

# Mycodo Manual

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## About Mycodo

Mycodo is an automated monitoring and regulation system that was built to run on the Raspberry Pi (versions Zero, 1, 2, and 3).

Originally designed to cultivate edible mushrooms, Mycodo has grown to include the ability to do much more, including cultivating plants, culturing microorganisms, maintaining honey bee apiary homeostasis, incubating animals and eggs, maintaining aquatic systems, aging cheeses, fermenting foods and tobacco, cooking food (vous-vide), and more.

The system comprises a backend (daemon) and a frontend (user interface). The backend conducts measurements from sensors and devices, then coordinate a diverse set of responses to those measurements, including the ability to modulate outputs (relays, PWM, wireless outlets), regulate environmental conditions with electrical devices under PID control (steady regulation or changing over time), schedule timers, capture photos and stream video, trigger actions when measurements meet certain conditions (modulate relays, execute commands, notify by email, etc.), and more. The frontend is a web interface that enables easy navigation and configuration from any browser-enabled device.

## Brief Overview

There are a number of different uses for Mycodo. Some users simply store sensor measurements to monitor conditions remotely from their phone, others regulate the environmental conditions of a physical space, while others capture motion-activated or timelapse photography, and more.

Input controllers acquire measurements and store them in a time series database. Measurements typically come from sensors, but may also be configured to use the return value of a linux command, making integrating new inputs very easy.

Output controllers produce changes to the general input/output (GPIO) pins or may be configured to execute linux commands in order to allow an unlimited number of potential uses. There are a few different types of outputs: simple switching of pins (HIGH/LOW), generating pulse-width modulated (PWM) signals, switching 433 MHz wireless relays, and linux command execution. The most common setup is using a relay to switch electrical devices on and off.

When Inputs and Outputs are combined, PID controllers may be used to create a feedback loop that uses the Output device to modulate an environmental condition the Input detects. Certain Inputs may be coupled with certain Outputs to create a variety of different control and regulation applications. Beyond simple regulation, Methods may be used to create changing setpoints over time, enabling such things as thermal cyclers, reflow ovens, environmental simulation for terrariums, food and beverage fermentation or curing, and cooking food (sous-vide), to name a few.

Conditionals can be set to trigger events based on specific dates and times or according to durations of time. Conditionals are fairly basic, but can be configured in very complex ways. Don't underestimate a good conditional.

## Frequently Asked Questions

*What should I do if I have an issue?*

First, read through this manual to make sure you understand how the system works and you're using the system properly. Also check out the Mycodo Wiki. You may even want to look through recent GitHub Issues. If you haven't resolved your issue by this point, make a New GitHub Issue describing the issue and attaching a sufficient amount of evidence (screenshots, log files, etc.) to aid in diagnosing the issue.

---

*How do I add an Input (like a sensor) to the system if it's not currently supported?*

Currently, adding an Input device that's not currently supported can be achieved by two different methods:

The first involves editing several internal Mycodo files. There has been effort to make the addition process as simple as possible. See the Adding Support for a New Input Wiki page for how to do this. All changes will be lost during an upgrade, therefore it is suggested to make a GitHub pull request with your changes to permanently integrate them into Mycodo.

The second way to add an Input is to create a script that obtains and returns a numerical value when executed in the linux system of the Raspberry Pi. This script may be configured to be executed by a “Linux Command” Input type. This will periodically execute the command and store the returned value to the database for use with the rest of the Mycodo system.

---

### *How do I set up simple regulation?*

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 as the input and an electric heater (or cooler) as the output.
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). Remember to select a relay that can handle the load and doesn't exceed the maximum current draw from the Raspberry Pi GPIO pins.
3. See the Device Specific Information for information about what sensors are supported. Acquire sensor(s) and relay(s) and connect them to the Raspberry Pi according to the manufacturer's instructions.
4. On the **Data** page, create a new input using the dropdown to select the correct sensor or input device. Configure the input with the correct communication pins and other options. Activate the input to begin recording measurements to the database.
5. Go to the **Info -> Live Measurements** page to ensure there is recent data being acquired from the input.
6. On the **Output** 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. A pulse-width modulated (PWM) output may also be used, among others.
7. Test the relay by switching it On and Off or generating a PWM signal from the **Output** 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 **Function** page, create a PID controller with the appropriate input, output, and other parameters. Activate the PID controller.
9. On the **Info -> Dashboard** page, create a graph that includes the input measurement, the output that is being used by the PID, and the PID output and setpoint. This provides a good visualization for tuning the PID. See Quick Setup Examples for a greater detail of this process and tuning tips.

---

### *Can I communicate with Mycodo from the command line?*

Yes, ~/Mycodo/mycodo/mycodo\_client.py has this functionality, but there's a lot to be desired. Below may not be the most current list of commands, so it's recommended to execute the installed symlink `mycodo-client -h` to see a full list with descriptions.

```
pi@raspberrypi:~/Mycodo $ mycodo-client --help
usage: mycodo-client [-h] [--activatecontroller CONTROLLER ID]
                    [--deactivatecontroller CONTROLLER ID] [--pid_pause ID]
                    [--pid_hold ID] [--pid_resume ID] [--pid_get_setpoint ID]
                    [--pid_get_error ID] [--pid_get_integrator ID]
                    [--pid_get_derivator ID] [--pid_get_kp ID]
                    [--pid_get_ki ID] [--pid_get_kd ID]
                    [--pid_set_setpoint ID SETPOINT]
                    [--pid_set_integrator ID INTEGRATOR]
                    [--pid_set_derivator ID DERIVATOR] [--pid_set_kp ID KP]
                    [--pid_set_ki ID KI] [--pid_set_kd ID KD] [-c] [--ramuse]
                    [--relayoff RELAYID] [--relayon RELAYID]
                    [--duration SECONDS] [--dutyicycle DUTYCYCLE] [-t]
```

---

### *Can I variably-control the speed of motors or other devices with the PWM output signal from the PID?*

Yes, as long as you have the proper hardware to do that. The PWM signal being produced by the PID should be handled appropriately, whether by a fast-switching solid state relay, an AC modulation circuit, DC modulation circuit, or something else.

---

## Upgrading

If you already have Mycodo installed (version  $\geq 4.0.0$ ), you can perform an upgrade to the latest Mycodo Release by either using the Upgrade option in the web interface (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
```

## Features

The following sections describe the essential modules of Mycodo that can be used to perform functions or communicate with other parts of Mycodo. Each section performs specific tasks or groups of related tasks.

### Data

Data includes controllers that produce and store data in the measurement database. Input controllers generally acquire measurements from sensors, but they may also come from executed commands. Math controllers, on the other hand, perform math on already-stored values to create new values that are stored.

### Input

Inputs (such as sensors or analog signals) measure environmental conditions, which will be stored in a time-series database (InfluxDB). This database will provide measurements for Graphs, LCDs, PID Controllers, Conditional Statements, and other parts of Mycodo to operate from.

In addition to several supported sensors and devices, a Linux command may be specified that will be executed and the return value stored in the measurement database to be used throughout the Mycodo system.

Setting	Description
Activate	After the sensor has been properly configured, activation begins acquiring measurements from the sensor. Any activated conditional statements will now be operating.
Deactivate	Deactivation stops measurements from being acquired from the sensor. All associated conditional statements will cease to operate.
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.
Power Output	Select an output that powers the sensor. This enables powering cycling (turn off then on) when the sensor returns 3 consecutive errors to attempt to fix the issue. Transistors may also be used instead of a relay (note: NPN transistors are preferred over PNP for powering sensors).
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. or other.
I2C Bus	The bus to be used to communicate with the I2C address.
Period (seconds)	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.
Measurement Unit	Select the unit to save the measurement as (only available for select measurements).

Setting	Description
Pre Output	If you require a output 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 output number that will be activated. The output will be activated for a duration defined by the Pre Duration, then once the output turns off, a measurement by the sensor is made.
Pre Output Duration (seconds)	This is the duration of time that the Pre Output runs for before the sensor measurement is obtained.
Pre Output During Measurement	If enabled, the Pre Output stays on during the acquisition of a measurement. If disabled, the Pre Output is turned off directly before acquiring a measurement.
Command	A linux command (executed as the user 'mycodo') that the return value becomes the measurement
Command Measurement	The measured condition (e.g. temperature, humidity, etc.) from the linux command
Command Units	The units of the measurement condition from the linux command
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.
Bounce Time (ms)	Edge sensors only: This is the number of milliseconds to bounce the input signal. This is commonly called debouncing a signal < <a href="http://kylegabriel.com/projects/2016/02/morse-code-translator.html#debouncing">http://kylegabriel.com/projects/2016/02/morse-code-translator.html#debouncing</a> >____. and may be necessary if using a mechanical circuit.
Reset Period (seconds)	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.
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".
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".
BT Adapter	The Bluetooth adapter to communicate with the input.
Clock Pin	The GPIO (using BCM numbering) connected to the Clock pin of the ADC
CS Pin	The GPIO (using BCM numbering) connected to the CS pin of the ADC
MISO Pin	The GPIO (using BCM numbering) connected to the MISO pin of the ADC
MOSI Pin	The GPIO (using BCM numbering) connected to the MOSI pin of the ADC
RTD Probe Type	Select to measure from a PT100 or PT1000 probe.
Resistor Reference (Ohm)	If your reference resistor is not the default (400 Ohm for PT100, 4000 Ohm for PT1000), you can manually set this value. Several manufacturers now use 430 Ohm resistors on their circuit boards, therefore it's recommended to verify the accuracy of your measurements and adjust this value if necessary.
Channel	Analog-to-digital converter only: This is the channel to obtain the voltage measurement from the ADC.
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".
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 is 1 - 60, and a voltage of 0.5 is measured, in addition to 0.5 being stored in the database, 30 will be stored as well. This enables creating calibrated scales to use with your particular circuit.

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.
Weighting	The This is a number between 0 and 1 and indicates how much the old reading affects the new reading. It defaults to 0 which means the old reading has no effect. This may be used to smooth the data.
Pulses Per Rev	The number of pulses for a complete revolution.
Port	The server port to be queried (Server Port Open input).
Times to Check	The number of times to attempt to ping a server (Server Ping input).
Deadline (seconds)	The maximum amount of time to wait for each ping attempt, after which 0 (offline) will be returned (Server Ping input).

## Math

Math controllers allow one or more Inputs to have math applied to produce a new value that may be used within Mycodo.

Type	Description
Average (Multiple Measurements)	Stores the statistical mean of multiple selected measurements.
Average (Single Measurement)	Stores the statistical mean of one selected measurement over a duration of time determined by the Max Age (seconds) option.
Difference	Stores the mathematical difference (value_1 -value_2).
Equation	Stores the calculated value of an equation.
Median	Stores the statistical median from the selected measurements.
Maximum	Stores the largest measurement from the selected measurements.
Minimum	Stores the smallest measurement from the selected measurements.
Humidity	Calculates and stores the percent relative humidity from the dry-bulb and wet-bulb temperatures, and optional pressure.
Verification	Ensures the greatest difference between any selected Inputs is less than Max Difference, and if so, stores the average of the selected measurements.

Setting	Description
Input	Select the Inputs to use with the particular Math controller
Period (seconds)	The duration of time between calculating and storing a new value
Max Age (seconds)	The maximum allowed age of the Input measurements. If an Input measurement is older than this period, the calculation is cancelled and the new value is not stored in the database. Consequently, if another controller has a Max Age set and cannot retrieve a current Math value, it will cease functioning. A PID controller, for instance, may stop regulating if there is no new Math value created, preventing the PID controller from continuing to run when it should not.
Measurement	This is the condition being measured. For instance, if all of the selected measurements are temperature, this should also be temperature. A list of the pre-defined measurements that may be used is below.
Units	This is the units to display along with the measurement, on Graphs. If a pre-defined measurement is used, this field will default to the units associated with that measurement.
Reverse Equation	For Difference calculations, this will reverse the equation order, from <code>value_1 - value_2</code> to <code>value_2 - value_1</code> .
Absolute Value	For Difference calculations, this will yield an absolute value (positive number).
Max Difference	If the difference between any selected Input is greater than this value, no new value will be stored in the database.
Dry-Bulb Temperature	The measurement that will serve as the dry-bulb temperature (this is the warmer of the two temperature measurements)
Wet-Bulb Temperature	The measurement that will serve as the wet-bulb temperature (this is the colder of the two temperature measurements)

Setting	Description
Pressure	This is an optional pressure measurement that can be used to calculate the percent relative humidity. If disabled, a default 101325 Pa will be used in the calculation.
Equation	An equation that will be solved with Python's eval() function. Let "x" represent the input value. Valid equation symbols include: + - * / ^

## Output

Outputs are various signals that can be generated that operate devices. An output can be a PWM signal, a simple HIGH/LOW signal to operate a relay, or a 433MHz signal to switch a radio frequency-operated relay, or an execution of a command on the linux system Mycodo runs on.

### PWM

Pulse-width modulation (PWM) is a modulation technique used to encode a message into a pulsing signal, at a specific frequency in Hertz (Hz). The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. The rate (or frequency) at which the power supply must switch can vary greatly depending on load and application, for example

Switching has to be done several times a minute in an electric stove; 120 Hz in a lamp dimmer; between a few kilohertz (kHz) to tens of kHz for a motor drive; and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

PWM pins can be set up on the Output page, then it may be used by a PWM PID Controller.

Setting	Description
Library	Select the method for producing the PWM signal. Hardware pins can produce up to a 30 MHz PWM signal, while any other (non-hardware PWM) pin can produce up to a 40 kHz PWM signal. See the table, below, for the hardware pins on various Pi boards.
BCM Pin	This is the GPIO that will output the PWM signal, using BCM numbering.
Hertz	This is frequency of the PWM signal.
Duty Cycle	This is the proportion of the time on to the time off, expressed in percent (0 - 100).
Current Draw (amps)	This is the current draw, in amps, when the duty cycle is 100%. Note: this value should be calculated based on the voltage set in the Output Usage Settings.

### Non-hardware PWM Pins

When using non-hardware PWM pins, there are only certain frequencies that can be used. These frequencies in Hertz are 40000, 20000, 10000, 8000, 5000, 4000, 2500, 2000, 1600, 1250, 1000, 800, 500, 400, 250, 200, 100, and 50 Hz. If you attempt to set a frequency that is not listed here, the nearest frequency from this list will be used.

### Hardware PWM Pins

The exact frequency may be set when using hardware PWM pins. The same PWM channel is available on multiple GPIO. The latest frequency and duty cycle setting will be used by all GPIO pins which share a PWM channel.

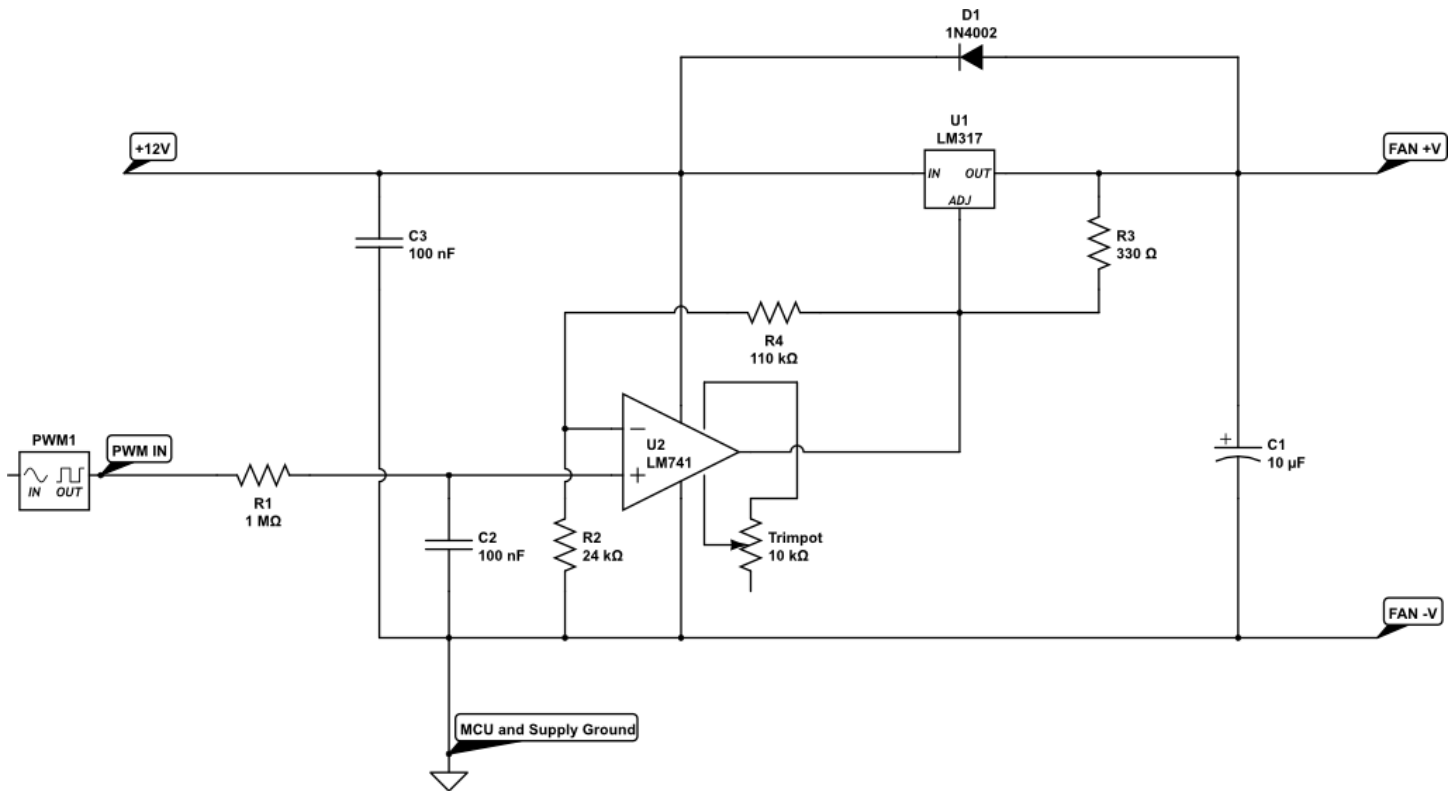


BCM Pin	PWM Channel	Raspberry Pi Version
12	0	All models except A and B
13	1	All models except A and B
18	0	All models
19	1	All models except A and B
40	0	Compute module only
41	1	Compute module only
45	1	Compute module only
52	0	Compute module only
53	1	Compute module only

### Schematics for DC Fan Control

Below are hardware schematics that enable controlling direct current (DC) fans from the PWM output from Mycodo.

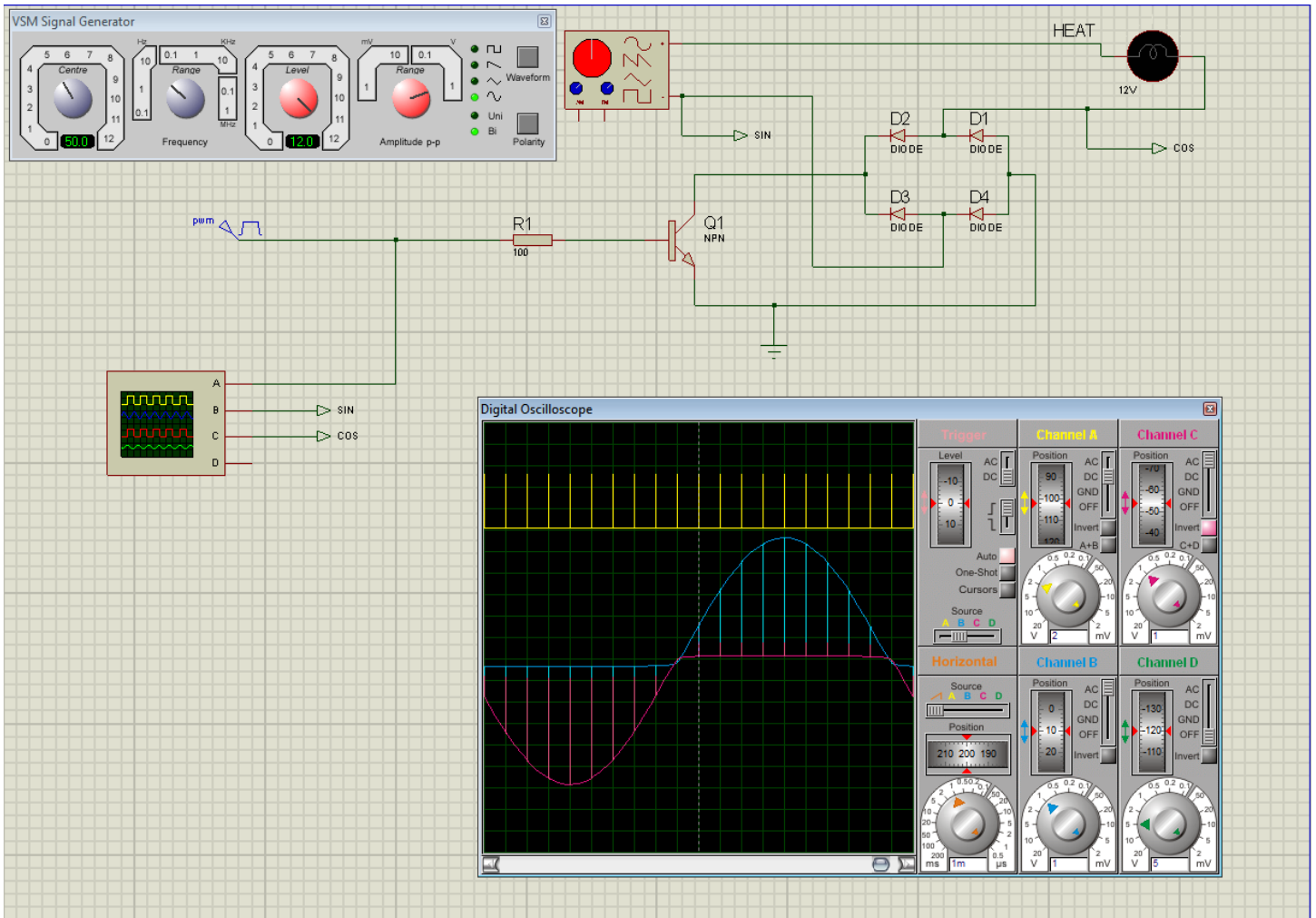
PWM output controlling a 12-volt DC fan (such as a PC fan)



### Schematics for AC Modulation

Below are hardware schematics that enable the modulation of alternating current (AC) from the PWM output from Mycodo.

PWM output modulating alternating current (AC) at 1% duty cycle



PWM output modulating alternating current (AC) at 50% duty cycle



PWM output modulating alternating current (AC) at 99% duty cycle



## 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.

Add and configure outputs in the Output tab. Outputs must be properly set up before PID regulation can be achieved.

## Wired

To set up a wired relay, 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”.

## Wireless

Certain 433 MHz wireless relays may be used, however you will need to set the pin of the transmitter (using BCM numbering), pulse length, bit length, protocol, on command, and off command. To determine your On and Off commands, connect a 433 MHz receiver to your Pi, then run the receiver script, below, replacing 17 with the pin your receiver is connected to (BCM numbering), and press one of the buttons (either on or off) on your remote to detect the numeric code associated with that button.

```
sudo ~/Mycodo/env/bin/python ~/Mycodo/mycodo/devices/wireless_433mhz.py -d 2 -g 17
```

433 MHz wireless relays have been successfully tested with SMAKN 433MHz RF Transmitters/Receivers and Etekcitcity Wireless Remote Control Electrical Outlets (see Issue 88 for more information). If you have a 433 MHz transmitter/receiver and a wireless relay that does not work with the current code, submit a new issue with details of your hardware.

## Command

Another option for output control is to execute a terminal command when the output is turned on, off, or a duty cycle. Commands will be executed as the user 'root'.

Wireless and Command Output Note: Since the wireless protocol only allows 1-way communication to 433 MHz devices, wireless relays are assumed to be off until they are turned on, and therefore will appear red (off) when added. If a wireless relay is turned off or on outside Mycodo (by a remote, for instance), Mycodo will **not** be able to determine the state of the relay and will indicate whichever state the relay was last. This is, if Mycodo turns the wireless relay on, and a remote is used to turn the relay off, Mycodo will still assume the relay is on.

Setting	Description
BCM Pin	This is the GPIO that will be the signal to the output, using BCM numbering.
On Trigger	This is the state of the GPIO to signal the output to turn the device on. HIGH will send a 3.3-volt signal and LOW will send a 0-volt signal. If you output 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.
WiringPi Pin	This is the GPIO that will be the signal to the output, using WiringPi numbering.
Protocol	This is the protocol to use to transmit via 433MHz. Default is 1, but if this doesn't work, increment the number.
Pulse Length	This is the pulse length to transmit via 433MHz. Default is 189 ms.
Bit Length	This is the bit length to transmit via 433MHz. Default is 24-bit.
On Command	This is the command used to turn the output on. For wireless relays, this is the numerical command to be transmitted, and for command outputs this is the command to be executed.
Off Command	This is the command used to turn the output off. For wireless relays, this is the numerical command to be transmitted, and for command outputs this is the command to be executed.
PWM Command	This is the command used to set the duty cycle. The string "((duty_cycle))" in the command will be replaced with the actual duty cycle before the command is executed. Ensure "((duty_cycle))" is included in your command for this feature to work correctly.
Current Draw (amps)	This is the amount of current the device powered by the output draws. Note: this value should be calculated based on the voltage set in the Output Usage Settings.
Start State	This specifies whether the output should be ON or OFF when mycodo initially starts. Wireless relays have an additional option 'Neither' which will not issue an on or off command when Mycodo starts or stops.
Seconds to turn On	This is a way to turn a output on for a specific duration of time. This can be useful for testing the outputs and powered devices or the measured effects a device may have on an environmental condition.

## Function

Functions couple Inputs with Outputs to perform specific tasks. For example, this could be regulation of temperature with a temperature sensor and heater with a PID Controller.

### PID Controller

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 control variable will not be updated and the PID will not turn on the associated outputs. Settings can be changed without losing current PID output values.
Hold	When held, the control variable will not be updated but the PID will turn on the associated outputs, Settings can be changed without losing current PID output values.
Resume	Resume a PID controller from being held or paused.
Setpoint	This is the specific point you would like the environment to be regulated at. For example, if you would like the humidity regulated to 60%, enter 60.
Band (+/- Setpoint)	Hysteresis option. If set to a non-0 value, the setpoint will become a band, which will be between the band_max=setpoint+band and band_min=setpoint-band. If Raising, the PID will raise above band_max, then wait until the condition falls below band_min to resume regulation. If Lowering, the PID will lower below band_min, then wait until the condition rises above band_max to resume regulating. If set to Both, regulation will only occur to the outside min and max of the band, and cease when within the band. Set to 0 to disable Hysteresis.
Store Lower as Negative	Checking this will store all output variables (PID and output duration/duty cycle) as a negative values in the measurement database. This is useful for displaying graphs that indicate whether the PID is currently lowering or raising. Disable this if you desire all positive values to be stored in the measurement database.
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.”
Period	This is the duration between when the PID acquires a measurement, the PID is updated, and the output is modulated.
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 output. This is a safety measure to ensure the PID is only using recent measurements.
Raise Output	This is the output that will cause the particular environmental condition to rise. In the case of raising the temperature, this may be a heating pad or coil.
Min Duration (raise)	This is the minimum that the PID output must be before the Up Output turns on. If the PID output exceeds this minimum, the Up Output will turn on for the PID output number of seconds.
Max Duration (raise)	This is the maximum duration the Up Output is allowed to turn on for. If the PID output exceeds this number, the Up Output will turn on for no greater than this duration of time.
Lower Output	This is the output that will cause the particular environmental condition to lower. In the case of lowering the CO2, this may be an exhaust fan.
Min Duration (lower)	This is the minimum that the PID output must be before the Down Output turns on. If the PID output exceeds this minimum, the Down Output will turn on for the PID output number of seconds.
Max Duration (lower)	This is the maximum duration the Down Output is allowed to turn on for. if the PID output exceeds this number, the Down Output will turn on for no greater than this duration of time.
K <sub>P</sub>	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.
K <sub>I</sub>	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.
K <sub>D</sub>	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)

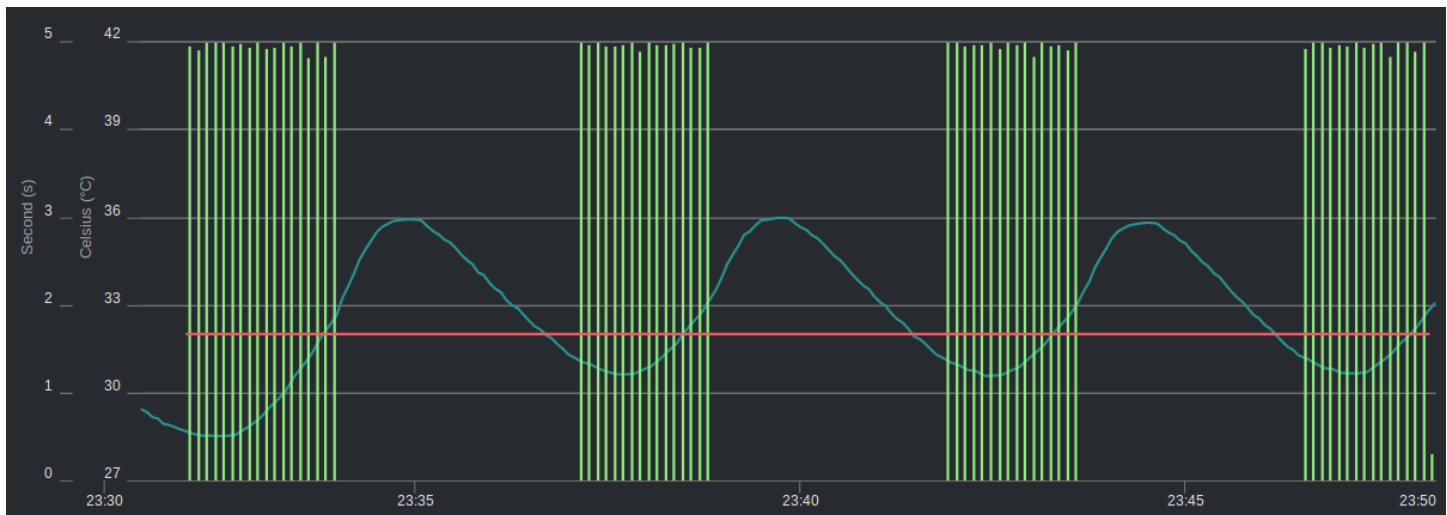
Setting	Description
Integrator Max	The maximum allowed integrator value, for calculating Ki_total: (Ki_total = Ki * integrator; and PID output = Kp_total + Ki_total + Kd_total)

## PID Autotune

The PID Autotune feature is useful for determining appropriate Kp, Ki, and Kd gains. The autotuner will manipulate an output and measure the response in the environment being measured by a sensor. It will take several cycles to determine the gains according to several rules. In order to use this feature, the PID controller must be properly configured, and a Noise Band and Outstep selected, then select "Start Autotune". The output of the autotuner will appear in the daemon log (Config -> Mycodo Logs -> Daemon). While the autotune is being performed, it is recommended to create a graph that includes the Input, Output, and PID Setpoint/Output in order to see what the PID Autotuner is doing and to notice any issues. If your autotune is taking a long time to complete, there may not be enough stability in the system being manipulated to calculate a reliable set of PID gains. This may be because there are too many disturbances to the system, or conditions are changing too rapidly to acquire consistent measurement oscillations. If this is the case, try modifying your system to reduce disturbances. Once the autotune successfully completes, disturbances may be reintroduced in order to further tune the PID controller to handle them.

Setting	Description
Noise band	This is the amount above the setpoint the measured condition must reach before the output turns off. This is also how much below the setpoint the measured condition must fall before the output turns back on.
Outstep	This is how many seconds the output will turn on every PID Period. For instance, to autotune with 50% power, ensure the Outstep is half the value of the PID Period.

Typical graph output will look like this:



And typical Daemon Log output will look like this:

```

2018-08-04 23:32:20,876 - mycodo.pid_3b533dff - INFO - Activated in 187.2 ms
2018-08-04 23:32:20,877 - mycodo.pid_autotune - INFO - PID Autotune started
2018-08-04 23:33:50,823 - mycodo.pid_autotune - INFO - 
2018-08-04 23:33:50,830 - mycodo.pid_autotune - INFO - Cycle: 19
2018-08-04 23:33:50,831 - mycodo.pid_autotune - INFO - switched state: relay step down
2018-08-04 23:33:50,832 - mycodo.pid_autotune - INFO - input: 32.52
2018-08-04 23:36:00,854 - mycodo.pid_autotune - INFO - 
2018-08-04 23:36:00,860 - mycodo.pid_autotune - INFO - Cycle: 45
2018-08-04 23:36:00,862 - mycodo.pid_autotune - INFO - found peak: 34.03
2018-08-04 23:36:00,863 - mycodo.pid_autotune - INFO - peak count: 1
2018-08-04 23:37:20,802 - mycodo.pid_autotune - INFO - 
2018-08-04 23:37:20,809 - mycodo.pid_autotune - INFO - Cycle: 61

```

2018-08-04 23:37:20,810 - mycodo.pid\_autotune - INFO - switched state: relay step up  
 2018-08-04 23:37:20,811 - mycodo.pid\_autotune - INFO - input: 31.28  
 2018-08-04 23:38:30,867 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:38:30,874 - mycodo.pid\_autotune - INFO - Cycle: 75  
 2018-08-04 23:38:30,876 - mycodo.pid\_autotune - INFO - found peak: 32.17  
 2018-08-04 23:38:30,878 - mycodo.pid\_autotune - INFO - peak count: 2  
 2018-08-04 23:38:40,852 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:38:40,858 - mycodo.pid\_autotune - INFO - Cycle: 77  
 2018-08-04 23:38:40,860 - mycodo.pid\_autotune - INFO - switched state: relay step down  
 2018-08-04 23:38:40,861 - mycodo.pid\_autotune - INFO - input: 32.85  
 2018-08-04 23:40:50,834 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:40:50,835 - mycodo.pid\_autotune - INFO - Cycle: 103  
 2018-08-04 23:40:50,836 - mycodo.pid\_autotune - INFO - found peak: 33.93  
 2018-08-04 23:40:50,836 - mycodo.pid\_autotune - INFO - peak count: 3  
 2018-08-04 23:42:05,799 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:42:05,805 - mycodo.pid\_autotune - INFO - Cycle: 118  
 2018-08-04 23:42:05,806 - mycodo.pid\_autotune - INFO - switched state: relay step up  
 2018-08-04 23:42:05,807 - mycodo.pid\_autotune - INFO - input: 31.27  
 2018-08-04 23:43:15,816 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:43:15,822 - mycodo.pid\_autotune - INFO - Cycle: 132  
 2018-08-04 23:43:15,824 - mycodo.pid\_autotune - INFO - found peak: 32.09  
 2018-08-04 23:43:15,825 - mycodo.pid\_autotune - INFO - peak count: 4  
 2018-08-04 23:43:25,790 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:43:25,796 - mycodo.pid\_autotune - INFO - Cycle: 134  
 2018-08-04 23:43:25,797 - mycodo.pid\_autotune - INFO - switched state: relay step down  
 2018-08-04 23:43:25,798 - mycodo.pid\_autotune - INFO - input: 32.76  
 2018-08-04 23:45:30,802 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:45:30,808 - mycodo.pid\_autotune - INFO - Cycle: 159  
 2018-08-04 23:45:30,810 - mycodo.pid\_autotune - INFO - found peak: 33.98  
 2018-08-04 23:45:30,811 - mycodo.pid\_autotune - INFO - peak count: 5  
 2018-08-04 23:45:30,812 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:45:30,814 - mycodo.pid\_autotune - INFO - amplitude: 0.90999999999999989  
 2018-08-04 23:45:30,815 - mycodo.pid\_autotune - INFO - amplitude deviation: 0.06593406593406595  
 2018-08-04 23:46:40,851 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:46:40,857 - mycodo.pid\_autotune - INFO - Cycle: 173  
 2018-08-04 23:46:40,858 - mycodo.pid\_autotune - INFO - switched state: relay step up  
 2018-08-04 23:46:40,859 - mycodo.pid\_autotune - INFO - input: 31.37  
 2018-08-04 23:47:55,860 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:47:55,866 - mycodo.pid\_autotune - INFO - Cycle: 188  
 2018-08-04 23:47:55,868 - mycodo.pid\_autotune - INFO - found peak: 32.36  
 2018-08-04 23:47:55,869 - mycodo.pid\_autotune - INFO - peak count: 6  
 2018-08-04 23:47:55,870 - mycodo.pid\_autotune - INFO -  
 2018-08-04 23:47:55,871 - mycodo.pid\_autotune - INFO - amplitude: 0.91499999999999979  
 2018-08-04 23:47:55,872 - mycodo.pid\_autotune - INFO - amplitude deviation: 0.032786885245900406  
 2018-08-04 23:47:55,873 - mycodo.pid\_3b533dff - INFO - time: 16 min  
 2018-08-04 23:47:55,874 - mycodo.pid\_3b533dff - INFO - state: succeeded  
 2018-08-04 23:47:55,874 - mycodo.pid\_3b533dff - INFO -  
 2018-08-04 23:47:55,875 - mycodo.pid\_3b533dff - INFO - rule: ziegler-nichols  
 2018-08-04 23:47:55,876 - mycodo.pid\_3b533dff - INFO - Kp: 0.40927018474290117  
 2018-08-04 23:47:55,877 - mycodo.pid\_3b533dff - INFO - Ki: 0.05846588600007114  
 2018-08-04 23:47:55,879 - mycodo.pid\_3b533dff - INFO - Kd: 0.7162385434443115  
 2018-08-04 23:47:55,880 - mycodo.pid\_3b533dff - INFO -  
 2018-08-04 23:47:55,881 - mycodo.pid\_3b533dff - INFO - rule: tyreus-luyben  
 2018-08-04 23:47:55,887 - mycodo.pid\_3b533dff - INFO - Kp: 0.3162542336649691  
 2018-08-04 23:47:55,889 - mycodo.pid\_3b533dff - INFO - Ki: 0.010165091543194185  
 2018-08-04 23:47:55,890 - mycodo.pid\_3b533dff - INFO - Kd: 0.7028026111719073  
 2018-08-04 23:47:55,891 - mycodo.pid\_3b533dff - INFO -  
 2018-08-04 23:47:55,892 - mycodo.pid\_3b533dff - INFO - rule: ciancone-marlin  
 2018-08-04 23:47:55,892 - mycodo.pid\_3b533dff - INFO - Kp: 0.21083615577664605  
 2018-08-04 23:47:55,893 - mycodo.pid\_3b533dff - INFO - Ki: 0.06626133746674728



```

2018-08-04 23:47:55,893 - mycodo.pid_3b533dff - INFO - Kd: 0.3644161687558038
2018-08-04 23:47:55,894 - mycodo.pid_3b533dff - INFO -
2018-08-04 23:47:55,894 - mycodo.pid_3b533dff - INFO - rule: pessen-integral
2018-08-04 23:47:55,895 - mycodo.pid_3b533dff - INFO - Kp: 0.49697093861638
2018-08-04 23:47:55,895 - mycodo.pid_3b533dff - INFO - Ki: 0.0887428626786794
2018-08-04 23:47:55,896 - mycodo.pid_3b533dff - INFO - Kd: 1.04627757151908
2018-08-04 23:47:55,896 - mycodo.pid_3b533dff - INFO -
2018-08-04 23:47:55,897 - mycodo.pid_3b533dff - INFO - rule: some-overshoot
2018-08-04 23:47:55,898 - mycodo.pid_3b533dff - INFO - Kp: 0.23191977135431066
2018-08-04 23:47:55,898 - mycodo.pid_3b533dff - INFO - Ki: 0.03313066873337365
2018-08-04 23:47:55,899 - mycodo.pid_3b533dff - INFO - Kd: 1.0823160212047374
2018-08-04 23:47:55,899 - mycodo.pid_3b533dff - INFO -
2018-08-04 23:47:55,900 - mycodo.pid_3b533dff - INFO - rule: no-overshoot
2018-08-04 23:47:55,900 - mycodo.pid_3b533dff - INFO - Kp: 0.1391518628125864
2018-08-04 23:47:55,901 - mycodo.pid_3b533dff - INFO - Ki: 0.01987840124002419
2018-08-04 23:47:55,901 - mycodo.pid_3b533dff - INFO - Kd: 0.6493896127228425
2018-08-04 23:47:55,902 - mycodo.pid_3b533dff - INFO -
2018-08-04 23:47:55,902 - mycodo.pid_3b533dff - INFO - rule: brewing
2018-08-04 23:47:55,903 - mycodo.pid_3b533dff - INFO - Kp: 5.566074512503456
2018-08-04 23:47:55,904 - mycodo.pid_3b533dff - INFO - Ki: 0.11927040744014512
2018-08-04 23:47:55,904 - mycodo.pid_3b533dff - INFO - Kd: 4.101408080354794

```

## 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 inputs and outputs. Possible conditional statements include:

- If Output #1 turns ON, turn Output #3 ON
- If Output #1 turns ON, turn Output #4 ON for 40 seconds and notify critical-issue@domain.com
- If Output #1 turns ON for any duration, turn Output #4 ON
- If Output #4 turns ON for 21 seconds, turn Output #5 ON for 50 seconds
- If Output #4 turns ON for 20 seconds, turn Output #1 OFF
- If Humidity is Greater Than 80%, turn Output #4 ON for 40 seconds
- If Humidity if Less Than 50%, turn Output #1 ON for 21 seconds, execute ‘/usr/local/bin/script.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 outputs. Some devices or outputs may respond atypically or fail when switched on and off in rapid succession. Therefore, avoid creating an infinite loop with conditional statements.

## Measurement Conditional Statement If Options

Check if the latest measurement is above or below the set value.

Setting	Description
If Measurement	The measurement that will be checked every Period. By default, a measurement will only be checked for in the past 120 seconds, unless “None Found Last x seconds” in which case the Value will determine the measurement age. The takeaway from this is if a measurement is more than 120 seconds
If State	The conditional will trigger if the measurement Greater Than or Less Than the set If Value, or if “No Measurement” is set and the measurement age is greater than Max Age.
If Value	The value that the measurement will be checked against (greater or less than).
Period (seconds)	The period (seconds) between conditional checks.
Refractory Period (seconds)	The minimum duration (seconds) to wait after a conditional has been triggered to begin evaluating the conditional again.

Setting	Description
Max Age (seconds)	The maximum age the measurement can be. If a measurement isn't available within this time frame, the conditional will not trigger. The only exception is if "If State" is set to "No Measurement", which will cause the conditional to trigger when there is no measurement available (indicating the input or measuring device has stopped working).

### Output (On/Off) Conditional Statement If Options

Monitor the state of an output.

Setting	Description
If Output	The Output to monitor for a change of state.
If State	If the state of the output changes to On or Off the conditional will trigger. If "On (any duration)" is selected, the trigger will occur no matter how long the output turns on for, whereas if only "On" is selected, the conditional will trigger only when the output turns on for a duration of time equal to the set "Duration (seconds)".
If Duration (seconds)	If "On" is selected, an optional duration (seconds) may be set that will trigger the conditional only if the Output is turned on for this specific duration.

### Output (PWM) Conditional Statement If Options

Monitor the state of a PWM output.

Setting	Description
If Output	The Output to monitor for a change of state.
If State	If the duty cycle of the output is greater than, less than, or equal to the set value, trigger the Conditional Actions.
If Duty Cycle (%)	The duty cycle for the Output to be checked against.

### Edge Conditional Statement If Options

Monitor the state of a pin for a rising and/or falling edge.

Setting	Description
If Edge Detected	The conditional will be triggered if a change in state is detected, either Rising when the state changes from LOW (0 volts) to HIGH (3.5 volts) or Falling when the state changes from HIGH (3.3 volts) to LOW (0 volts), or Both (Rising and Falling).

### Run PWM Method Conditional Statement If Options

Select a Duration Method and this will set the selected PWM Output to the duty cycle specified by the method.

Setting	Description
Duration Method	Select which Method to use.
PWM Output	Select which PWM Output to use.
Period (seconds)	Select the interval of time to calculate the duty cycle, then apply to the PWM Output.
Trigger Every Period	Trigger Conditional Actions every period.
Trigger when Activated	Trigger Conditional Actions when the Conditional is activated.

### Sunrise/Sunset Conditional Statement If Options

Trigger events at sunrise or sunset (or a time offset of those), based on latitude and longitude.

Setting	Description
Rise or Set	Select which to trigger the conditional, at sunrise or sunset.
Latitude (decimal)	Latitude of the sunrise/sunset, using decimal format.
Longitude (decimal)	Longitude of the sunrise/sunset, using decimal format.
Zenith	The Zenith angle of the sun.
Date Offset (days)	Set a sunrise/sunset offset in days (positive or negative).
Time Offset (minutes)	Set a sunrise/sunset offset in minutes (positive or negative).

### Timer (Duration) Conditional Statement If Options

Run a timer that triggers Conditional Actions every period.

Setting	Description
Period (seconds)	The period of time between triggering Conditional Actions.
Start Offset (seconds)	Set this to start the first trigger a number of seconds after the Conditional is activated.

[illegible]

Run a timer that triggers Conditional Actions at a specific time every day.

Setting	Description
Start Time (HH:MM)	Set the time to trigger Conditional Actions, in the format “HH:MM”, with HH denoting hours, and MM denoting minutes. Time is in 24-hour format.

## Timer (Daily Time Span) Conditional Statement If Options

Run a timer that triggers Conditional Actions at a specific period if it's between the set start and end times. For example, if the Start Time is set to 10:00 and End Time set to 11:00 and Period set to 120 seconds, the Conditional Actions will trigger every 120 seconds when the time is between 10 AM and 11 AM.

This may be useful, for instance, if you desire an Output to remain on during a particular time period and you want to prevent power outages from interrupting the cycle (which a simple Time Point Timer could not prevent against because it only triggers once at the Start Time). By setting an Output to turn the lights on every few minutes during the Start -> End period, it ensured the Output remains on during this period.

Setting	Description
Start Time (HH:MM)	Set the start time to trigger Conditional Actions, in the format “HH:MM”, with HH denoting hours, and MM denoting minutes. Time is in 24-hour format.
End Time (HH:MM)	Set the end time to trigger Conditional Actions, in the format “HH:MM”, with HH denoting hours, and MM denoting minutes. Time is in 24-hour format.
Period (seconds)	The period of time between triggering Conditional Actions.

## Conditional Statement Actions

Setting	Description
Output	Turn a output 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.
Pause PID	Pause a particular PID controller.
Hold PID	Hold a particular PID controller.

Setting	Description
Resume PID	Resume a particular PID controller.
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.

### Conditional Statement variables

Commands that are executed by conditional statements can now include variables. To use, just place the variable name, including “((” and “))” in your command, and it will be replaced with the variable’s value before execution. See the tables below for the currently-supported variables.

It is recommended to output a test string to a text file to verify the output is as expected, with a command such as the following (for a Conditional using the Raspberry Pi CPU temperature Input as the measurement):

```
echo "TEST: ((measure_temperature)), ((measure_location)), ((measure_period))" > /home/mycodo/test_measure.txt
```

Or for an Output Conditional:

```
echo "TEST: ((output_pin)), ((output_action)), ((output_duration)), ((output_pwm))" > /home/mycodo/test_output.txt
```

### Measurement Conditional command variables

Variable	Description
((measure_location))	Input location (such as GPIO pin, I2C address, etc.)
((measure_period))	The period (seconds) between measurements (input, math, or PID)
((measure_linux_command))	Input measurement: Linux Command return value
((measure_altitude))	Input measurement: altitude
((measure_battery))	Input measurement: battery
((measure_boolean))	Input measurement: boolean
((measure_co2))	Input measurement: CO2
((measure_cpu_load_1m))	Input measurement: CPU load (1 min)
((measure_cpu_load_5m))	Input measurement: CPU load (5 min)
((measure_cpu_load_15m))	Input measurement: CPU load (15 min)
((measure_dewpoint))	Input measurement: dew point
((measure_disk_space))	Input measurement: disk space
((measure_duty_cycle))	Input measurement: duty cycle
((measure_edge))	Input measurement: edge detected (1 or -1)
((measure_electrical_conductivity))	Input measurement: Electrical Conductivity (uS/cm)
((measure_frequency))	Input measurement: frequency
((measure_humidity))	Input measurement: humidity
((measure_lux))	Input measurement: lux
((measure_moisture))	Input measurement: moisture
((measure_ph))	Input measurement: ph
((measure_pressure))	Input measurement: pressure
((measure_pulse_width))	Input measurement: pulse width
((measure_rpm))	Input measurement: RPM
((measure_temperature))	Input measurement: temperature
((measure_temperature_die))	Input measurement: temperature (die)
((measure_temperature_object))	Input measurement: temperature (object)
((measure_voltage))	Input measurement: voltage

### Output Conditional command variables

Variable	Description
((output_pin))	The output pin

Variable	Description
((output_action))	The state change of the output (turned on = 1, turned off = 0)
((output_duration))	The number of seconds the output turned on for (will return 0 if not applicable)
((output_pwm))	The PWM duty cycle the output turned on for (will return 0 if not applicable)

### Edge Conditional command variables

Variable	Description
((edge_state))	The state of the GPIO pin (on/rising = 1, off/falling = 0)

## LCDs

More -> LCDs

Data may be output to a liquid crystal display (LCD) for easy viewing. Please see LCD Displays for specific information regarding compatibility.

There may be multiple displays created for each LCD. If there is only one display created for the LCD, it will refresh at the set period. If there is more than one display, it will cycle from one display to the next every set period.

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.
Period	This is the period of time (in seconds) between redrawing the LCD with new data or switching to the next set of displays (if multiple displays are used).
Add Display Set	Add a set of display lines to the LCD.
Display Line #	Select which measurement to display on each line of the LCD.
Max Age (seconds)	The maximum age the measurement is allowed to be. If no measurement was acquired in this time frame, the display will indicate "NO DATA".

## Methods

More -> Methods

Methods enable Setpoint Tracking in PIDs and time-based duty cycle changes in timers. 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. Methods may also be used to change a duty cycle over time when used with a Run PWM Method Conditional.

### 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 **Setpoint** (for PIDs) or **Duty Cycle** (for Conditional) to be set after specific durations of time. Each new duration added will stack, meaning it will come after the previous duration, meaning a newly-added **Start Setpoint** will begin after the previous entry's **End Setpoint**.

If the "Repeat Method" option is used, this will cause the method to repeat once it has reached the end. If this option is used, no more durations may be added to the method. If the repeat option is deleted then more durations may be added. For instance, if your method is 200 seconds total, if the Repeat Duration is set to 600 seconds, the method will repeat 3 times and then automatically turn off the PID or Conditional.

### 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

Function -> PIDs

### 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 **Proportional** takes the error and multiplies it by the constant  $K_p$ , to yield an output value. When the error is large, there will be a large proportional output.

The **Integral** takes the error and multiplies it by  $K_i$ , then integrates it ( $K_i \cdot 1/s$ ). As the error changes over time, the integral will continually sum it and multiply it by the constant  $K_i$ . The integral is used to remove perpetual error in the control system. If using  $K_p$  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 **Derivative** multiplies the error by  $K_d$ , then differentiates it ( $K_d \cdot s$ ). 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.

Therefore, 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 outputs, 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 Output* 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.

## Configuration Settings

[Gear Icon] -> Configuration

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

[Gear Icon] -> Configuration -> General

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://.
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.
Check for Updates	Automatically check for updates every 2 days and notify through the web interface. If there is a new update, the Configure (Gear Icon) as well as the Upgrade menu will turn the color red.

### Output Usage Settings

In order to calculate accurate output 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 output usage calculations also rely on the correct current draw to be set for each output (see Output Settings).

Setting	Description
Max Amps	Set the maximum allowed amperage to be switched on at any given time. If a output that's instructed to turn on will cause the sum of active devices to exceed this amount, the output will not be allowed to turn on, to prevent any damage that may result from exceeding current limits.
Voltage	Alternating current (AC) voltage that is switched by the outputs. 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.



Setting	Description
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).

## Measurement Settings

[Gear Icon] -> Configuration -> Measurement

New measurements, units, and conversions can be created that can extend functionality of Mycodo beyond the built-in types and equations. Be sure to create units before measurements, as units need to be selected when creating a measurement. A measurement can be created that already exists, allowing additional units to be added to a pre-existing measurement. For example, the measurement 'altitude' already exists, however if you wanted to add the unit 'fathom', first create the unit 'fathom', then create the measurement 'altitude' with the 'fathom' unit selected. It is okay to create a custom measurement for a measurement that already exist (this is how new units for a currently-installed measurement is added).

Setting	Description
Measurement Name	Name for the measurement (e.g. "Weight", "Length").
Measurement Units	Select all the units that are associated with the measurement.
Unit Name	Name for the unit (e.g. "Kilogram", "Meter").
Unit Abbreviation	Abbreviation for the unit (e.g. "kg", "m").
Convert From Unit	The unit that will be converted from.
Convert To Unit	The unit that will be converted to.
Equation	The equation used to convert one unit to another. The lowercase letter "x" must be included in the equation (e.g. "x/1000+20", "250*(x/3)"). This "x" will be replaced with the actual measurement being converted.

## Users

[Gear Icon] -> Configuration -> 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 lower-case).
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.
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. Four roles are provided by default, but custom roles may be created.

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	

Role	Admin	Editor	Monitor	Guest
View Logs	X	X	X	

1The **Edit Controllers** permission protects the editing of Conditionals, Graphs, LCDs, Methods, PIDs, Outputs, and Inputs.

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

## Pi Settings

[Gear Icon] -> Configuration -> Pi

Pi settings configure parts of the linux system that Mycodo runs on.

pigpiod is required if you wish to use PWM Outputs, as well as PWM, RPM, DHT22, DHT11, HTU21D Inputs.

Setting	Description
Enable/Disable Feature	These are system interfaces that can be enabled and disabled from the web UI via the <b>raspi-config</b> command.
pigpiod Sample Rate	This is the sample rate the pigpiod service will operate at. The lower number enables faster PWM frequencies, but may significantly increase processor load on the Pi Zeros. pigpiod may also be disabled completely if it's not required (see note, above).

## Alert Settings

[Gear Icon] -> Configuration -> Alerts

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 TLS).
Enable SSL	Check to enable SSL, uncheck to enable TLS.
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.
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.
Send Test Email	Test the email configuration by sending a test email.

## Camera Settings

[Gear Icon] -> Configuration -> Camera

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 USB cameras should be set to fswebcam.

Setting	Description
Device	The device to use to connect to the camera. fswebcam is the only library that uses this option.
Output	This output will turn on during the capture of any still image (which includes timelapses).
Output Duration	Turn output on for this duration of time before the image is captured.
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.
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.

## Miscellaneous

### Dashboard

Info -> Dashboard

The dashboard is where you can add pieces of data for easy viewing. It is highly customizable and provides an easy way to see exactly what data you want to see on one screen.

Setting	Description
Width	The width of the dashboard object on the page, in 1/12th increments. Multiple dashboard object can share the sme row if their combined fraction doesn't exceed 12/12.
Height (pixels)	The height of the dashboard object.

Specific options for each Dashboard element are below.

### 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 graph may have one or more data from inputs, outputs, or PIDs rendered onto it. To edit graph options, select the plus sign on the top-right of a graph.

Setting	Description
x-Axis (minutes)	The duration to display on the x-axis of the graph.
Enable Auto Refresh	Automatically refresh the data on the graph Refresh Period.
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.
Inputs/Outputs/PIDs	The Inputs, Outputs, and PIDs to display on the graph.
Enable X-Axis Reset	Reset the x-axis min/max every time new data comes in during the auto refresh.
Enable Title	Show a title of the graph name.
Enable Navbar	Show a slidable navigation bar at the bottom of the graph.
Enable Export	Enable a button on the top right of the graph to allow exporting of the currently-displayed data as PNG, JPEG, PDF, SVG, CSV, XLS.
Enable Range Selector	Show a set of navigation buttons at the top of the graph to quickly change the display duration.
Enable Graph Shift	If enabled, old data points are removed when new data is added to the graph. Only recommended to enable if Enable Navbar is enabled.

Setting	Description
Enable Custom Colors	Use custom colors for Input, Output, and PID lines. Select the colors with the buttons that appear below this checkbox.
Enable Manual Y-Axis Min/Max	Set the minimum and maximum y-axes of a particular graph. Set both the minimum and maximum to 0 to disable for a particular y-axis.
Enable Y-Axis Align Ticks	Align the ticks of several y-axes of the same graph.
Enable Y-Axis Start On Tick	Start all y-axes of a graph on the same tick.
Enable Y-Axis End On Tick	End all y-axes of a graph on the same tick.

## Gauges

Gauges are visual objects that allow one to quickly see what the latest measurement is of an input. An example that you may be familiar with is a speedometer in a car.

Setting	Description
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.
Max Age (seconds)	The maximum allowable age of the measurement. If the age is greater than this, the gauge will turn off, indicating there is an issue.
Gauge Min	The lowest value of the gauge.
Gauge Max	The highest value of the gauge.
Show Timestamp	Show the timestamp of the current gauge measurement.

## Cameras

Cameras may be added to keep a continuous view on areas.

Setting	Description
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.
Max Age (seconds)	The maximum allowed age of the image timestamp before a “No Recent Image” message is returned.
Acquire Image (and save new file)	Acquire a new images and save the previous image.
Acquire Image (and erase last file)	Acquire a new image but erase the previous image.
Display Live Video Stream	Automatically start a video stream and display it.
Display Latest Timelapse Image	Display the latest timelapse image that exists.
Add Timestamp	Append a timestamp to the image.

## Measurement

Setting	Description
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.
Max Age (seconds)	The maximum allowable age of the measurement. If the age is greater than this, the gauge will turn off, indicating there is an issue.
Value Font Size (em)	The font size of the measurement value in em.
Timestamp Font Size (em)	The font size of the timestamp value in em.
Decimal Places	The number of digits to display to the right of the decimal.
Measurement	The device to display information about.

## Output

Setting	Description
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.

Setting	Description
Max Age (seconds)	The maximum allowable age of the measurement. If the age is greater than this, the gauge will turn off, indicating there is an issue.
Value Font Size (em)	The font size of the output value in em.
Timestamp Font Size (em)	The font size of the timestamp value in em.
Decimal Places	The number of digits to display to the right of the decimal.
Feature Output Controls	Display buttons to turn On and Off the relay from the dashboard element.
Output	The output to display information about.

## PID Control

Setting	Description
Refresh (seconds)	The duration between acquisitions of new data to display on the graph.
Max Age (seconds)	The maximum allowable age of the measurement. If the age is greater than this, the gauge will turn off, indicating there is an issue.
Value Font Size (em)	The font size of the measurement value in em.
Timestamp Font Size (em)	The font size of the timestamp value in em.
Decimal Places	The number of digits to display to the right of the decimal.
Show PID Information	Show extra PID information on the dashboard element.
Show Set Setpoint	Allow setting the PID setpoint on the dashboard element.
PID	The PID to display information about.

## Live Measurements

Info -> Live Measurements

The Live Measurements page is the first page a user sees after logging in to Mycodo. It will display the current measurements being acquired from Input and Math controllers. If there is nothing displayed on the Live Measurements page, ensure an Input or Math controller is both configured correctly and activated. Data will be automatically updated on the page from the measurement database.

## Asynchronous Graphs

Info -> 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.

## Export-Import

More -> Export Import

Measurements that fall within the selected date/time frame may be exported as CSV with their corresponding timestamps.

Additionally, the entire measurement database (influxdb) may be exported as a ZIP file backup. This ZIP may be imported back in any Mycodo system to restore these measurements. Note that an import will override the current data (i.e. destroying it).

Mycodo settings may be exported as a ZIP file containing the Mycodo settings database (sqlite). This ZIP file may be used to restore the settings database to another Mycodo install, as long as the Mycodo version and database versions are the same. Future support for installing older (or newer) databases and performing an automatic upgrade/downgrade is in the works.

## Dependencies

[Gear Icon] -> Dependencies

The dependency page allows viewing of dependency information and the ability to initiate their installation.

During the installation of Mycodo, there is an option to select which dependencies to install. If “Minimal Install” or “Custom Install” was selected (rather than “Full Install”), there may be unmet dependencies on your system. Don’t worry, this isn’t necessarily a problem. These optional dependencies only need to be installed when there’s a particular feature you want to use. When a user attempts to use a feature that has an unmet dependency, the user will be forwarded to the Dependency page in order to install it.

## Camera

More -> Cameras

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 by Conditional Statements to trigger a camera image or video capture (as well as the ability to email the image/video with a notification).

## Output Usage

More -> Output Usage

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

## Backup-Restore

[Gear Icon] -> Backup Restore

A backup is made to /var/Mycodo-backups when the system is upgraded or through the web interface on the Config -> Backup / Restore page.

If you need to restore a backup, this can be done on the Config -> Backup / Restore page. Find the backup you would like restored and press the Restore button beside it. A restore can also be initialized through the command line. Use the following commands to initialize a restore, changing the appropriate directory names, ‘user’ to your user name, and TIME and COMMIT to the appropriate text found as the directory names in /var/Mycodo-backups/

```
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/mycodo/scripts/upgrade_post.sh
```

## System Information

[Gear Icon] -> System Information

This page serves to provide information about the Mycodo frontend and backend as well as the linux system it’s running on. Several commands and their output are listed to give the user information about how their system is running.

Command	Description
Mycodo Version	The current version of Mycodo, reported by the configuration file.
Python Version	The version of python currently running the web user interface.

Command	Description
Database Version	The current version of the settings database. If the current version is different from what it should be, an error will appear indicating the issue and a link to find out more information about the issue.
Daemon Status	This will be a green “Running” or a red “Stopped”. Additionally, the Mycodo version and hostname text at the top-left of the screen May be Green, Yellow, or Red to indicate the status. Green = daemon running, yellow = unable to connect, and red = daemon not running.
...	Several other status indicators and commands are listed to provide information about the health of the system. Use these in addition to others to investigate software or hardware issues.

## Troubleshooting

### Daemon Not Running

- Check the Logs: From the **Configure** [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/mycodo-root/env/bin/python /var/mycodo-root/myco` 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.

### Incorrect Database Version

- Check the System Information page (from the web UI: select [Gear Icon] -> System Information or select the mycodo logo in the top-left).
- An incorrect database version error means the version stored in the Mycodo settings database (`~/Mycodo/databases/mycodo.db`) is not correct for the latest version of Mycodo, determined in the Mycodo config file (`~/Mycodo/mycodo/config.py`).
- This can be caused by an error in the upgrade process from an older database version to a newer version, or from a database that did not upgrade during the Mycodo upgrade process.
- Check the Upgrade Log for any issues that may have occurred. The log is located at `/var/log/mycodo/mycodoupgrade.log` but may also be accessed from the web UI (if you’re able to): select [Gear Icon] -> Mycodo Logs -> Upgrade Log.
- Sometimes issues may not immediately present themselves. It is not uncommon to be experiencing a database issue that was actually introduced several Mycodo versions ago, before the latest upgrade.
- Because of the nature of how many versions the database can be in, correcting a database issue may be very difficult. It may be much easier to delete your database and let Mycodo generate a new one.
- Use the following commands to rename your database and restart the web UI. If both commands are successful, refresh your web UI page in your browser in order to generate a new database and create a new Admin user.

```
mv ~/Mycodo/databases/mycodo.db ~/Mycodo/databases/mycodo.db.backup
sudo service mycodoflask restart
```

### More

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

## Device Interfaces

Inputs are categorized below by their communication interface.

## 1-Wire

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

DS18B20: Temperature link

DS18S20: Temperature link

DS1822: Temperature link

DS28EA00: Temperature link

DS1825: Temperature link

MAX31850K: Temperature link

## GPIO

DHT11, DHT22/AM2302: Relative humidity and temperature link

SHT1x/SHT7x, SHT2x: Relative humidity and temperature link

## Serial

Atlas Scientific pH: pH link

Atlas Scientific PT-1000: Temperature link

K30: Carbon dioxide (CO2) in ppmv link

MAX31855K: Temperature link

MAX31856: Temperature link

MAX31865: Temperature link

MH-Z19: Carbon dioxide (CO2) in ppmv link

This documentation provides specific installation procedures for configuring UART with the Raspberry Pi version 1 or 2.

The K30 may be tested 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 the addition of bluetooth, there are a different set of instructions. If installing Mycodo on a Raspberry Pi 3, you only need to perform these steps to configure UART:

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`.

### Sensors

AM2315: Relative humidity, temperature link

Atlas Scientific pH: pH link

Atlas Scientific PT-1000: Temperature link

BH1750: Light link



BME280: Barometric pressure, humidity, temperature link  
BMP085, BMP180: Barometric pressure, temperature link  
CCS811: CO2, VOC, temperature link  
HTU21D: Relative humidity and temperature link  
TMP006, TMP007: Contactless temperature link  
TSL2561: Light link  
TSL2591: 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.

## 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 inputs 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.

Multiplexers can be set up by loading a kernel driver to handle the communication, producing a new I2C bus device for each multiplexer channel. To enable the driver for the TCA9548A/PCA9548A, visit [GPIO-pca9548](#) to get the code and latest install instructions. If successfully set up, there will be 8 new I2C busses on the **Config -> System Information** page.

The driver for the TCA9545A can be found at <https://github.com/camrex/i2c-mux-pca9545a> and other drivers are available elsewhere. See the manufacturer or user forums for details. Some multiplexers I've tested are below.

TCA9548A/PCA9548A: 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 also creates 4 new I2C busses, but each with their own selectable voltage, either 3.3 or 5.0 volts.

## 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: Analog-to-digital converter link  
MCP3008: Analog-to-digital converter link  
MCP342x: Analog-to-digital converter link

## Device Specific Information

### LCD Displays

There are only a few number fo LCDs that are supported. Only 16x2 and 20x4 character LCD displays with I2C backpacks are supported. The below image is the type of device that should be compatible.



### 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

- Serial or I2C
- Accuracy  $\pm(0.15 + (0.002 \cdot t))$
- 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.

### **Specifications**

- Usable temperature range: -55°C to 125°C
- 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
- $\pm 0.5^\circ\text{C}$  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

## **DS18S20**

### **Specifications**

- Usable temperature range: -55°C to 125°C
- $\pm 0.5^\circ\text{C}$  Accuracy from -10°C to +85°C
- 9-bit resolution

## **DS1822**

### **Specifications**

- Usable temperature range: -55°C to 125°C
- $\pm 2.0^\circ\text{C}$  Accuracy from -10°C to +85°C
- 9 to 12 bit selectable resolution

## **DS28EA00**

### **Specifications**

- Usable temperature range: -40°C to 85°C
- 9 to 12 bit selectable resolution

## **DS1825**

### **Specifications**

- Usable temperature range: -55°C to 125°C
- $\pm 0.5^\circ\text{C}$  Accuracy from -10°C to +85°C
- 9 to 12 bit selectable resolution

## **MAX31850K**

### **Specifications**

- Measures K-type thermocouples
- 14-bit, 0.25°C resolution

## **MAX31855K**

### **Specifications**

- Measures K-type thermocouples
- Serial interface
- -200°C to +1350°C output in 0.25 degree increments
- K thermocouples have about  $\pm 2^\circ\text{C}$  to  $\pm 6^\circ\text{C}$  accuracy
- Internal temperature reading

## **MAX31856**

Measures several types of thermocouples (K, J, N, R, S, T, E, and B).

### **Specifications**

- Serial interface
- -210°C to +1800°C output in 0.0078125° resolution (many thermocouples have about  $\pm 2^\circ\text{C}$  to  $\pm 6^\circ\text{C}$  accuracy or worse depending on the temperature and type, so the resolution will be a lot better than the accuracy)
- Works with any K, J, N, R, S, T, E, or B type thermocouple
- Internal temperature reading

## **MAX31865**

Measures the PT100 or PT1000 platinum resistance temperature detectors (RTDs).

### **Specifications**

- Serial interface
- -200°C to +850°C
- Works with the PT100 and PT1000 RTD

## **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  $\pm 0.1^\circ\text{C}$  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)

#### Notes

From [Theoi-Meteoroi](<https://github.com/kizniche/Mycode/issues/315#issuecomment-344798815>) on GitHub:

I figured out why this [AM2315] sensor is unreliable with Rpi3 hardware I2C. It is among a number of I2C devices that really hates the BCM2835 clock stretching blunder (hardware bug: raspberrypi/linux#254). The wakeup attempts fail, consistently. I checked the bitstream with a sniffer, and see that the sensor may respond once out of 20 or so tries (or not at all) but only with a single byte returned. The solution is to use a software implementation of the I2C bus. You need to add pull-up resistors (4.7k is dandy) to 3.3v and install the i2c\_gpio device overlay. Seems to work fine now, will run for a few days, but the CRC failures are gone and I get good readings, every time. And no twiddling the power for the sensor is required.

To enable software I2C, add the following line to your `/boot/config.txt`

```
dtoverlay=i2c-gpio,i2c_gpio_sda=23,i2c_gpio_scl=24,i2c_gpio_delay_us=4
```

After rebooting, a new I2C bus at `/dev/i2c-3` should exist with SDA on pin 23 (BCM) and SCL on pin 24 (BCM). Make sure you add the appropriate pull-up resistors before connecting any devices.

### 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  $\pm 2^\circ\text{C}$  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  $\pm 0.5^\circ\text{C}$  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  $\pm 1^\circ\text{C}$  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  $\pm 0.5^{\circ}\text{C}$ ,  $\pm 0.4^{\circ}\text{C}$ , and  $\pm 0.3^{\circ}\text{C}$  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  $\pm 0.4^{\circ}\text{C}$  and  $\pm 0.3^{\circ}\text{C}$  typical accuracy (respectively)
- 2.4 to 5.5V power and I/O
- No more than 0.125 Hz sampling rate (once every 8 seconds)

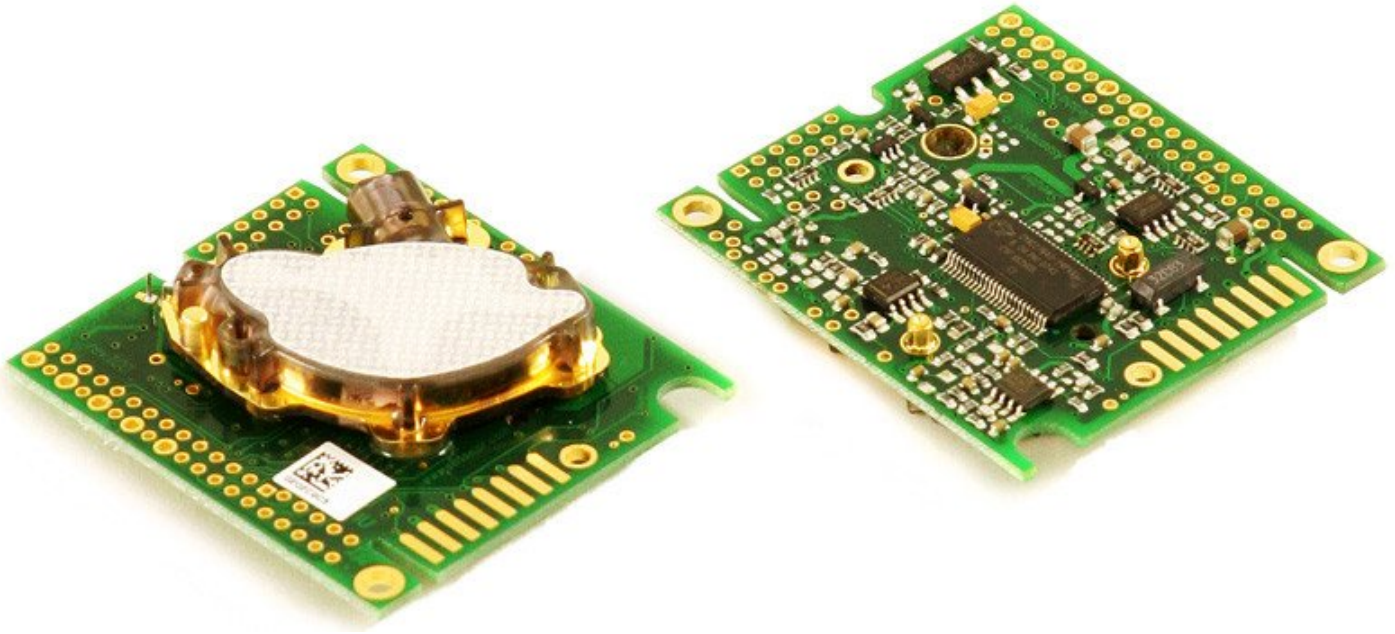
## **CO2 Sensors**

### **CCS811**

Be aware that the CCS811 datasheet recommends a burn-in of 48 hours and a run-in of 20 minutes (you must allow 20 minutes for the sensor to warm up and output valid data).

### **Specifications**

- 400 – 8,192 ppmv CO2
- 0 - 1,187 ppbv VOC
- Ambient temperature measured from 10K NTC Thermistor (separate from chip, may or may not be included on the board you purchase)
- Warm-up time: ~ 20 min.



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

Wiring instructions for the Raspberry Pi can be found [here](#).

### Specifications

- 0 – 10,000 ppmv (0 - 5,000 ppmv within specifications)
- Repeatability:  $\pm 20$  ppm  $\pm 1\%$  of measured value within specifications
- Accuracy:  $\pm 30$  ppm  $\pm 3\%$  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)

### MH-Z19

#### Specifications

- 0 – 5,000 ppmv
- Accuracy:  $\pm 50$  ppm  $\pm 5\%$  of measured value within specifications
- Non-dispersive infrared (NDIR) technology
- Sensor life expectancy: > 5 years
- Warm-up time: 3 min.
- 0.2 Hz sampling rate (once every 5 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

- UART or I2C
- 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 upgrade to the BMP085/BMP180/BMP183. It has 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
- $\pm 3\%$  humidity accuracy tolerance
- $\pm 1\%$  humidity hysteresis
- $\pm 1$  hPa pressure accuracy
- $\pm 2^\circ\text{C}$  temperature accuracy
- Vin: 3 to 5V
- Logic: 3 to 5V compliant
- I2C 7-bit address 0x76 or 0x77

### BMP085, BMP180

The BMP180 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
- $\pm 2^\circ\text{C}$  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 Luminosity Sensor 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.

## **TSL2591**

### **Specifications**

- Light range: 188 uLux to 88,000 Lux

## **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

### **MCP3008**

### **Specifications**

- Interface: SPI
- 8 channels
- 10-bit resolution
- 0 - 3.3 volt measurements

### **MCP342x**

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

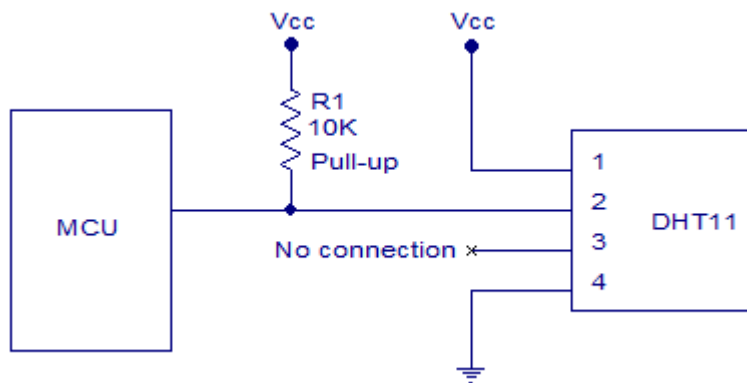
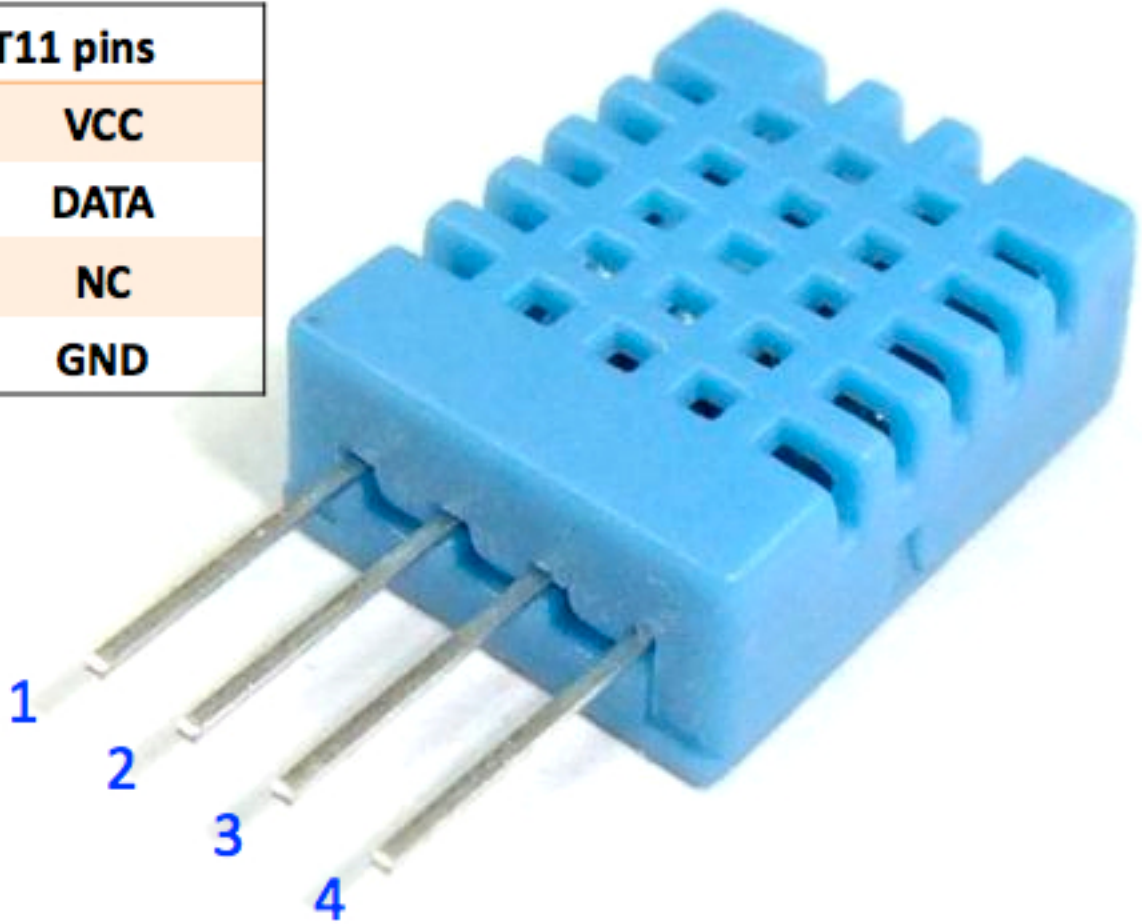
### **Specifications**

- 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

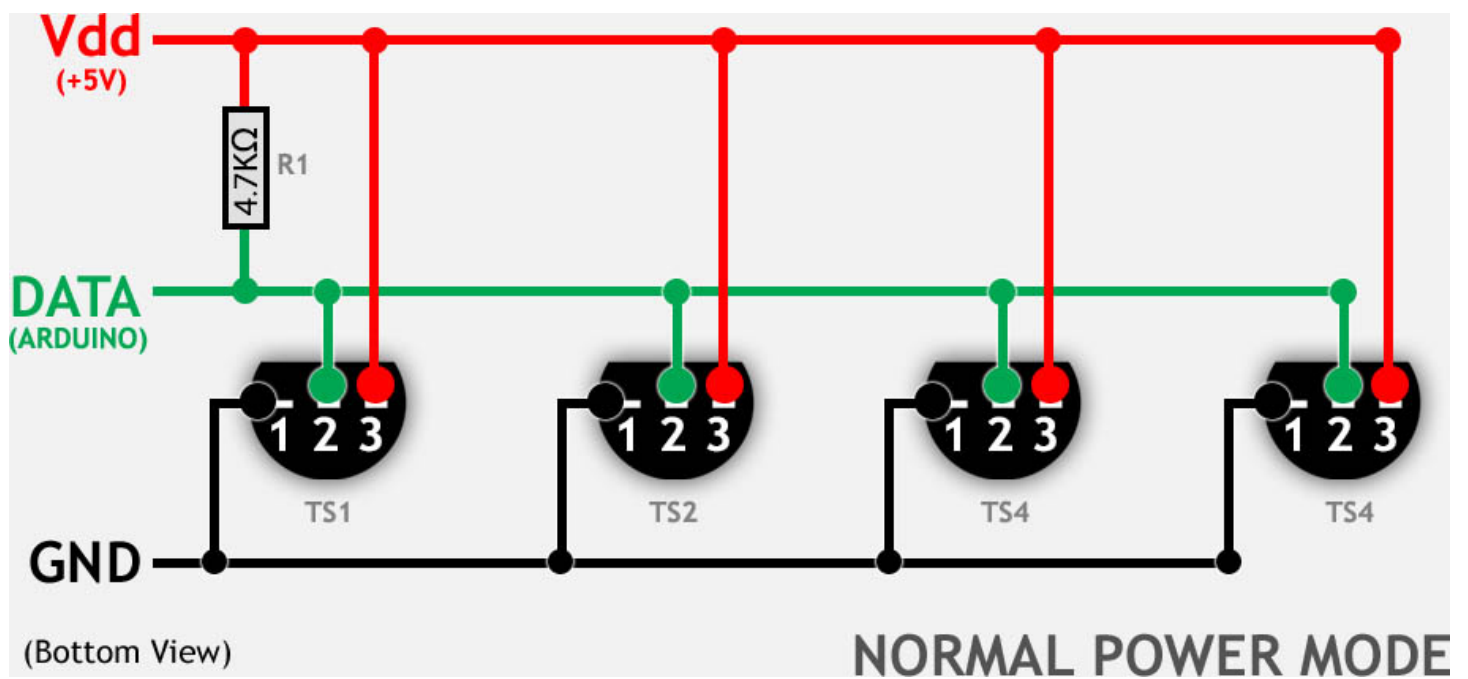
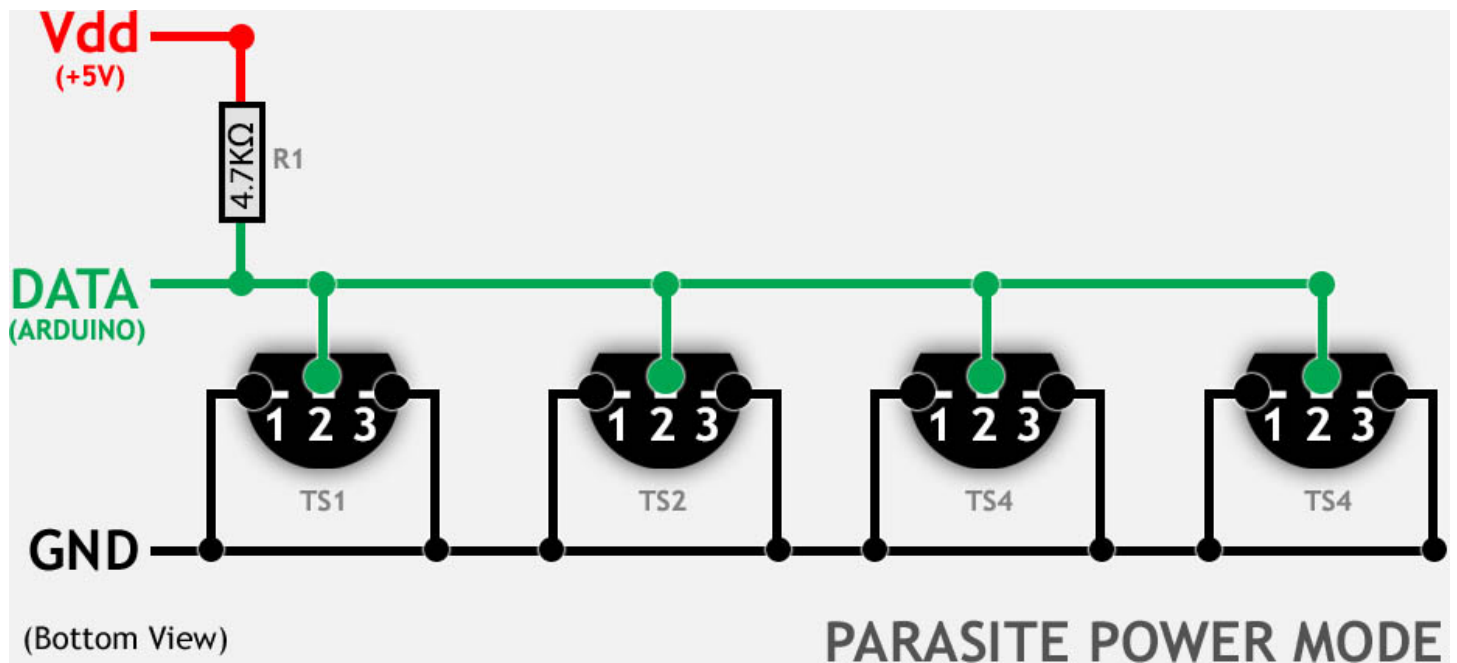
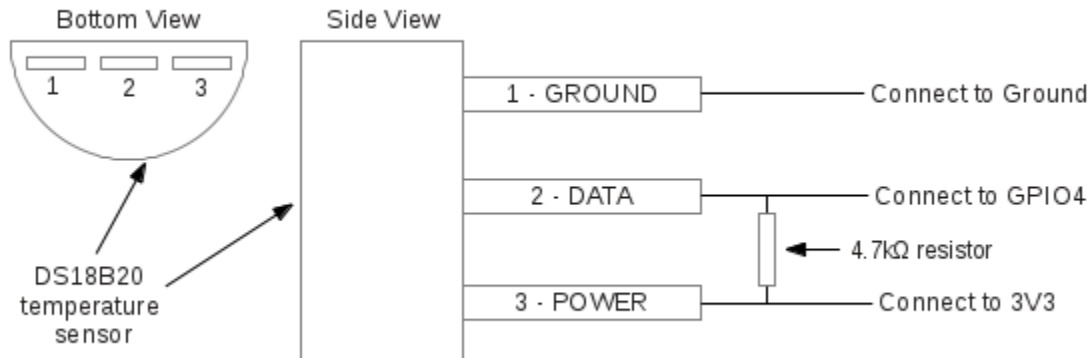
## Diagrams

### DHT11 Diagrams

DHT11 pins	
1	VCC
2	DATA
3	NC
4	GND

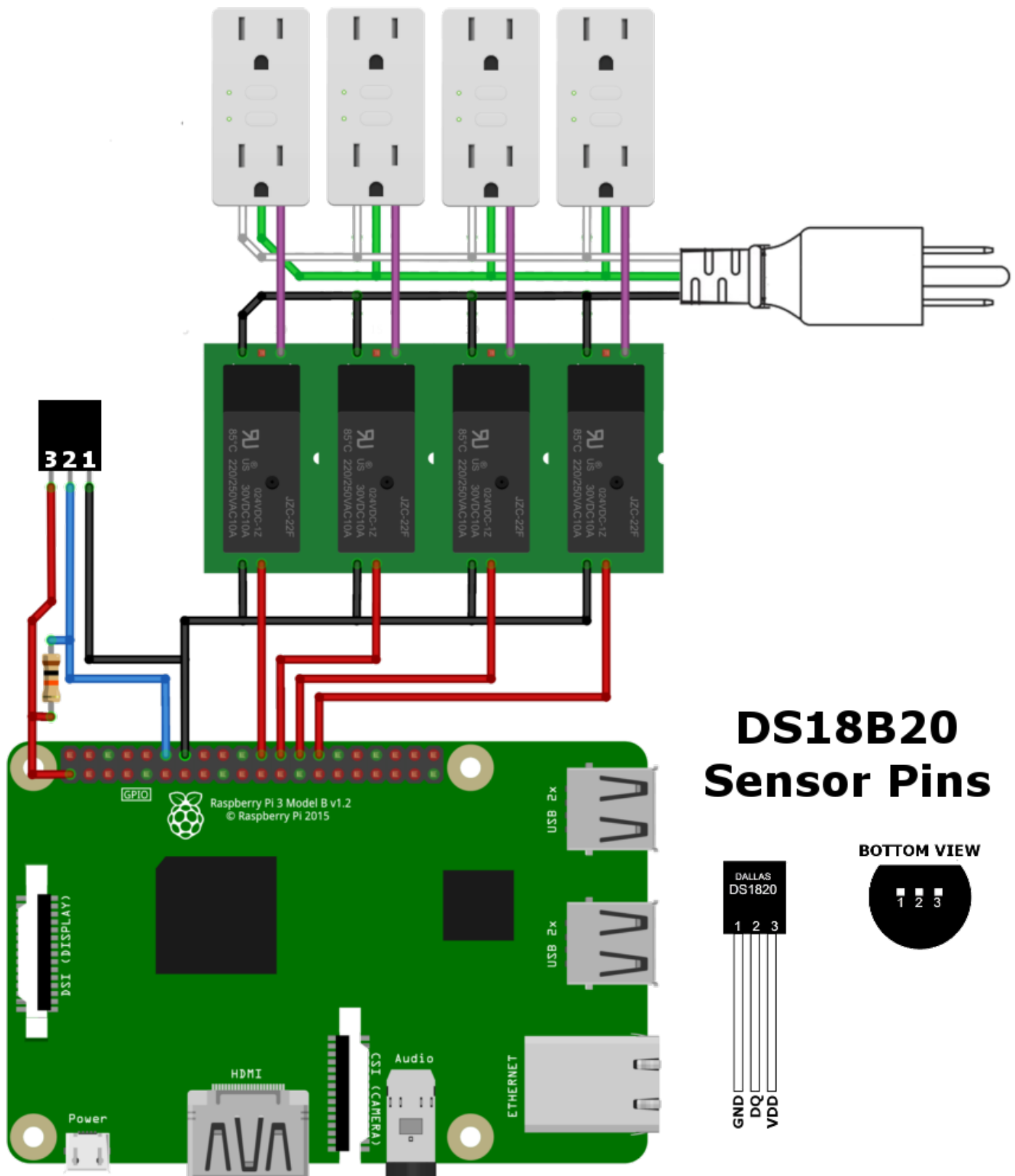


## DS18B20 Diagrams



## 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

