH) and 2%-5% (0-20% RH and 80-100% RH) accuracy
- Optimum accuracy measurements within 5 to 95% RH
- -30 to 90°C temperature readings ±1°C typical accuracy

SHT1x

(SHT10, SHT11, SHT15)

Specifications

- 0-100% humidity readings with 2%-5% (10-90% RH) and 2%-7.5% (0-10% RH and 90-100% RH) accuracy
- -40 to 125°C temperature readings ±0.5°C, ±0.4°C, and ±0.3°C typical accuracy (respectively)
- 2.4 to 5.5V power and I/O
- No more than 0.125 Hz sampling rate (once every 8 seconds)

SHT7x

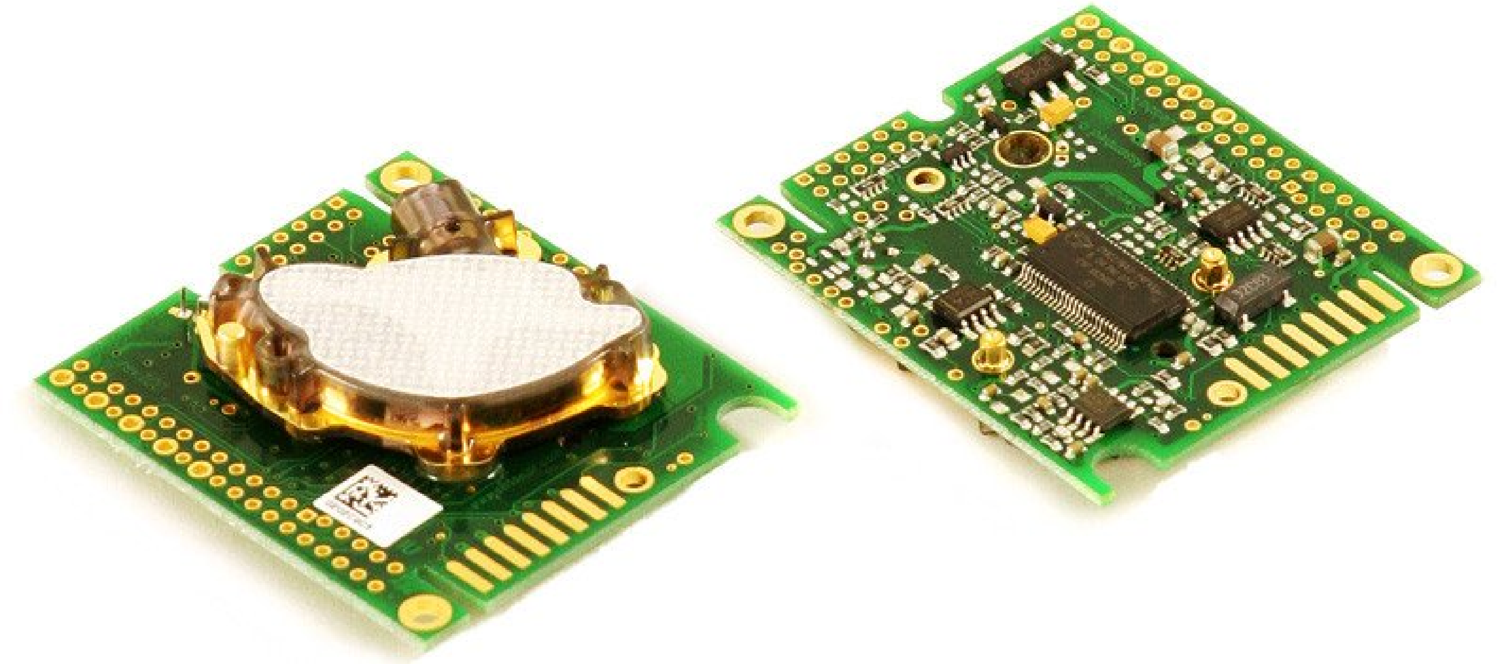
(SHT71, SHT75)

Specifications

- 0-100% humidity readings with 2%-3% (10-90% RH) and 2%-5% (0-10% RH and 90-100% RH) accuracy
- -40 to 125°C temperature readings ±0.4°C and ±0.3°C typical accuracy (respectively)
- 2.4 to 5.5V power and I/O
- No more than 0.125 Hz sampling rate (once every 8 seconds)

CO_2 Sensors

K-30



Be very careful when connecting the K-30, as there is no reverse-voltage protection. Improper connections could destroy your sensor.

Wiring instructions for the Raspberry Pi can be found here.

Specifications

- 0 – 10,000 ppm (0-5,000 ppm within specifications)
- Repeatability: ±20 ppm ±1% of measured value within specifications
- Accuracy: ±30 ppm ±3% of measured value within specifications
- Non-dispersive infrared (NDIR) technology
- Sensor life expectancy: > 15 years
- Self-diagnostics: complete function check of the sensor module
- Warm-up time: < 1 min. (@ full specs < 15 min)
- 0.5 Hz sampling rate (once every 2 seconds)

Moisture Sensors

Chirp

The Chirp sensor measures moisture, light, and temperature.

Specifications

- Vin: 3 to 5V
- I2C 7-bit address 0x77

pH Sensors

Atlas Scientific pH

The Atlas Scientific pH sensor measures the pH of a liquid.

Specifications

- Probe Max Pressure: 690 kPa (100PSI)
- Probe Max Depth 60 M (197 ft)
- Probe Weight: 49 grams
- Probe can be fully submerged in fresh or salt water indefinitely

Pressure Sensors

BME280

The BME280 is the next-generation of sensors from Bosch, and is the upgrade to the BMP085/BMP180/BMP183 - with a low altitude noise of 0.25m and the same fast conversion time. It has the same specifications, but can use either I2C or SPI.

Specifications

- 300-1100 hPa (9000m to -500m above sea level)
- -40 to +85°C operational range
- ±3% humidity accuracy tollerance
- ±1% humidity hysteresis
- ±1 hPa pressure accuracy
- ±2°C temperature accuracy
- Vin: 3 to 5V
- Logic: 3 to 5V compliant
- I2C 7-bit address 0x76 or 0x77

BMP085, BMP180

The BMP180 is the next-generation of sensors from Bosch, and replaces the BMP085. It is completely identical to the BMP085 in terms of firmware/software/interfacing.

Specifications

- 300-1100 hPa (9000m to -500m above sea level)
- Up to 0.03hPa / 0.25m resolution
- -40 to +85°C operational range
- ±2°C temperature accuracy
- Vin: 3 to 5V
- Logic: 3 to 5V compliant
- I2C 7-bit address 0x77

Luminosity Sensors

BH1750

The BH1750 is an I2C luminosity sensor that provides a digital value in lux (Lx) over a range of 1 - 65535 lx.

TSL2561

The TSL2561 SparkFun Luminosity Sensor Breakout is a sophisticated light sensor which has a flat response across most of the visible spectrum. Unlike simpler sensors, the TSL2561 measures both infrared and visible light to better approximate the response of the human eye. And because the TSL2561 is an integrating sensor (it soaks up light for a predetermined amount of time), it is capable of measuring both small and large amounts of light by changing the integration time.

Specifications

- Light range: 0.1 - 40k+ Lux
- Vin: 3V and a low supply
- Max current: 0.6mA.

Analog to Digital Converters

ADS1x15

(ADS1015, ADS1115)

Specifications

- Interface: I2C
- I2C 7-bit addresses 0x48 - 0x4B
- Input channels: 2 (differential), 4 (single-ended)
- Power: 2.0V to 5.5V
- Sample Rate: 1015: 128SPS to 3.3kSPS, 1115: 8SPS to 860SPS
- Resolution: 1015: 12-bit, 1115: 16-bit

MCP342x

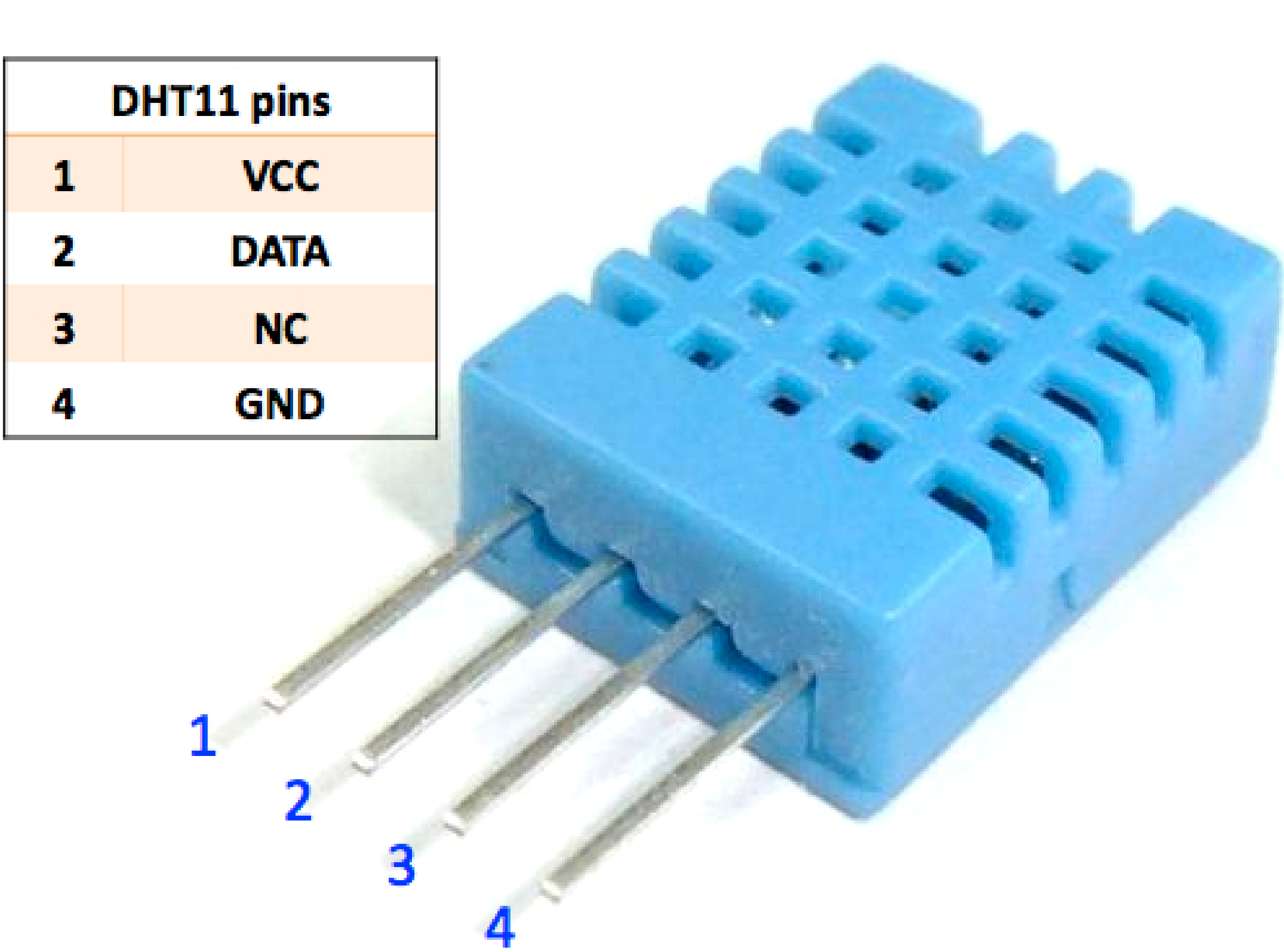
(MCP3422, MCP3423, MCP3424, MCP3426, MCP3427, MCP3428)

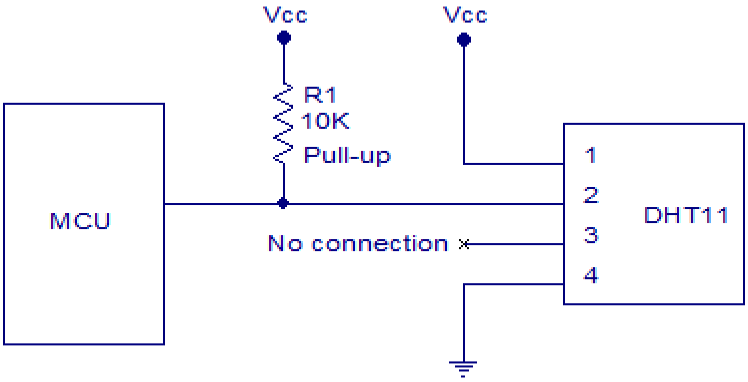
Specifications

- Interface: I2C
- I2C 7-bit addresses 0x68 - 0x6F
- MCP3422: 2 channel, 12, 14, 16, or 18 bit
- MCP3423: 2 channel, 12, 14, 16, or 18 bit
- MCP3424: 4 channel, 12, 14, 16, or 18 bit
- MCP3426: 2 channel, 12, 14, or 16 bit
- MCP3427: 2 channel, 12, 14, or 16 bit
- MCP3428: 4 channel, 12, 14, or 16 bit

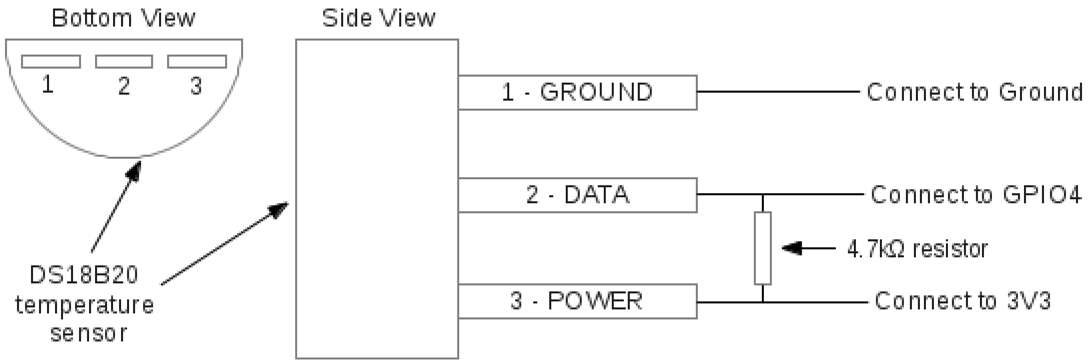
Diagrams

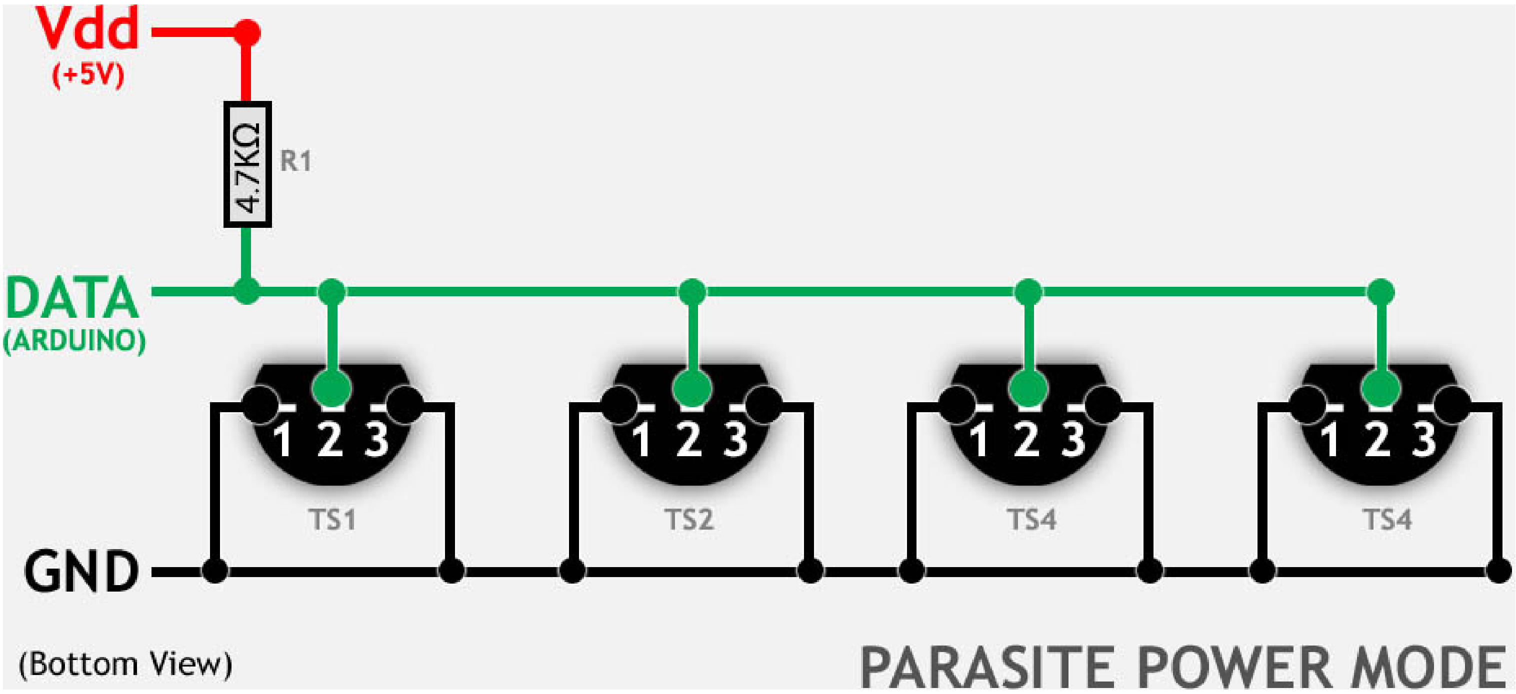
DHT11 Diagrams

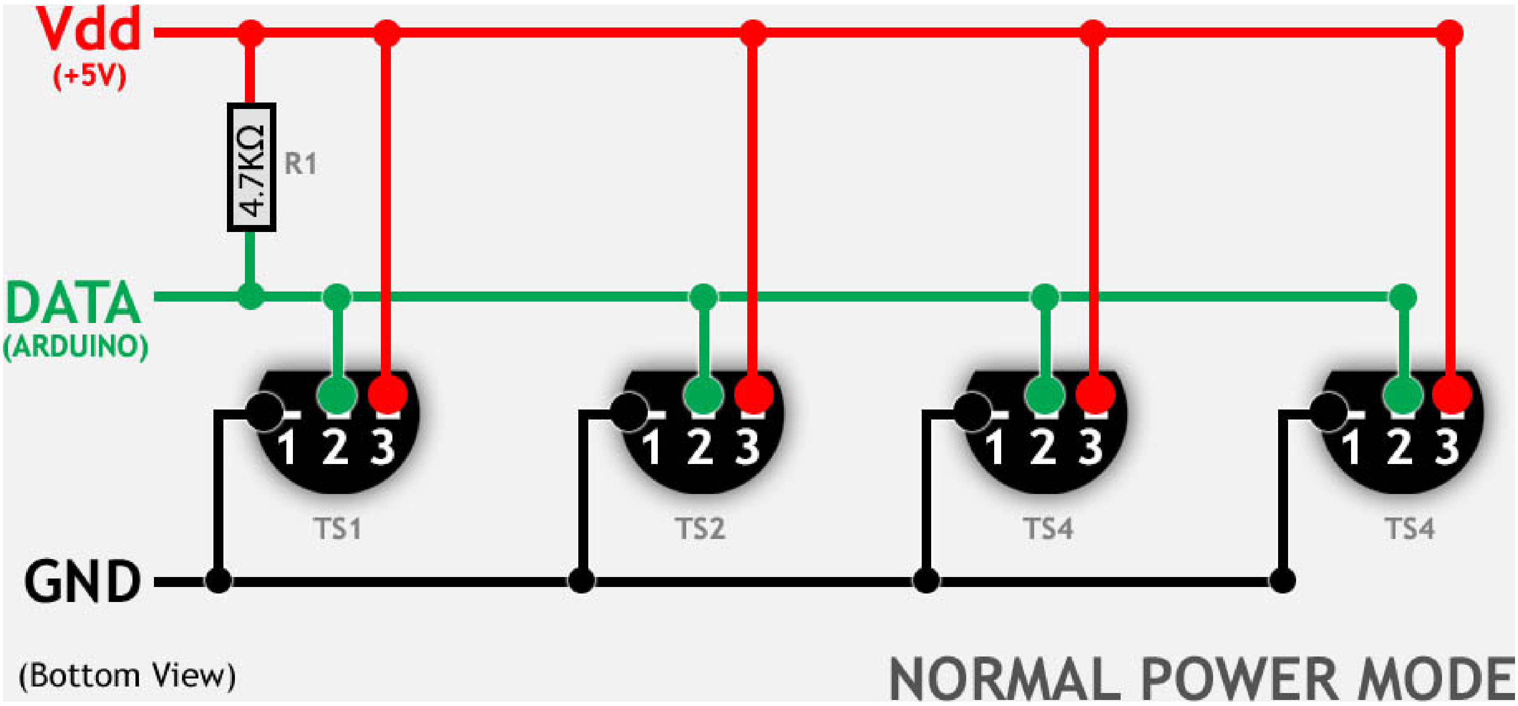




DS18B20 Diagrams

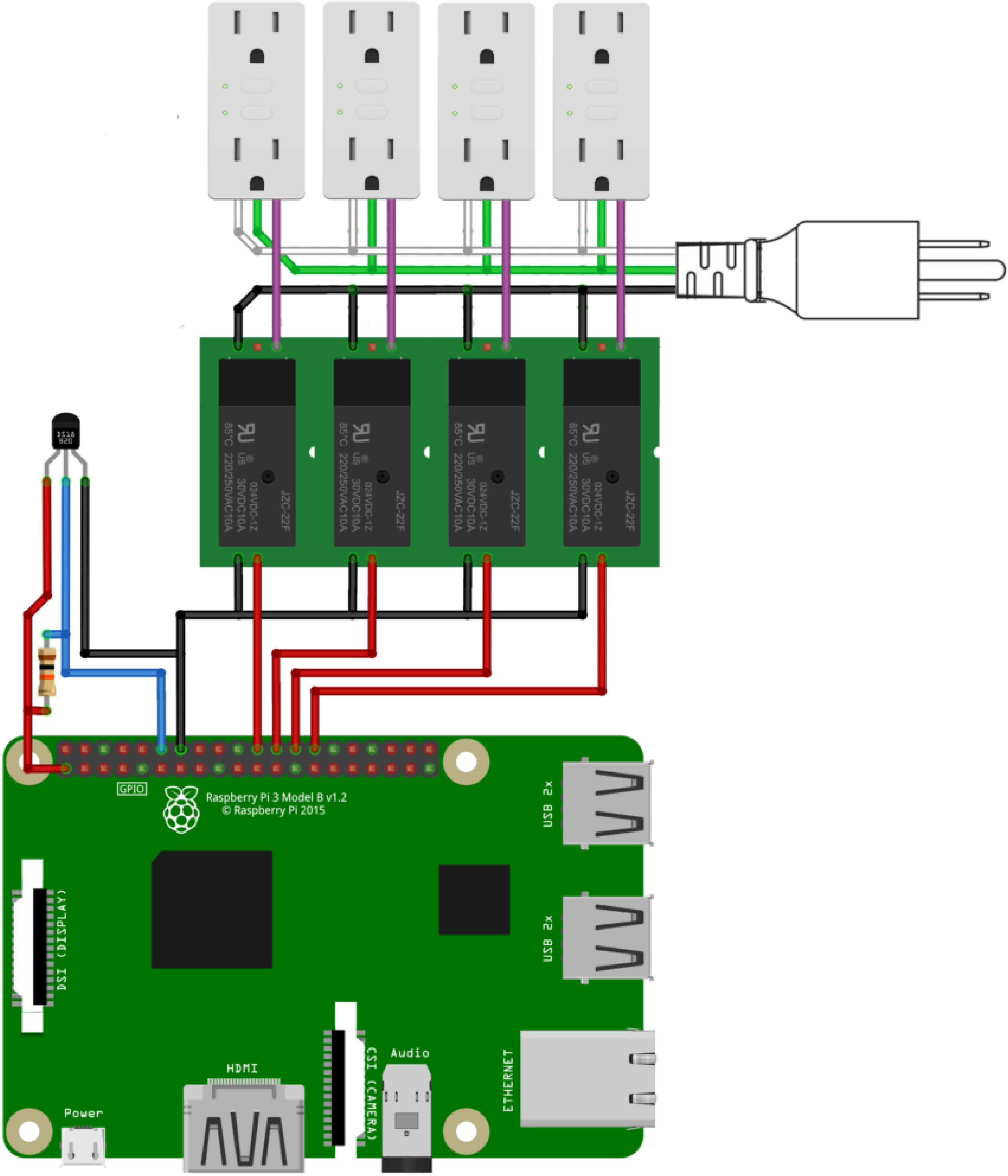




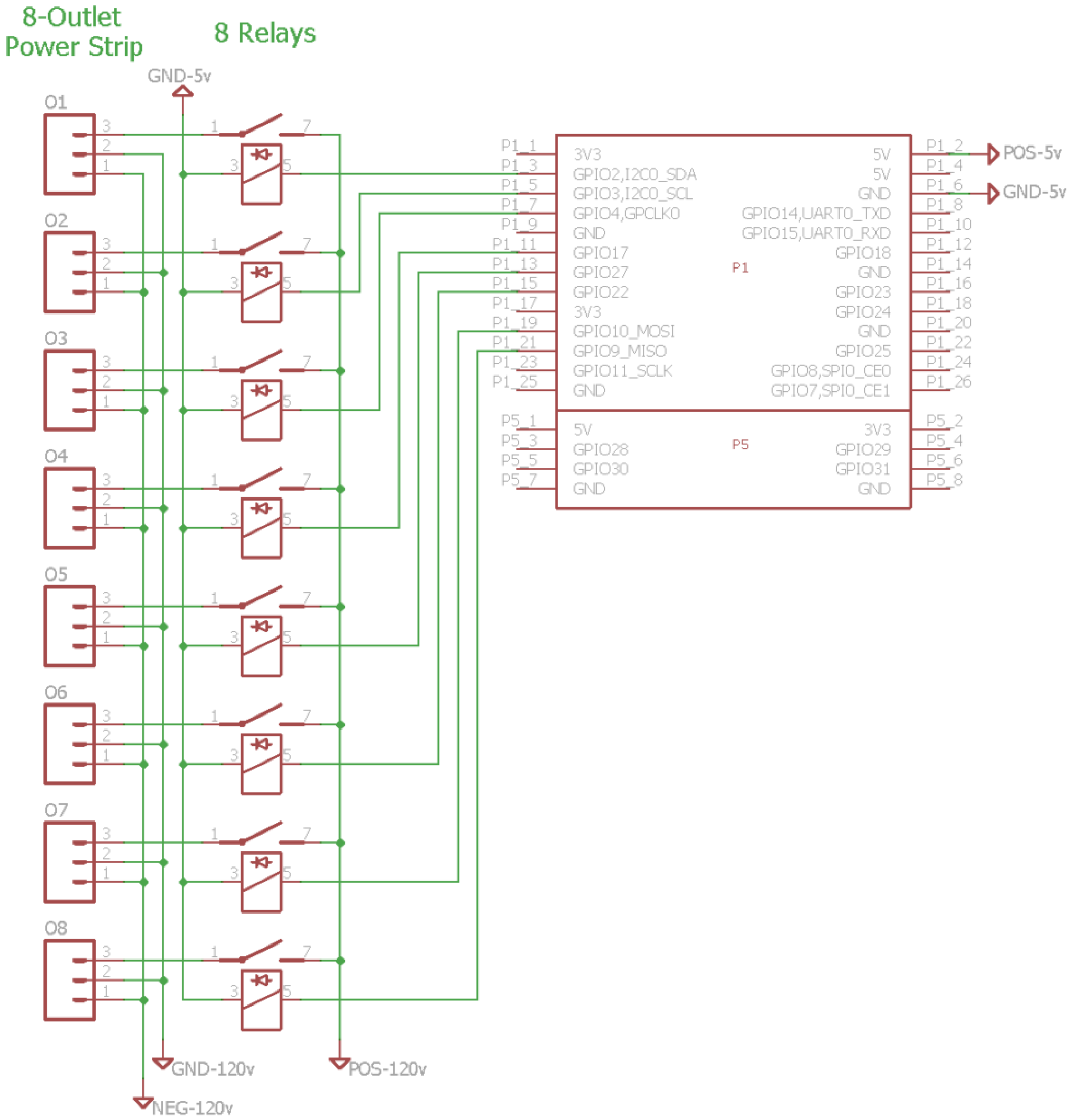


Raspberry Pi and Relay Diagrams

Raspberry Pi, 4 relays, 4 outlets, 1 DS18B20 sensor.



Raspberry Pi, 8 relays, 8 outlets.


8-Outlet
Power Strip
8 Relays
GND-5v
O1
O2
O3
O4
O5
O6
O7
O8
P1
3V3
GPIO2,I2C0_SDA
GPIO3,I2C0_SCL
GPIO4,GPCLK0
GND
GPIO17
GPIO27
GPIO22
3V3
GPIO10_MOSI
GPIO9_MISO
GPIO11_SCLK
GND
5V
5V
GND
GPIO14,UART0_TXD
GPIO15,UART0_RXD
GPIO18
GND
GPIO23
GPIO24
GND
GPIO25
GPIO8,SPI0_CE0
GPIO7,SPI0_CE1
P5
5V
GPIO28
GPIO30
GND
3V3
GPIO29
GPIO31
GND
P1_1
P1_3
P1_5
P1_7
P1_9
P1_11
P1_13
P1_15
P1_17
P1_19
P1_21
P1_23
P1_25
P1_2
P1_4
P1_6
P1_8
P1_10
P1_12
P1_14
P1_16
P1_18
P1_20
P1_22
P1_24
P1_26
P5_1
P5_3
P5_5
P5_7
P5_2
P5_4
P5_6
P5_8
POS-5v
GND-5v
GND-120v
POS-120v
NEG-120v