adafruit learning system

PyGamer Thermal Camera

Created by Jan Goolsbey

Last updated on 2020-01-29 12:50:09 AM UTC

Overview

This pocket-sized, portable thermal camera project combines an AMG8833 IR Thermal Camera FeatherWing with a PyGamer to provide a full-featured thermal imaging camera. CircuitPython will be in charge of reading and displaying the thermal image as well as interacting with operator controls.

A thermal camera can be very useful for finding home heating leaks, looking for electrical circuit hot spots, troubleshooting printed circuit board components, and for knowing when your tea is just right for sipping. The initial reason I built one was to watch the rate of heat buildup along a length of clothes dryer exhaust duct.

The camera displays a thermal image or histogram and sports a shutter button to freeze the image. The focus feature fine-tunes the display's temperature range to match the current images maxumum and maximum measurements. A settable alarm flashes lights and beeps when the camera sees a temperature at or above the threshold. The setup function is used to set the temperature display range and the alarm threshold. An editable configuration file contains the camera's power-up settings.

The heart of the camera is a thermal imaging sensor with an 8 by 8 thermopile array that reads temperatures from 32°F to 176°F (0°C to 80°C) with an absolute accuracy of +- 4.5°F (2.5°C) and resolution of 0.9°F (0.5°C). The 64 elements in the array are too few to see a lot of detail, but it is possible to recognize general thermal zones and shapes.

This version of the camera displays numeric temperature values as degrees Fahrenheit. Converting the displayed values to Celsius is possible but is left as an exercise.

CAUTION: The AMG8833 sensor used in this project is not accurate or stable enough to be used for health or safety purposes.

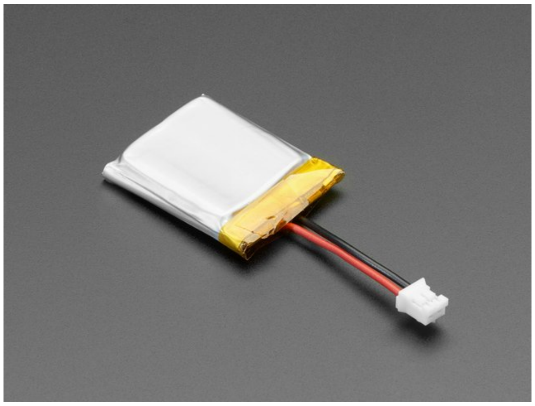
Your browser does not support the video tag.

Adafruit AMG8833 IR Thermal Camera FeatherWing

$39.95
IN STOCK
Add To Cart

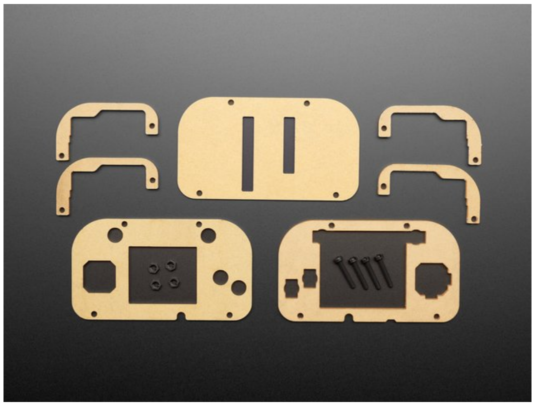
Adafruit PyGamer for MakeCode Arcade, CircuitPython or Arduino

$39.95
IN STOCK
Add To Cart



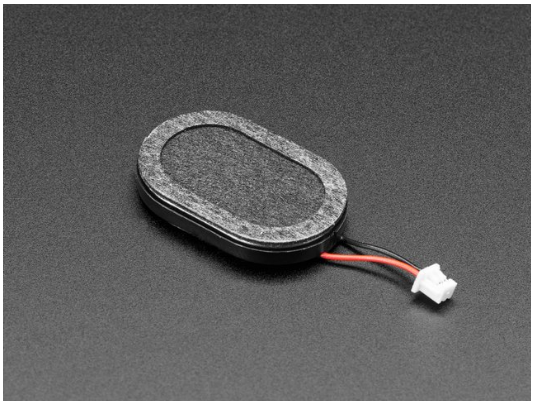
Lithium Ion Polymer Battery with Short Cable - 3.7V 350mAh

$5.95
IN STOCK
Add To Cart



Adafruit PyGamer Acrylic Enclosure Kit

OUT OF STOCK
Out Of Stock



Mini Oval Speaker with Short Wires - 8 Ohm 1 Watt

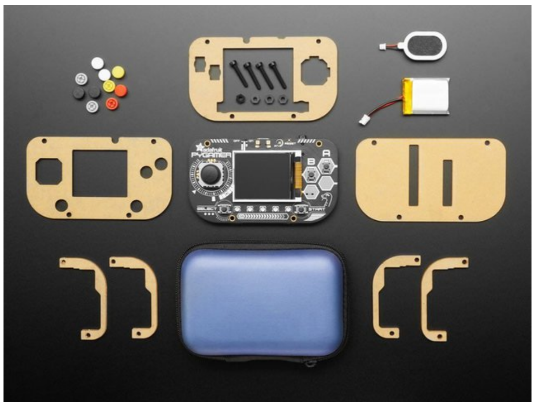
$1.95
IN STOCK
Add To Cart

Plastic Button Caps For Square Top (10-pack) - 8mm Diameter

$0.95

IN STOCK

Add To Cart



Adafruit PyGamer Starter Kit

OUT OF STOCK

Out Of Stock

Build the Camera

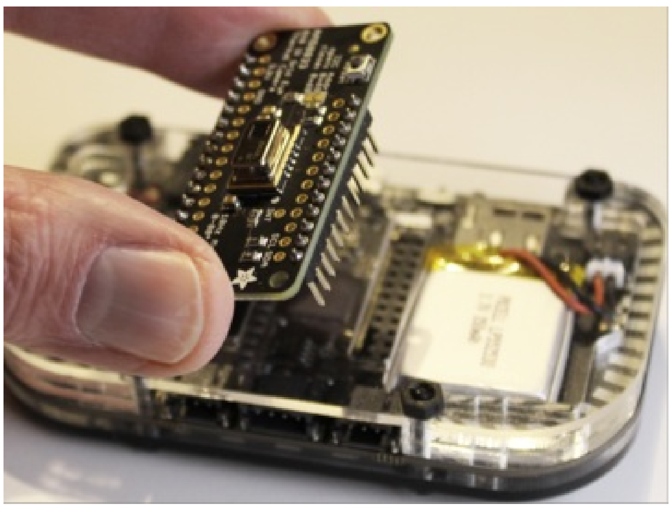
It's time to get the PyGamer ready by installing CircuitPython and its libraries, plug in the speaker and battery, and put it into an elegant enclosure. Once the enclosure is in place, we'll attach the AMG8833 FeatherWing and load the Thermal Camera code.

You can build the Thermal Camera from individual components or from the PyGamer Starter Kit (https://adafru.it/IAh). Add the AMG8833 FeatherWing (https://adafru.it/IAi) and you'll be ready to go.

Preparing the PyGamer with CircuitPython, Libraries, and Accessories

The PyGamer Introduction (https://adafru.it/pygamer) will guide you through the process of setting up the PyGamer, assembling the enclosure (https://adafru.it/IAj), and installing CircuitPython (https://adafru.it/FoA) and its libraries (https://adafru.it/IAk).

After preparing the PyGamer to run CircuitPython, follow the Starter Kit enclosure instructions (https://adafru.it/IAj) for installing the speaker and battery, even if you don't plan to use the enclosure.



Prepare the FeatherWing

Solder the included male headers onto the AMG8833 FeatherWing and attach it through the acrylic back panel into the PyGamer's Feather connector. Refer to the soldering guide (https://adafru.it/dxy) if this is your first time with a soldering iron.

CircuitPython Libraries

Your PyGamer should now have the latest version of CircuitPython and the collection of libraries needed for this project. Confirm that the lib folder contains these required libraries:

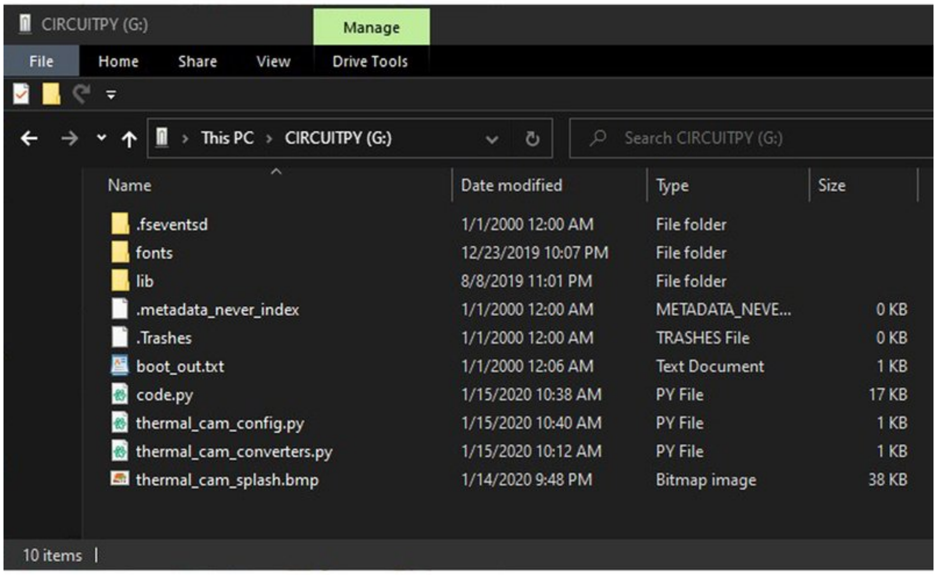
- **adafruit_simpleio**
- **adafruit_display_text**
- **adafruit_bitmap_font**
- **adafruit_display_shapes**
- **adafruit_amg88xx**
- **adafruit_pybadger**

PyGamer Thermal Camera Source Code

Download the project's source files and copy them to the PyGamer's **CIRCUITPY** root directory, with the exception of the *OpenSans-9.bdf* font file which should be placed into a *fonts* folder.

https://adafru.it/svF

https://adafru.it/svF



The zip folder contains the following folders and files:

- **fonts** folder
    - **OpenSans-9.bdf** font file
- **code.py** main thermal camera code
- **thermal_cam_config.py** power-up default settings
- **thermal_cam_converters.py** temperature unit converter helpers
- **thermal_cam_splash.bmp** startup screen graphic

Here's the main CircuitPython code for the Thermal Camera. It's also contained in the project zip folder as **code.py** .

```
# Thermal_Cam_v31.py
# 2020-01-22 v3.1
# (c) 2020 Jan Goolsbey for Adafruit Industries

print("Thermal_Cam_v31.py")

import time
import board
import displayio
from simpleio import map_range
from collections import namedtuple
from adafruit_display_text.label import Label
from adafruit_bitmap_font import bitmap_font
from adafruit_display_shapes.rect import Rect
import adafruit_amg88xx
from adafruit_pybadger import PyBadger
from thermal_cam_converters import celsius_to_fahrenheit, fahrenheit_to_celsius

# Establish panel instance and check for joystick
```

```
panel = PyBadger(pixels_brightness=0.1)  # Set NeoPixel brightness
panel.pixels.fill(0)                      # Clear all NeoPixels
if hasattr(board, "JOYSTICK_X"):
    panel.has_joystick = True     # PyGamer
else: panel.has_joystick = False  # Must be PyBadge

# Establish I2C interface for the AMG8833 Thermal Camera
i2c = board.I2C()
amg8833 = adafruit_amg88xx.AMG88XX(i2c)

# Load the text font from the fonts folder
font = bitmap_font.load_font("/fonts/OpenSans-9.bdf")

# Display spash graphics and play startup tones
with open("/thermal_cam_splash.bmp", "rb") as bitmap_file:
    bitmap = displayio.OnDiskBitmap(bitmap_file)
    splash = displayio.Group()
    splash.append(displayio.TileGrid(bitmap,
                  pixel_shader=displayio.ColorConverter()))
    board.DISPLAY.show(splash)
    time.sleep(0.1)  # Allow the splash to display
panel.play_tone(440, 0.1)  # A4
panel.play_tone(880, 0.1)  # A5

# The image sensor's design-limited temperature range
MIN_SENSOR_C = 0
MAX_SENSOR_C = 80
MIN_SENSOR_F = celsius_to_fahrenheit(MIN_SENSOR_C)
MAX_SENSOR_F = celsius_to_fahrenheit(MAX_SENSOR_C)

# Load default alarm and min/max range values list from config file
from thermal_cam_config import *

# Convert default alarm and min/max range values from config file
ALARM_C     = fahrenheit_to_celsius(ALARM_F)
MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)

# The board's integral display size
WIDTH  = board.DISPLAY.width   # 160 for PyGamer and PyBadge
HEIGHT = board.DISPLAY.height  # 128 for PyGamer and PyBadge

ELEMENT_SIZE = WIDTH // 10  # Size of element_grid blocks in pixels

# Default colors
BLACK   = 0x000000
RED     = 0xFF0000
ORANGE  = 0xFF8811
YELLOW  = 0xFFFF00
GREEN   = 0x00FF00
CYAN    = 0x00FFFF
BLUE    = 0x0000FF
VIOLET  = 0x9900FF
WHITE   = 0xFFFFFF
GRAY    = 0x444455

# Block colors for the thermal image grid
element_color = [GRAY, BLUE, GREEN, YELLOW, ORANGE, RED, VIOLET, WHITE]
# Text colors for on-screen parameters
param_list = [("ALARM", WHITE), ("RANGE", RED), ("RANGE", CYAN)]
```

```
### Helpers ###
Coords = namedtuple("Point", "x y")  # Used by element_grid()

def element_grid(col, row):  # Determine display coordinates for column, row
    return Coords(int(ELEMENT_SIZE * col + 30), int(ELEMENT_SIZE * row + 1))

def flash_status(text="", duration=0.05):  # Flash status message once
    status_label.color = WHITE
    status_label.text  = text
    time.sleep(duration)
    status_label.color = BLACK
    time.sleep(duration)
    return

def update_image_frame():  # Get camera data and display
    minimum = MAX_SENSOR_C  # Set minimum to sensor's maximum C value
    maximum = MIN_SENSOR_C  # Set maximum to sensor's minimum C value

    min_histo.text   = ""  # Clear histogram legend
    max_histo.text   = ""
    range_histo.text = ""

    sum_bucket = 0  # Clear bucket for building average value

    for row in range(0, 8):  # Parse camera data list and update display
        for col in range(0, 8):
            value = map_range(image[7 - row][7 - col],
                              MIN_SENSOR_C, MAX_SENSOR_C,
                              MIN_SENSOR_C, MAX_SENSOR_C)
            color_index = int(map_range(value, MIN_RANGE_C, MAX_RANGE_C, 0, 7))
            image_group[((row * 8) + col) + 1].fill = element_color[color_index]
            sum_bucket = sum_bucket + value  # Calculate sum for average
            minimum = min(value, minimum)
            maximum = max(value, maximum)
    return minimum, maximum, sum_bucket

def update_histo_frame():
    minimum = MAX_SENSOR_C  # Set minimum to sensor's maximum C value
    maximum = MIN_SENSOR_C  # Set maximum to sensor's minimum C value

    min_histo.text   = str(MIN_RANGE_F)  # Display histogram legend
    max_histo.text   = str(MAX_RANGE_F)
    range_histo.text = "-RANGE-"

    sum_bucket = 0  # Clear bucket for building average value

    histo_bucket = [0, 0, 0, 0, 0, 0, 0, 0]  # Clear histogram bucket
    for row in range(7, -1, -1):  # Collect camera data and calculate spectrum
        for col in range(0, 8):
            value = map_range(image[col][row],
                              MIN_SENSOR_C, MAX_SENSOR_C,
                              MIN_SENSOR_C, MAX_SENSOR_C)
            histo_index = int(map_range(value, MIN_RANGE_C, MAX_RANGE_C, 0, 7))
            histo_bucket[histo_index] = histo_bucket[histo_index] + 1
            sum_bucket = sum_bucket + value  # Calculate sum for average
            minimum = min(value, minimum)
            maximum = max(value, maximum)

    for col in range(0, 8):  # Display histogram
```

```
    for col in range(0, 8):  # Display histogram
        for row in range(0, 8):
            if histo_bucket[col] / 8 > 7 - row:
                image_group[((row * 8) + col) + 1].fill = element_color[col]
            else:
                image_group[((row * 8) + col) + 1].fill = BLACK
    return minimum, maximum, sum_bucket

def setup_mode():  # Set alarm threshold and minimum/maximum range values
    status_label.color = WHITE
    status_label.text  = "-SET-"

    ave_label.color = BLACK  # Turn off average label and value display
    ave_value.color = BLACK

    max_value.text = str(MAX_RANGE_F)  # Display maximum range value
    min_value.text = str(MIN_RANGE_F)  # Display minimum range value

    time.sleep(0.8)  # Show SET status text before setting parameters
    status_label.text  = ""  # Clear status text

    param_index = 0  # Reset index of parameter to set

    # Select parameter to set
    while not panel.button.start:
        while (not panel.button.a) and (not panel.button.start):
            left, right, up, down = move_buttons(joystick=panel.has_joystick)
            if up:
                param_index = param_index - 1
            if down:
                param_index = param_index + 1
            param_index = max(0, min(2, param_index))
            status_label.text = param_list[param_index][0]
            image_group[param_index + 66].color = BLACK
            status_label.color = BLACK
            time.sleep(0.2)
            image_group[param_index + 66].color = param_list[param_index][1]
            status_label.color = WHITE
            time.sleep(0.2)

        if panel.button.a:  # Button A pressed
            panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:  # wait for button release
            pass

        # Adjust parameter value
        param_value = int(image_group[param_index + 70].text)
        while (not panel.button.a) and (not panel.button.start):
            left, right, up, down = move_buttons(joystick=panel.has_joystick)
            if up:
                param_value = param_value + 1
            if down:
                param_value = param_value - 1
            param_value = max(MIN_SENSOR_F, min(MAX_SENSOR_F, param_value))
            image_group[param_index + 70].text = str(param_value)
            image_group[param_index + 70].color = BLACK
            status_label.color = BLACK
            time.sleep(0.05)
            image_group[param_index + 70].color = param_list[param_index][1]
            status_label.color = WHITE
```

```
            time.sleep(0.2)

        if panel.button.a:  # Button A pressed
            panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:  # wait for button release
            pass

    # Exit setup process
    if panel.button.start:  # Start button pressed
        panel.play_tone(784, 0.030)  # G5
    while panel.button.start:  # wait for button release
        pass

    status_label.text = "RESUME"
    time.sleep(0.5)
    status_label.text = ""

    # Display average label and value
    ave_label.color = YELLOW
    ave_value.color = YELLOW
    return int(alarm_value.text), int(max_value.text), int(min_value.text)

def move_buttons(joystick=False):  # Read position buttons and joystick
    move_r = move_l = False
    move_u = move_d = False
    if joystick:  # For PyGamer: interpret joystick as buttons
        if   panel.joystick[0] > 44000:
            move_r = True
        elif panel.joystick[0] < 20000:
            move_l = True
        if   panel.joystick[1] < 20000:
            move_u = True
        elif panel.joystick[1] > 44000:
            move_d = True
    else:  # For PyBadge read the buttons
        if panel.button.right:
            move_r = True
        if panel.button.left:
            move_l = True
        if panel.button.up:
            move_u = True
        if panel.button.down:
            move_d = True
    return move_r, move_l, move_u, move_d

### Define the display group ###
image_group = displayio.Group(max_size=77)

# Create a background color fill layer; image_group[0]
color_bitmap = displayio.Bitmap(WIDTH, HEIGHT, 1)
color_palette = displayio.Palette(1)
color_palette[0] = BLACK
background = displayio.TileGrid(color_bitmap, pixel_shader=color_palette,
                                x=0, y=0)
image_group.append(background)

# Define the foundational thermal image element layers; image_group[1:64]
#   image_group[#]=(row * 8) + column
for row in range(0, 8):
    for col in range(0, 8):
```

```
    for col in range(0, 8):
        pos = element_grid(col, row)
        element = Rect(x=pos.x, y=pos.y,
                       width=ELEMENT_SIZE, height=ELEMENT_SIZE,
                       fill=None, outline=None, stroke=0)
        image_group.append(element)

# Define labels and values using element grid coordinates
status_label = Label(font, text="", color=BLACK, max_glyphs=6)
pos = element_grid(2.5, 4)
status_label.x = pos.x
status_label.y = pos.y
image_group.append(status_label)  # image_group[65]

alarm_label = Label(font, text="alm", color=WHITE, max_glyphs=3)
pos = element_grid(-1.8, 1.5)
alarm_label.x = pos.x
alarm_label.y = pos.y
image_group.append(alarm_label)  # image_group[66]

max_label = Label(font, text="max", color=RED, max_glyphs=3)
pos = element_grid(-1.8, 3.5)
max_label.x = pos.x
max_label.y = pos.y
image_group.append(max_label)  # image_group[67]

min_label = Label(font, text="min", color=CYAN, max_glyphs=3)
pos = element_grid(-1.8, 7.5)
min_label.x = pos.x
min_label.y = pos.y
image_group.append(min_label)  # image_group[68]

ave_label = Label(font, text="ave", color=YELLOW, max_glyphs=3)
pos = element_grid(-1.8, 5.5)
ave_label.x = pos.x
ave_label.y = pos.y
image_group.append(ave_label)  # image_group[69]

alarm_value = Label(font, text=str(ALARM_F), color=WHITE, max_glyphs=5)
pos = element_grid(-1.8, 0.5)
alarm_value.x = pos.x
alarm_value.y = pos.y
image_group.append(alarm_value)  # image_group[70]

max_value = Label(font, text=str(MAX_RANGE_F), color=RED, max_glyphs=5)
pos = element_grid(-1.8, 2.5)
max_value.x = pos.x
max_value.y = pos.y
image_group.append(max_value)  # image_group[71]

min_value = Label(font, text=str(MIN_RANGE_F), color=CYAN, max_glyphs=5)
pos = element_grid(-1.8, 6.5)
min_value.x = pos.x
min_value.y = pos.y
image_group.append(min_value)  # image_group[72]

ave_value = Label(font, text="---", color=YELLOW, max_glyphs=5)
pos = element_grid(-1.8, 4.5)
ave_value.x = pos.x
ave_value.y = pos.y
```

```
image_group.append(ave_value)  # image_group[73]

min_histo = Label(font, text="", color=CYAN, max_glyphs=3)
pos = element_grid(0.5, 7.5)
min_histo.x = pos.x
min_histo.y = pos.y
image_group.append(min_histo)  # image_group[74]

max_histo = Label(font, text="", color=RED, max_glyphs=3)
pos = element_grid(6.5, 7.5)
max_histo.x = pos.x
max_histo.y = pos.y
image_group.append(max_histo)  # image_group[75]

range_histo = Label(font, text="", color=BLUE, max_glyphs=7)
pos = element_grid(2.5, 7.5)
range_histo.x = pos.x
range_histo.y = pos.y
image_group.append(range_histo)  # image_group[76]

###--- PRIMARY PROCESS SETUP ---###
display_image = True   # Image display mode; False for histogram
display_hold  = False  # Active display mode; True to hold display
display_focus = False  # Standard display range; True to focus display range

# Activate display and play welcome tone
board.DISPLAY.show(image_group)
panel.play_tone(880, 0.1)  # A5; ready to start looking

###--- PRIMARY PROCESS LOOP ---###
while True:
    if display_hold:  # Flash hold status text label
        flash_status("-HOLD-")
    else:
        image = amg8833.pixels  # Get camera data list if not in hold mode
        status_label.text = ""  # Clear hold mode status text label

    if display_image:  # Image display mode and gather min, max, and sum stats
        v_min, v_max, v_sum = update_image_frame()
    else:  # Histogram display mode and gather min, max, and sum stats
        v_min, v_max, v_sum = update_histo_frame()

    # Display alarm setting and maxumum, minimum, and average stats
    alarm_value.text = str(ALARM_F)
    max_value.text   = str(celsius_to_fahrenheit(v_max))
    min_value.text   = str(celsius_to_fahrenheit(v_min))
    ave_value.text   = str(celsius_to_fahrenheit(v_sum // 64))

    # Flash first NeoPixel and play alarm notes if alarm threshold is exceeded
    # Second alarm note frequency is proportional to value above threshold
    if v_max >= ALARM_C:
        panel.pixels.fill(RED)
        panel.play_tone(880, 0.015)  # A5
        panel.play_tone(880 + (10 * (v_max - ALARM_C)), 0.015)  # A5
        panel.pixels.fill(BLACK)

    # See if a panel button is pressed
    if panel.button.a:  # Toggle display hold (shutter = button A)
        panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:
```

```
        while panel.button.a:
            pass   # wait for button release
        if display_hold == False:
            display_hold = True
        else:
            display_hold = False

    if panel.button.b:  # Toggle image/histogram mode (display mode = button B)
        panel.play_tone(659, 0.030)  # E5
        while panel.button.b:  pass  # wait for button release
        if display_image:
            display_image = False
        else:
            display_image = True

    if panel.button.select:  # toggle focus mode (focus mode = select button)
        panel.play_tone(698, 0.030)  # F5
        if display_focus:
            display_focus = False  # restore previous (original) range values
            MIN_RANGE_F = temp_min_range_f
            MAX_RANGE_F = temp_max_range_f
            # update range min and max values in Celsius
            MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
            MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)
            flash_status("ORIG", 0.2)
        else:
            display_focus = True  # set range values to image min/max
            temp_min_range_f = MIN_RANGE_F
            temp_max_range_f = MAX_RANGE_F
            MIN_RANGE_F = celsius_to_fahrenheit(v_min)
            MAX_RANGE_F = celsius_to_fahrenheit(v_max)
            MIN_RANGE_C = v_min  # update range temp in Celsius
            MAX_RANGE_C = v_max  # update range temp in Celsius
            flash_status("FOCUS", 0.2)
        while panel.button.select:
            pass  # wait for button release

    if panel.button.start:  # activate setup mode (setup mode = start button)
        panel.play_tone(784, 0.030)  # G5
        while panel.button.start:
            pass  # wait for button release

        # Update alarm and range values
        ALARM_F, MAX_RANGE_F, MIN_RANGE_F = setup_mode()
        ALARM_C = fahrenheit_to_celsius(ALARM_F)
        MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
        MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)

    pass  # bottom of primary loop
```

The Thermal Camera needs some helpers to convert back and forth between Celsius and Fahrenheit units. This file is contained in the project zip folder as **thermal_cam_converters.py**.

```
# thermal_cam_converters.py

def celsius_to_fahrenheit(deg_c=None):  # convert C to F; round to 1 degree C
    return round(((9 / 5) * deg_c) + 32)

def fahrenheit_to_celsius(deg_f=None):  # convert F to C; round to 1 degree F
    return round((deg_f - 32) * (5 / 9))
```

Finally, the power-up alarm and temperature display range settings are contained in the **thermal_cam_config.py** file. All values are in degrees Fahrenheit.

```
# thermal_cam_config.py
### Alarm and range default values in Farenheit ###
ALARM_F     = 120
MIN_RANGE_F =  60
MAX_RANGE_F = 120
```

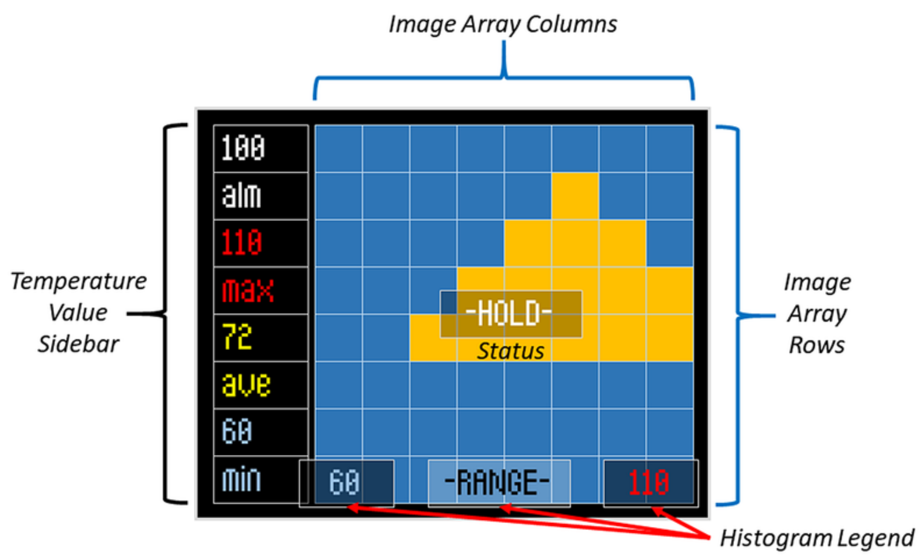
After copying all the project files to the PyGamer, you'll see the camera's splash graphics, hear a couple of beeps, and the thermal image will appear.

The next section shows the features of the camera and how it operates.

Features and Operation

The Thermal Camera's controls are used to switch display modes, take snapshots, automatically increase or decrease image temperature gradient detail, and facilitate setting alarm and maximum/minimum display range parameters. The display shows the image or histogram and the currently measured maximum, minimum, and average temperature values in Fahrenheit.

Display Layout



The camera's display is divided into four zones. The temperature value sidebar is used to display the alarm (**alm**) threshold setting, the measured maximum temperature (**max**), the average temperature calculation (**ave**), and the measured minimum temperature (**min**). The sidebar continuously displays measured values during normal operation. When in the **Setup** mode, the sidebar indicates the current alarm threshold, the maximum display range, and the minimum display range.

The image array area consists of 64 blocks in an 8 column by 8 row array. The image array is used to display a thermal sensor image or histogram.

Superimposed over the display grid are the status message area (centered in the image array area) and the histogram legend area (near the bottom of the image array area). The status message area indicates various operational states including **Hold**, **Focus**, and the **Setup** mode. The histogram legend area shows the current minimum and maximum display range settings when viewing a histogram

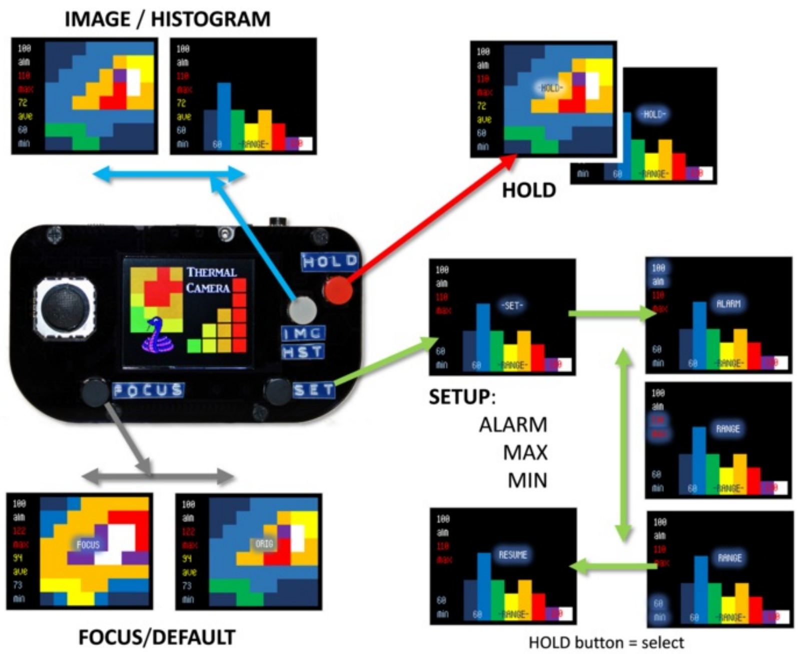


Image / Histogram Mode

The **IMG-HST** button (PyGamer button B) is used to toggle between a temperature gradient image and a temperature distribution representation of the thermopile sensor's measurements. The **IMG-HST** button is operational when in **Hold** mode to allow analysis of held measurements.

Hold Mode

The **HOLD** button (PyGamer button A) freezes and releases the image or histogram display contents. Press the button once to hold the display; press it again to resume normal operation. The **IMG-HST** button continues to operate normally regardless of whether or not the display is held.

Focus Range / Default Range

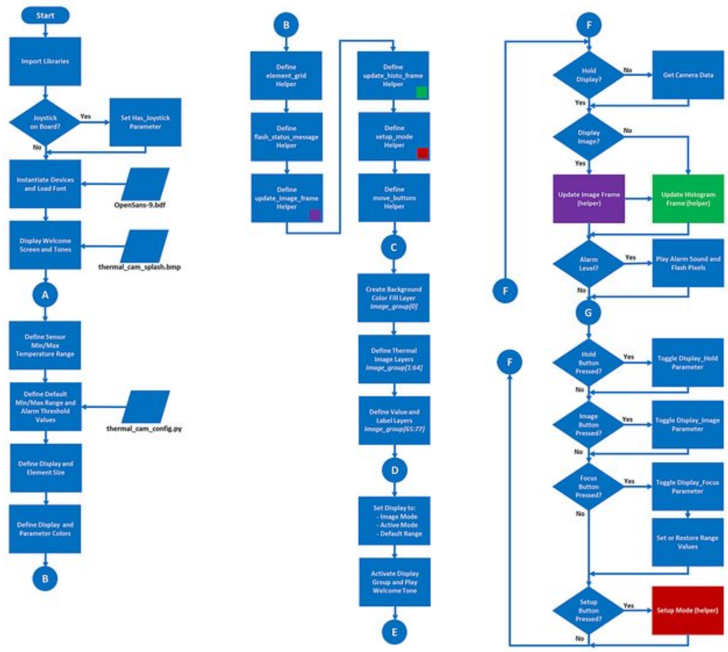
The **FOCUS** button (PyGamer Select button) automatically changes the minimum and maximum display range values to provide increased or decreased detail based on the currently measured maximum and minimum temperatures. Press **FOCUS** once to change the current display range from the current setting to a range that matches the measured minimum and maximum values. Press it again to return to the original display range settings. **Focus** mode is useful when looking for increased temperature gradient detail or when the temperature of the object is outside of the default or re-set display range.

Setup Function

Pressing the **SET** button (PyGamer Start button) will stop normal operation and enter the **Setup** mode where the alarm threshold and maximum/minimum display range are adjustable. Use the joystick or the PyBadge D-Pad buttons to highlight the parameter to change, then press the **HOLD** button to select. Use the joystick to increase or decrease the parameter value. Press the **HOLD** button to select the new value. To exit the **Setup** mode, press the **SET** button.

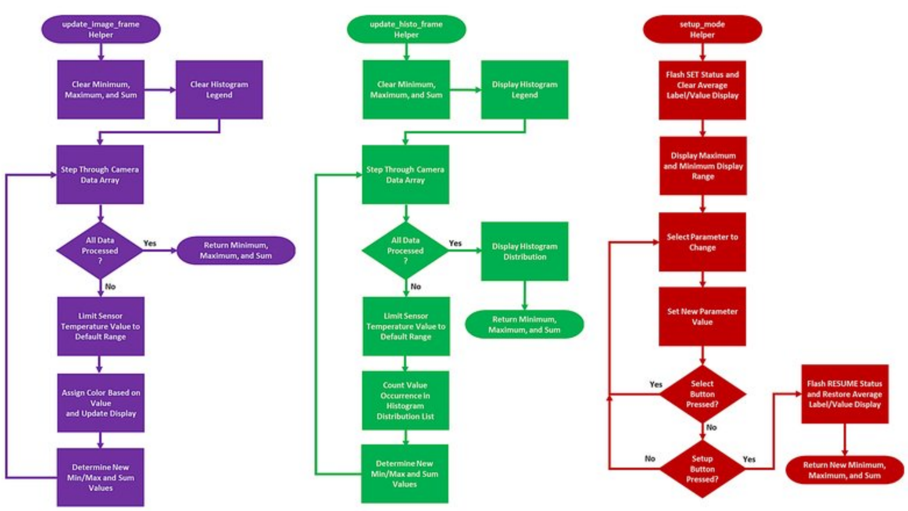
The newly selected values will go into effect when exiting **Setup** mode, but will not be preserved if the camera's power is turned off. To change power-on parameter values, edit the **thermal_cam_config.py** file with your favorite text editor.

CircuitPython Code Details



The CircuitPython code for the Thermal Camera project is contained in three files, the main **code.py** file, the temperature unit conversion helper **thermal_cam_converters.py** file, and the start-up default parameter **thermal_cam_config.py** file.

Let's take a walk through the code and look in more detail how each section works starting with the main module, **code.py**.



Details: Main Module

code.py

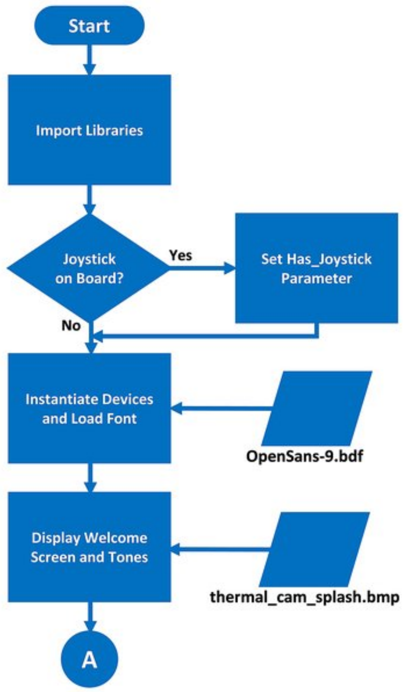
The main module, **code.py**, prepares and operates the Thermal Camera. It consists of the following major sections:

- **Import and Initialize:** Libraries, Devices, and Welcome Screen
- **Constants and Variables:** Display, Min/Max, and Alarm Threshold Values
- **Helpers:** Display, Buttons, and Setup Functions
- **Display:** Define Group Layers
- **Primary Process:** Setup and Loop

Let's get started with importing libraries, establishing devices, and saying hello.

Import and Initialize

Libraries, Devices, and Welcome Screen



When the PyGamer's power is turned on, the **code.py**module first imports all the required libraries. That includes the **thermal_cam_converters.py** helper file that we'll review later.

```
# Thermal_Cam_v31.py
# 2020-01-22 v3.1
# (c) 2020 Jan Goolsbey for Adafruit Industries

print("Thermal_Cam_v31.py")

import time
import board
import displayio
from simpleio import map_range
from collections import namedtuple
from adafruit_display_text.label import Label
from adafruit_bitmap_font import bitmap_font
from adafruit_display_shapes.rect import Rect
import adafruit_amg88xx
from adafruit_pybadger import PyBadger
from thermal_cam_converters import celsius_to_fahrenheit, fahrenheit_to_celsius
```

Next, the code checks to see if the PyGamer's joystick is present and sets the `panel.has_joystick` flag to `True`. If not, then the host device is probably a PyBadge or EdgeBadge; this code will work for those devices, interpreting the D-Pad buttons like a joystick.

```
# Establish panel instance and check for joystick
panel = PyBadger(pixels_brightness=0.1)  # Set NeoPixel brightness
panel.pixels.fill(0)                     # Clear all NeoPixels
if hasattr(board, "JOYSTICK_X"):
    panel.has_joystick = True     # PyGamer
else: panel.has_joystick = False  # Must be PyBadge
```

The AMG8833 FeatherWing is instantiated on the I2C communications bus, then the **OpenSans-9.bdf** font file is loaded from the **/fonts** folder.

```
# Establish I2C interface for the AMG8833 Thermal Camera
i2c = board.I2C()
amg8833 = adafruit_amg88xx.AMG88XX(i2c)
```

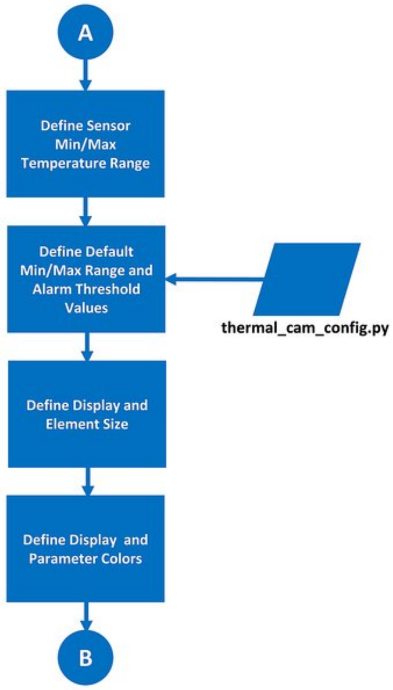
```
# Load the text font from the fonts folder
font = bitmap_font.load_font("/fonts/OpenSans-9.bdf")
```

Finally, the welcome graphics screen, **thermal_cam_splash.bmp** is displayed followed by a two-tone welcoming beep.

```
# Display spash graphics and play startup tones
with open("/thermal_cam_splash.bmp", "rb") as bitmap_file:
    bitmap = displayio.OnDiskBitmap(bitmap_file)
    splash = displayio.Group()
    splash.append(displayio.TileGrid(bitmap,
                  pixel_shader=displayio.ColorConverter()))
    board.DISPLAY.show(splash)
    time.sleep(0.1)  # Allow the splash to display
panel.play_tone(440, 0.1)  # A4
panel.play_tone(880, 0.1)  # A5
```

Constants and Variables

Display, Minimum/Maximum, and Alarm Threshold Values



After saying hello, a few commonly used constants and variables are defined. These include the sensor's minimum and maximum values (0°C to 80°C for the AMG8833 FeatherWing) as well as the alarm threshold and display min/max settings from the **thermal_cam_config.py** file. Default values in Celsius are converted to Fahrenheit where needed.

```
# The image sensor's design-limited temperature range
MIN_SENSOR_C = 0
MAX_SENSOR_C = 80
MIN_SENSOR_F = celsius_to_fahrenheit(MIN_SENSOR_C)
MAX_SENSOR_F = celsius_to_fahrenheit(MAX_SENSOR_C)

# Load default alarm and min/max range values list from config file
from thermal_cam_config import *

# Convert default alarm and min/max range values from config file
ALARM_C     = fahrenheit_to_celsius(ALARM_F)
MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)
```

Display width and height are retrieved from the PyGamer's board definitions. The size of individual display blocks is defined as 1/10th of the display's width, corresponding to 10 display columns. In this case, that's a 16 pixel square.

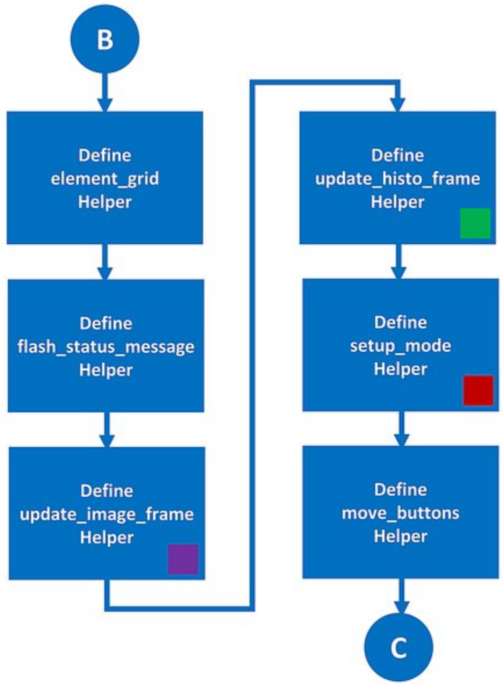
```
# The board's integral display size
WIDTH  = board.DISPLAY.width   # 160 for PyGamer and PyBadge
HEIGHT = board.DISPLAY.height  # 128 for PyGamer and PyBadge

ELEMENT_SIZE = WIDTH // 10  # Size of element_grid blocks in pixels
```

Color values are defined next and are incorporated into two lists, `element_color` and `param_list` that are used to color blocks in the image array according to temperature value and for text labels of measured values.

```
# Default colors
BLACK   = 0x000000
RED     = 0xFF0000
ORANGE  = 0xFF8811
YELLOW  = 0xFFFF00
GREEN   = 0x00FF00
CYAN    = 0x00FFFF
BLUE    = 0x0000FF
VIOLET  = 0x9900FF
WHITE   = 0xFFFFFF
GRAY    = 0x444455

# Block colors for the thermal image grid
element_color = [GRAY, BLUE, GREEN, YELLOW, ORANGE, RED, VIOLET, WHITE]
# Text colors for on-screen parameters
param_list = [("ALARM", WHITE), ("RANGE", RED), ("RANGE", CYAN)]
```

Helpers

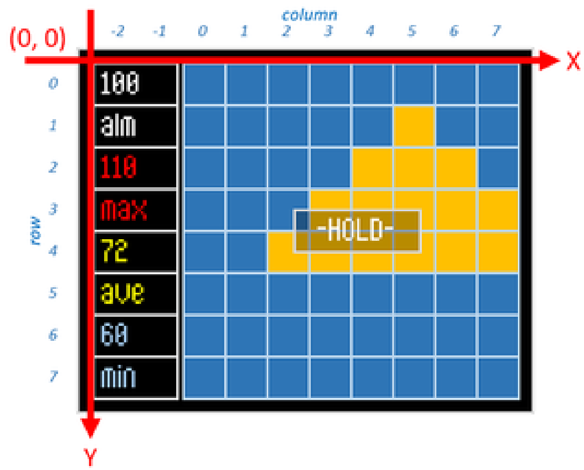
Helpers for Display, Buttons, and Setup Functions



Helpers are used to simplify the primary loop code. The helpers:

- Calculate display coordinates for the row/column grid of blocks used for the image and text labels and values;
- Display a status message in the center of the image area;
- Display and refresh the sensor image;
- Display and refresh the histogram image;
- The parameter setup process.

`element_grid()` Helper



The element_grid() helper accepts a column/row tuple and returns a display x/y coordinate address tuple for positioning the upper left corner of each graphic box or text label.

The display is divided into 80 blocks in a matrix of 10 columns and 8 rows. The temperature value sidebar uses all rows of the two leftmost columns while the image area uses the remaining 8 columns.

The Coords assignment is a simple way to create the named tuple of x/y values for use by element_grid() or elsewhere.

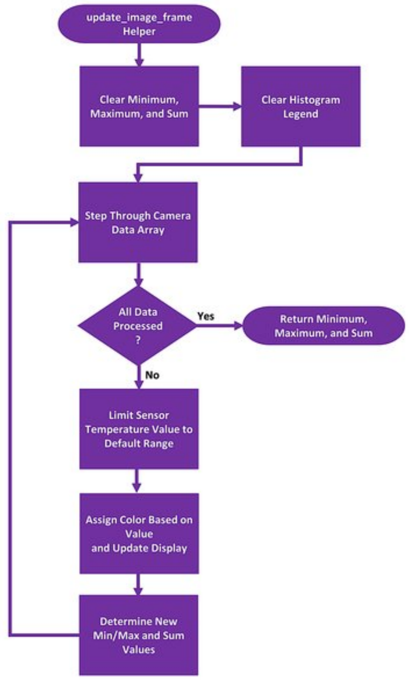
```
### Helpers ###
Coords = namedtuple("Point", "x y")  # Used by element_grid()

def element_grid(col, row):  # Determine display coordinates for column, row
    return Coords(int(ELEMENT_SIZE * col + 30), int(ELEMENT_SIZE * row + 1))
```

flash_status() Helper

The flash_status() helper accepts a text string and displays it in the status area of the display. The text appears for as white letters for a time specified by duration then as black letters for duration length in seconds. This is very useful for flashing a message that can be seen regardless of the background colors, especially handy while displaying a sensor image.

```
def flash_status(text="", duration=0.05):  # Flash status message once
    status_label.color = WHITE
    status_label.text  = text
    time.sleep(duration)
    status_label.color = BLACK
    time.sleep(duration)
    return
```

update_image_frame() Helper



The `update_image_frame()` helper looks through a list of 64 sensor temperature values stored by row and column in the `image` list. The helper analyzes all values in degrees Celsius leaving the conversion to Fahrenheit to the primary process loop.

When invoked, the helper clears variables used to find minimum and maximum sensor values as well as a "bucket" (`sum_bucket`) used to sum all values to be used later to calculate the average temperature. It also makes certain that histogram legend text is not displayed when showing a sensor image.

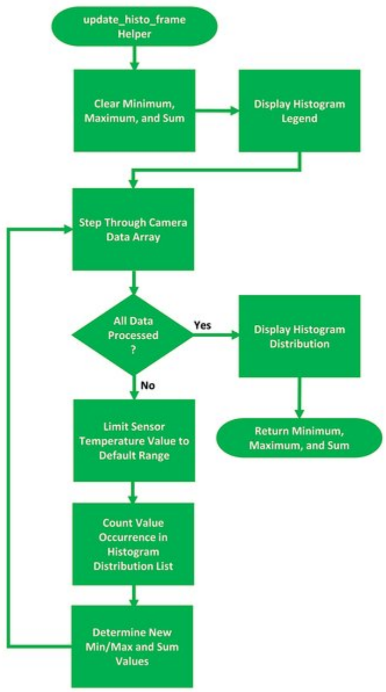
```
def update_image_frame():  # Get camera data and display
    minimum = MAX_SENSOR_C  # Set minimum to sensor's maximum C value
    maximum = MIN_SENSOR_C  # Set maximum to sensor's minimum C value

    min_histo.text   = ""  # Clear histogram legend
    max_histo.text   = ""
    range_histo.text = ""

    sum_bucket = 0  # Clear bucket for building average value
```

Next, the `image` list is examined one element at a time, starting at the upper left of the display's image area array and working down to the lower right. Each sensor element's temperature value is checked against the sensor's minimum and maximum allowed values since the sensor's output value can incorrectly fall outside of that range. Based on the sensor value's relationship to the entire temperature display range, a color is assigned to the value and the corresponding array block is filled with that color and displayed.

Finally, maximum, minimum, and `sum_bucket` values are returned to the primary process loop to convert to Fahrenheit and display in the sidebar.

```
for row in range(0, 8):  # Parse camera data list and update display
        for col in range(0, 8):
            value = map_range(image[7 - row][7 - col],
                              MIN_SENSOR_C, MAX_SENSOR_C,
                              MIN_SENSOR_C, MAX_SENSOR_C)
            color_index = int(map_range(value, MIN_RANGE_C, MAX_RANGE_C, 0, 7))
            image_group[((row * 8) + col) + 1].fill = element_color[color_index]
            sum_bucket = sum_bucket + value  # Calculate sum for average
            minimum = min(value, minimum)
            maximum = max(value, maximum)
    return minimum, maximum, sum_bucket
```

update_histo_frame() Helper



The update_histo_frame() helper collects a distribution of 8 temperature sub-ranges within the entire temperature display range (one for each color) and displays a histogram of relative temperature values. The helper scans all 64 sensor temperature values an counts the number of times a value falls within one of 8 sub-ranges. The helper analyzes all values in degrees Celsius leaving the conversion to Fahrenheit to the primary process loop.

When invoked, the helper clears variables used to find minimum and maximum sensor values, the average summing bucket, and the list containing the 8 "buckets" (histo_bucket) representing the distribution of values across the temperature display range. The helper displays the current temperature display range minimum and maximum values in the histogram legend area.

```
def update_histo_frame():
    minimum = MAX_SENSOR_C  # Set minimum to sensor's maximum C value
    maximum = MIN_SENSOR_C  # Set maximum to sensor's minimum C value

    min_histo.text   = str(MIN_RANGE_F)  # Display histogram legend
    max_histo.text   = str(MAX_RANGE_F)
    range_histo.text = "-RANGE-"

    sum_bucket = 0  # Clear bucket for building average value
```

Next, the 64 sensor values are examined one element at a time. The sensor element value is checked to make certain that it only falls within the allowable sensor range.

Each `value` is evaluated against the current display range to create the histogram distribution. An index is created (`histo_index`) that is used to increment the corresponding element of `histo_bucket` .

Minimum and maximum values are captured along with the summed values in `sum_bucket` as each element is evaluated.

The `histo_bucket` list now contains the distribution of 8 temperature sub-ranges found within the temperature display range. These values will be used to create the histogram image on the display.

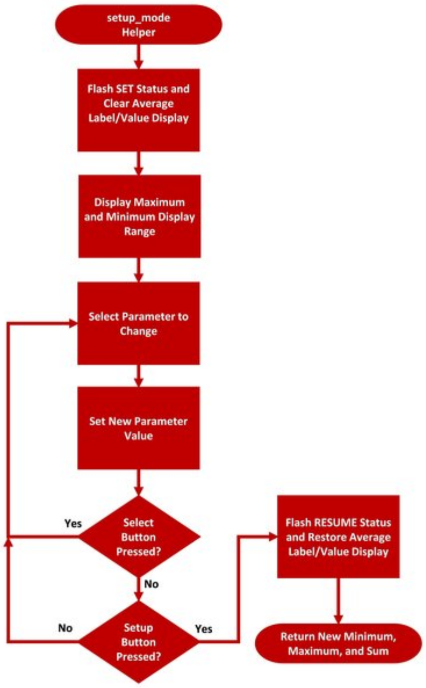
```
histo_bucket = [0, 0, 0, 0, 0, 0, 0, 0]  # Clear histogram bucket
    for row in range(7, -1, -1):  # Collect camera data and calculate spectrum
        for col in range(0, 8):
            value = map_range(image[col][row],
                              MIN_SENSOR_C, MAX_SENSOR_C,
                              MIN_SENSOR_C, MAX_SENSOR_C)
            histo_index = int(map_range(value, MIN_RANGE_C, MAX_RANGE_C, 0, 7))
            histo_bucket[histo_index] = histo_bucket[histo_index] + 1
            sum_bucket = sum_bucket + value  # Calculate sum for average
            minimum = min(value, minimum)
            maximum = max(value, maximum)
```

The second part of the helper updates the image area to show the histogram, starting at the upper left of the display's image array area and working down to the lower right. Each box in the array is filled with a color that corresponds to the relative temperature, proportional to the count in that sub-range. The remainder of boxes in the display are colored black.

Finally, minimum, maximum, and `sum_bucket` values are returned to the primary process loop to convert to Fahrenheit and display in the sidebar.

```
for col in range(0, 8):  # Display histogram
        for row in range(0, 8):
            if histo_bucket[col] / 8 > 7 - row:
                image_group[((row * 8) + col) + 1].fill = element_color[col]
            else:
                image_group[((row * 8) + col) + 1].fill = BLACK
    return minimum, maximum, sum_bucket
```

`setup_mode()` Helper



The `setup_mode()` helper pauses normal operation and collects user input to set alarm threshold and display range min/max values. During the **Setup** mode, the display's average value and label are blanked since it's not possible to set the computed average value.

The joystick or PyBadge D-Pad is used to select the parameter to change and to increase or decrease the parameter value. The **HOLD** button acts as a select button. Pressing the **SET** button at any time during the **Setup** mode will exit back to the primary process loop.

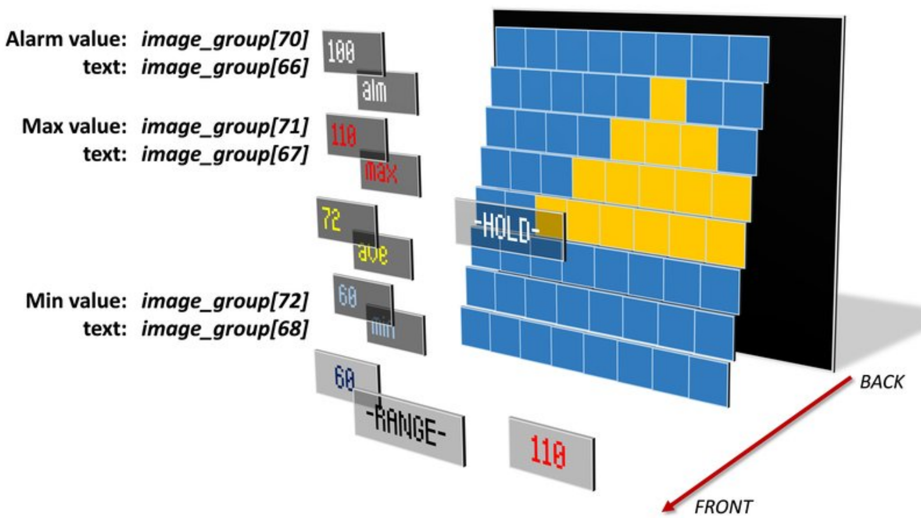
The first task is to temporarily display a status message that indicates the camera is in the **Setup** mode. The display's average value and label are blanked and the measured maximum and minimum values are replaced with the current maximum and minimum display range values (`MAX_RANGE_F` and `MIN_RANGE_F`).

After waiting a bit for the status message to be read and prior to watching for button and joystick changes, the index pointer (`param_index`) is reset to point to the alarm threshold parameter.

```
def setup_mode():  # Set alarm threshold and minimum/maximum range values
    status_label.color = WHITE
    status_label.text  = "-SET-"

    ave_label.color = BLACK  # Turn off average label and value display
    ave_value.color = BLACK

    max_value.text = str(MAX_RANGE_F)  # Display maximum range value
    min_value.text = str(MIN_RANGE_F)  # Display minimum range value

    time.sleep(0.8)  # Show SET status text before setting parameters
    status_label.text  = ""  # Clear status text

    param_index = 0  # Reset index of parameter to set
```

The following is the meat of the setup process. First, the process waits until the **SET** button has been released before moving on to choosing which parameter to set.

As long as the **HOLD** (select) or the **SET** (setup mode exit) buttons have not been pressed, the code loops. During the loop, the joystick is watched using the `move_buttons()` helper. If the joystick is moved down, the parameter index is incremented, pointing to the next parameter. If moved up, the index will point to the previous parameter. The parameter label text flashes black and white, indicating which parameter is ready to be changed.



In the `image_group` list (that is defined later, just before the primary process loop) the three parameter text labels for alarm, maximum, and minimum are sequentially positioned in the list:

- Alarm text label --> `image_group[66]`
- Maximum text label --> `image_group[67]`
- Minimum text label --> `image_group[68]`

Using an indexed position in `image_group` for the parameters makes it easer to sequentially step from one parameter to the next.

```
# Select parameter to set
    while not panel.button.start:
        while (not panel.button.a) and (not panel.button.start):
            left, right, up, down = move_buttons(joystick=panel.has_joystick)
            if up:
                param_index = param_index - 1
            if down:
                param_index = param_index + 1
            param_index = max(0, min(2, param_index))
            status_label.text = param_list[param_index][0]
            image_group[param_index + 66].color = BLACK
            status_label.color = BLACK
            time.sleep(0.2)
            image_group[param_index + 66].color = param_list[param_index][1]
            status_label.color = WHITE
            time.sleep(0.2)
```

After the **HOLD** button is pressed and released, the selected parameter, represented by the value of `param_index`, can be changed.

The selected parameter value is incrementally changed by the joystick's up and down movements as provided to this helper from the `move_buttons()` helper. The new value is checked against and limited to the sensor's factory min/max limits (`MIN_SENSOR_F`, `MAX_SENSOR_F`).

In the `image_group` list the three parameter value labels for alarm, maximum, and minimum are sequentially positioned in the list:

- Alarm value label --> `image_group[70]`
- Maximum value label --> `image_group[71]`
- Minimum value label --> `image_group[72]`

The value label for the selected parameter is changed and displayed.

Meanwhile, a flashing status message indicates which type of parameter is being changed, either the alarm or one of the range values.

When the desired value is reached and the **HOLD** (select) button is pressed, the Setup process continues back to the parameter select mode. If **SET** is pressed instead, the **Setup** process prepares to exit back to the primary process loop.

```
if panel.button.a:  # Button A pressed
            panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:  # wait for button release
            pass

        # Adjust parameter value
        param_value = int(image_group[param_index + 70].text)
        while (not panel.button.a) and (not panel.button.start):
            left, right, up, down = move_buttons(joystick=panel.has_joystick)
            if up:
                param_value = param_value + 1
            if down:
                param_value = param_value - 1
            param_value = max(MIN_SENSOR_F, min(MAX_SENSOR_F, param_value))
            image_group[param_index + 70].text = str(param_value)
            image_group[param_index + 70].color = BLACK
            status_label.color = BLACK
            time.sleep(0.05)
            image_group[param_index + 70].color = param_list[param_index][1]
            status_label.color = WHITE
            time.sleep(0.2)

        if panel.button.a:  # Button A pressed
            panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:  # wait for button release
            pass

    # Exit setup process
    if panel.button.start:  # Start button pressed
        panel.play_tone(784, 0.030)  # G5
    while panel.button.start:  # wait for button release
        pass
```

Before exiting, a resumption status message is displayed and the display of the average label and value are restored.

Finally, the text strings that may have changed during the **Setup** process are converted to integer numeric values and returned to the primary process loop.

```
status_label.text = "RESUME"
    time.sleep(0.5)
    status_label.text = ""

    # Display average label and value
    ave_label.color = YELLOW
    ave_value.color = YELLOW
    return int(alarm_value.text), int(max_value.text), int(min_value.text)
```

move_buttons() Helper

The move_buttons() helper first resets the variables that indicate joystick movement or D-Pad button presses. If the joystick argument is True, the joystick movements beyond set thresholds will be registered like button depressions. For example, a value for panel.joystick[1] of less than 20000 means that the joystick was moved upwards; greater than 44000 indicates downward movement.

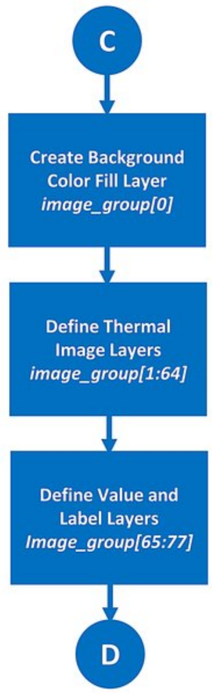
If the `joystick` argument is `False`, the D-Pad buttons are checked to see if any are depressed.

Finally, the movement indicating values are returned to the calling module.

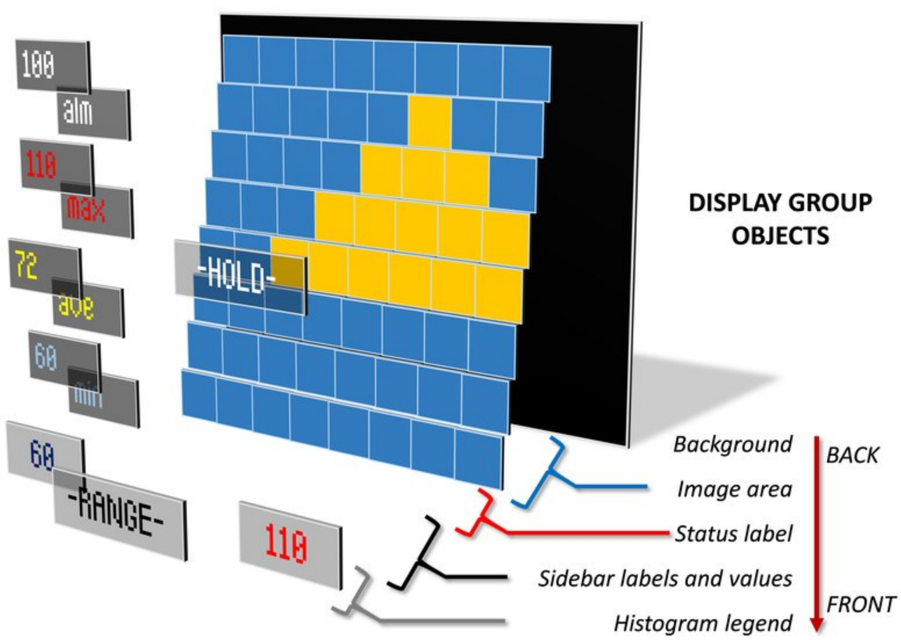
```
def move_buttons(joystick=False):  # Read position buttons and joystick
    move_r = move_l = False
    move_u = move_d = False
    if joystick:  # For PyGamer: interpret joystick as buttons
        if   panel.joystick[0] > 44000:
            move_r = True
        elif panel.joystick[0] < 20000:
            move_l = True
        if   panel.joystick[1] < 20000:
            move_u = True
        elif panel.joystick[1] > 44000:
            move_d = True
    else:  # For PyBadge read the buttons
        if panel.button.right:
            move_r = True
        if panel.button.left:
            move_l = True
        if panel.button.up:
            move_u = True
        if panel.button.down:
            move_d = True
    return move_r, move_l, move_u, move_d
```

Display

Define Display Group Layers



Within CircuitPython's `displayio` library, a display group is a list of label or graphic attributes that are defined for each object of the display. This section of the Thermal Camera's primary process module defines the `image_group` display group that the camera will use to show measured values, the sensor image or histogram, status message, and the histogram legend.

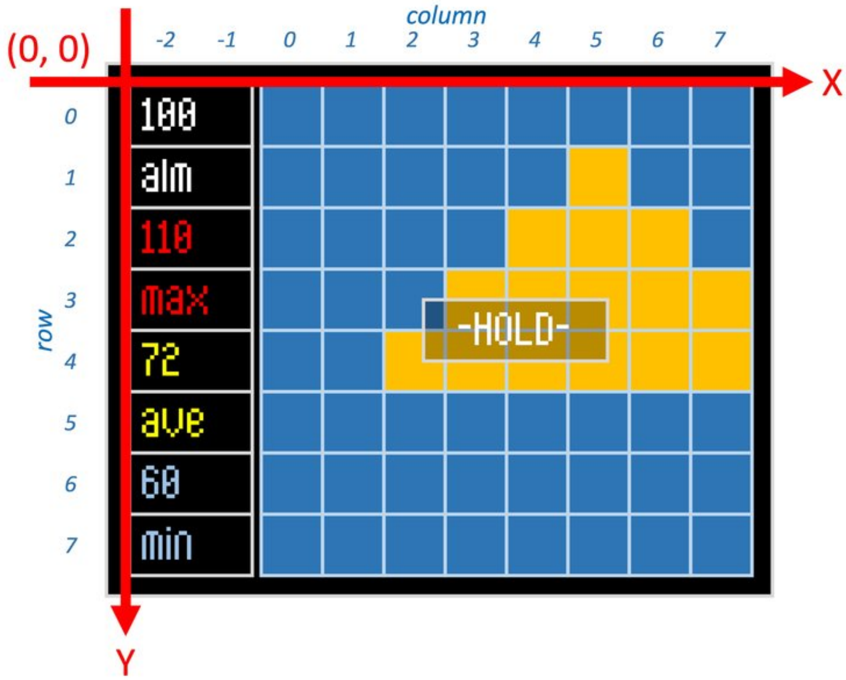


The camera's display group, image_group, consists of 77 layered objects that start with a black screen-sized background in the back-most position. The next 64 objects of the display make up the colored blocks used for the image area.

The status message label comes next, followed by the values and labels in the display sidebar area. Finally, objects that make up the histogram legend top off the stack of display objects in image_group.

The objects and their attributes are appended to the image_group list one-at-a-time when first defined. When appended to image_group, the attributes of each object are defined. For example, the alarm label **alm** is defined as a **Label** object with attributes that include the label's font, text contents, text color, and maximum character count (glyphs):

```
alarm_label = Label(font, text="alm", color=WHITE, max_glyphs=3)
```



The x/y position on the PyGamer's display screen is an attribute of the label object. Keeping with the grid block positioning scheme, the element_grid() helper is used to convert the block column/row position to the x/y coordinates of the board's display screen. In this case, element_grid() returns an x/y tuple for the intersection of column -1.8 and row 1.5:

```
pos = element_grid(-1.8, 1.5 )
```

The alarm label's display screen x/y coordinate attributes are set using the x/y tuple, pos:

```
alarm_label.x = pos.x
alarm_label.y = pos.y
```

After defining the display object's attributes, it is appended to the image_group display group:

```
image_group.append(alarm_label)
```

This process is repeated, starting from the back of the display and progressing towards the front, as each new object is appended to the display group.

Let's look at how all 77 display objects are defined for the Thermal camera.

Define Image Group and Create the Background Layer

The `image_group` list needs to be defined before we can append any display group objects. The `max_size` argument is set to the number of objects that will be used. In this case, we'll need 77 objects (`image_group[0:76]`).

Now that the display group is ready, we'll define the background bitmap object and its attributes. The bitmap's size is the same as the display's width and height; color is black. The bitmap will be placed at x/y coordinate 0,0 (the upper left corner of the display). After it's defined, the background object is appended as the first object in the `image_group` list.

```
### Define the display group ###
image_group = displayio.Group(max_size=77)

# Create a background color fill layer; image_group[0]
color_bitmap = displayio.Bitmap(WIDTH, HEIGHT, 1)
color_palette = displayio.Palette(1)
color_palette[0] = BLACK
background = displayio.TileGrid(color_bitmap, pixel_shader=color_palette,
                                x=0, y=0)
image_group.append(background)
```

Define the Thermal Image Display Group Layers

Next, the 64 squares used to represent sensor array temperatures will be defined and appended. Two `for` loops are used to step through each column and row of squares. Each square is defined as a rectangle with width and height equal to ELEMENT_SIZE. No color attribute is defined for the square, making it transparent -- for now.

```
# Define the foundational thermal image element layers; image_group[1:64]
#   image_group[#]=(row * 8) + column
for row in range(0, 8):
    for col in range(0, 8):
        pos = element_grid(col, row)
        element = Rect(x=pos.x, y=pos.y,
                       width=ELEMENT_SIZE, height=ELEMENT_SIZE,
                       fill=None, outline=None, stroke=0)
        image_group.append(element)
```

Define the Text Label Display Group Layers

Finally, the remaining text objects that display legends and values are defined and appended to the `image_group` display group.

For each object, the label name is defined along with the font, text contents, font color, and the maximum number of characters to display. Next, the object's position attribute is defined using the `element_grid()` helper to calculate the hardware-specific x/y display coordinates. After the attributes are defined, each object is appended to `image_group`.

```
# Define labels and values using element grid coordinates
status_label = Label(font, text="", color=BLACK, max_glyphs=6)
```

```
status_label = Label(font, text="", color=BLACK, max_glyphs=6)
pos = element_grid(2.5, 4)
status_label.x = pos.x
status_label.y = pos.y
image_group.append(status_label)  # image_group[65]

alarm_label = Label(font, text="alm", color=WHITE, max_glyphs=3)
pos = element_grid(-1.8, 1.5)
alarm_label.x = pos.x
alarm_label.y = pos.y
image_group.append(alarm_label)  # image_group[66]

max_label = Label(font, text="max", color=RED, max_glyphs=3)
pos = element_grid(-1.8, 3.5)
max_label.x = pos.x
max_label.y = pos.y
image_group.append(max_label)  # image_group[67]

min_label = Label(font, text="min", color=CYAN, max_glyphs=3)
pos = element_grid(-1.8, 7.5)
min_label.x = pos.x
min_label.y = pos.y
image_group.append(min_label)  # image_group[68]

ave_label = Label(font, text="ave", color=YELLOW, max_glyphs=3)
pos = element_grid(-1.8, 5.5)
ave_label.x = pos.x
ave_label.y = pos.y
image_group.append(ave_label)  # image_group[69]

alarm_value = Label(font, text=str(ALARM_F), color=WHITE, max_glyphs=5)
pos = element_grid(-1.8, 0.5)
alarm_value.x = pos.x
alarm_value.y = pos.y
image_group.append(alarm_value)  # image_group[70]

max_value = Label(font, text=str(MAX_RANGE_F), color=RED, max_glyphs=5)
pos = element_grid(-1.8, 2.5)
max_value.x = pos.x
max_value.y = pos.y
image_group.append(max_value)  # image_group[71]

min_value = Label(font, text=str(MIN_RANGE_F), color=CYAN, max_glyphs=5)
pos = element_grid(-1.8, 6.5)
min_value.x = pos.x
min_value.y = pos.y
image_group.append(min_value)  # image_group[72]

ave_value = Label(font, text="---", color=YELLOW, max_glyphs=5)
pos = element_grid(-1.8, 4.5)
ave_value.x = pos.x
ave_value.y = pos.y
image_group.append(ave_value)  # image_group[73]

min_histo = Label(font, text="", color=CYAN, max_glyphs=3)
pos = element_grid(0.5, 7.5)
min_histo.x = pos.x
min_histo.y = pos.y
image_group.append(min_histo)  # image_group[74]
```

```
max_histo = Label(font, text="", color=RED, max_glyphs=3)
pos = element_grid(6.5, 7.5)
max_histo.x = pos.x
max_histo.y = pos.y
image_group.append(max_histo)  # image_group[75]

range_histo = Label(font, text="", color=BLUE, max_glyphs=7)
pos = element_grid(2.5, 7.5)
range_histo.x = pos.x
range_histo.y = pos.y
image_group.append(range_histo)  # image_group[76]
```

Fun Facts about Display Group Objects

Objects and their attributes in the display group can be accessed in two ways. The most commonly-used method is to assign a name attribute to the object. For example, the text of the status message label can be set to display the text *WELCOME* in this manner:

`status_label.text = "WELCOME"`

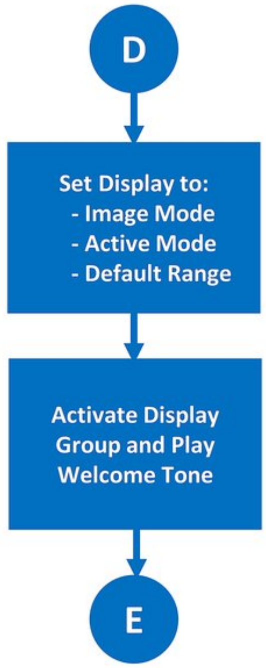
Objects in `image_group` can also be accessed by their indexed position in the display group. An index of 0 is the back-most object in the display group; the highest index value is front-most. The status message text can also be changed using the index:

`image_group[65].text = "WELCOME"`

The Thermal Camera uses both techniques. Named display objects are used whenever possible to clearly identify which object is being changed. For efficiency, however, the index position method is used when stepping through a sequence of `image_group` objects, as when displaying the 64 colored blocks for the sensor image. The index position method is also used by the `setup_mode()` helper when moving on-screen to select the alarm, maximum, or minimum parameter.

Primary Process Setup and Loop

Setup



We're finally in the main portion of the code that controls the Thermal Camera's primary process. We still need to define a couple of things to get ready to use the camera.

The first portion of the primary process loop sets the default display modes. The process sets the camera to display active images using the display range that was provided by the **thermal_cam_config.py** file.

After the default mode flags are set, the image_group display group is activated and a "ready" tone is sounded.

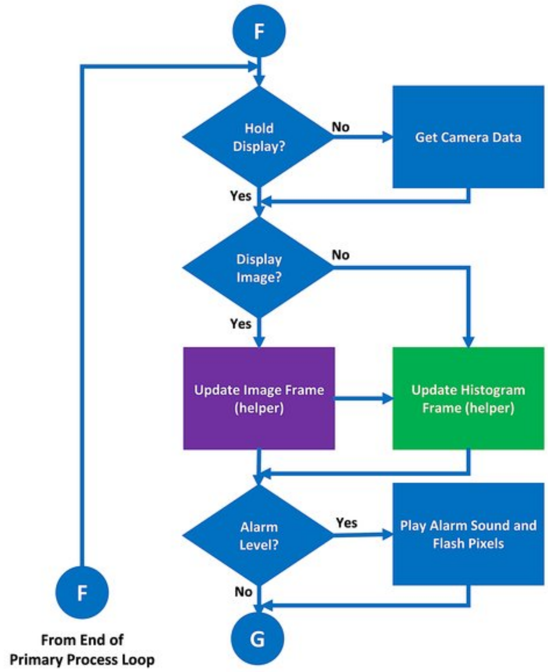
The primary is now ready to start looping.

```
###--- PRIMARY PROCESS SETUP ---###
display_image = True   # Image display mode; False for histogram
display_hold  = False  # Active display mode; True to hold display
display_focus = False  # Standard display range; True to focus display range

# Activate display and play welcome tone
board.DISPLAY.show(image_group)
panel.play_tone(880, 0.1)  # A5; ready to start looking
```

Primary Process Loop, Part I

Because of its complexity, the primary process loop is divided into two sections to make it easier to understand. The first section fetches the image sensor's data, analyzes and displays the sensor data as an image or histogram, and checks to see if any of the sensor elements have exceeded the alarm threshold.

Retrieve Sensor Data, Display Image or Histogram, Check Alarm Threshold



The image sensor's 64 data elements are moved into the `image` list as long as the `display_hold` flag is false; otherwise a "-HOLD-" status message is displayed. Also, the status message area is cleared whenever gathering image sensor data.

```
###--- PRIMARY PROCESS LOOP ---###
while True:
    if display_hold:  # Flash hold status text label
        flash_status("-HOLD-")
    else:
        image = amg8833.pixels  # Get camera data list if not in hold mode
        status_label.text = ""  # Clear hold mode status text label
```

This section checks the `display_image` flag to see whether to display a sensor image or histogram. If `display_image` is `True`, the `update_image_frame()` helper is used to display the data contained in the `image` list as an thermal image. When `False`, `update_histo_frame()` displays the data as a histogram distribution.

```
if display_image:  # Image display mode and gather min, max, and sum stats
        v_min, v_max, v_sum = update_image_frame()
    else:  # Histogram display mode and gather min, max, and sum stats
        v_min, v_max, v_sum = update_histo_frame()
```

The current alarm threshold value, `ALARM_F`, is converted to a string and displayed.

The minimum and maximum Celsius values returned by the `update_image_frame()` and `update_histo_frame()` helpers are converted to a string representation of the equivalent Fahrenheit temperature values and displayed.

The returned "sum bucket" value (`v_sum`) is divided by the number of sensor elements to produce an average temperature value. The average temperature value is converted to a string representation of the equivalent Fahrenheit value and displayed.

```
# Display alarm setting and maxumum, minimum, and average stats
    alarm_value.text = str(ALARM_F)
    max_value.text   = str(celsius_to_fahrenheit(v_max))
    min_value.text   = str(celsius_to_fahrenheit(v_min))
    ave_value.text   = str(celsius_to_fahrenheit(v_sum // 64))
```

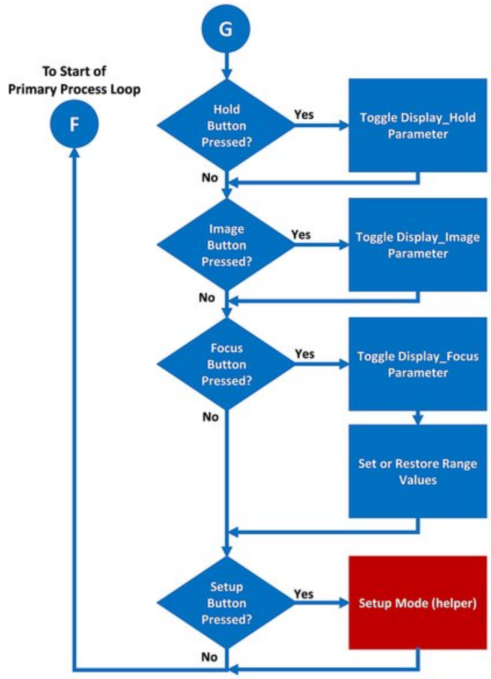
The next step in the primary process loop checks the returned maximum value against the current alarm threshold (ALARM_C). If the threshold is met or exceeded, the NeoPixels flash red while two tones are played through the speaker. The second tone's frequency is proportional to the maximum temperature's relative value above the alarm threshold.

```
# Flash first NeoPixel and play alarm notes if alarm threshold is exceeded
    # Second alarm note frequency is proportional to value above threshold
    if v_max >= ALARM_C:
        panel.pixels.fill(RED)
        panel.play_tone(880, 0.015)  # A5
        panel.play_tone(880 + (10 * (v_max - ALARM_C)), 0.015)  # A5
        panel.pixels.fill(BLACK)
```

Primary Process Loop, Part II

The second portion of the primary process loop checks to see if any buttons have been pressed and sets the appropriate flags to modify display functions. This section also watches the **SET** button to activate the `setup_mode()` helper to permit changing camera parameters.

Watch the Buttons and Change Parameters



This section of the primary loop code looks for any of the buttons to be pressed. If any of the **HOLD**, **IMG/HST**, or **FOCUS** buttons are pressed, then the corresponding display mode flag is toggled. After a flag is toggled, the code waits until the button is released then plays a short confirmation tone before continuing in the primary loop.

```
# See if a panel button is pressed
    if panel.button.a:  # Toggle display hold (shutter = button A)
        panel.play_tone(1319, 0.030)  # E6
        while panel.button.a:
            pass   # wait for button release
        if display_hold == False:
            display_hold = True
        else:
            display_hold = False

    if panel.button.b:  # Toggle image/histogram mode (display mode = button B)
        panel.play_tone(659, 0.030)  # E5
        while panel.button.b:  pass  # wait for button release
        if display_image:
            display_image = False
        else:
            display_image = True
```

When the **FOCUS** button is first pressed, not only is the display_focus flag set, but the currently measured minimum and maximum values are used as the display range. When in **FOCUS** mode, the new display range values will provide more detail based on the range of temperatures measured in the image. Pressing the **FOCUS** button the second time will restore the original default or set display range values, restoring the original image resolution.

```
if panel.button.select:  # toggle focus mode (focus mode = select button)
        panel.play_tone(698, 0.030)  # F5
        if display_focus:
            display_focus = False  # restore previous (original) range values
            MIN_RANGE_F = temp_min_range_f
            MAX_RANGE_F = temp_max_range_f
            # update range min and max values in Celsius
            MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
            MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)
            flash_status("ORIG", 0.2)
        else:
            display_focus = True  # set range values to image min/max
            temp_min_range_f = MIN_RANGE_F
            temp_max_range_f = MAX_RANGE_F
            MIN_RANGE_F = celsius_to_fahrenheit(v_min)
            MAX_RANGE_F = celsius_to_fahrenheit(v_max)
            MIN_RANGE_C = v_min  # update range temp in Celsius
            MAX_RANGE_C = v_max  # update range temp in Celsius
            flash_status("FOCUS", 0.2)
        while panel.button.select:
            pass  # wait for button release
```

When the **SET** button is pressed, the `setup_mode()` helper is executed. When setup has completed, this section of code goes back to the start of the primary loop to start the display and button monitoring process again.

```
if panel.button.start:  # activate setup mode (setup mode = start button)
        panel.play_tone(784, 0.030)  # G5
        while panel.button.start:
            pass  # wait for button release

        # Update alarm and range values
        ALARM_F, MAX_RANGE_F, MIN_RANGE_F = setup_mode()
        ALARM_C = fahrenheit_to_celsius(ALARM_F)
        MIN_RANGE_C = fahrenheit_to_celsius(MIN_RANGE_F)
        MAX_RANGE_C = fahrenheit_to_celsius(MAX_RANGE_F)

    pass  # bottom of primary loop
```

Details: Converter Helpers

thermal_cam_converters.py

The **thermal_cam_converters.py** module consists of two temperature converters, one for Celsius to Fahrenheit and the other for Fahrenheit to Celsius. The value to be converted is passed as an argument to the appropriate helper. Because the Thermal Camera's sensor has limited accuracy, a rounded integer value is returned.

```
# thermal_cam_converters.py

def celsius_to_fahrenheit(deg_c=None):  # convert C to F; round to 1 degree C
    return round(((9 / 5) * deg_c) + 32)

def fahrenheit_to_celsius(deg_f=None):  # convert F to C; round to 1 degree F
    return round((deg_f - 32) * (5 / 9))
```

Details: Configuration Module

thermal_cam_config.py

When imported, the **thermal_cam_config.py** file provides the Thermal Camera's initial power-up alarm threshold as well as minimum and maximum display range values. The power-up configuration parameters can be changed by editing the file with your favorite text editor.

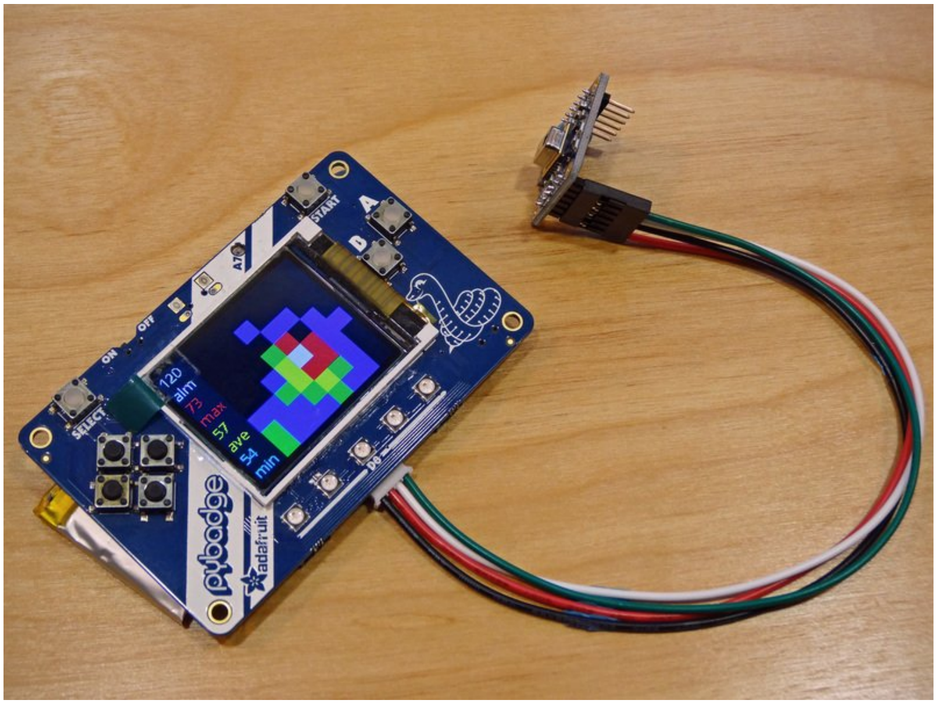
Values are in degrees Fahrenheit.

```
# thermal_cam_config.py
### Alarm and range default values in Farenheit ###
ALARM_F     = 120
MIN_RANGE_F =  60
MAX_RANGE_F = 120
```

Hacking the PyGamer Thermal Camera

This implementation of the Thermal Camera was focused on a limited set of requirements, one of which was to confirm that CircuitPython was fast enough to read, scale, and display an array of temperature values at a useful frame rate. Not only was CircuitPython's performance acceptable, it made it possible to add a few features to make the camera more robust.

To become even more useful, this implementation could easily be modified or expanded with some additional work. What would you do?



Here are some ideas to get you thinking about the camera's potential upgrades:

- The code is already compatible with the PyBadge. What other devices could easily run the code? Hallowing M4? Iot via the PyPortal?
- For a non-portable version, replace the AMG8833 FeatherWing with the breakout board version connected via Stemma so that the sensor could be positioned independently from the display board.
- Provide a setup selection for switching between Celsius and Fahrenheit displayed values.
- Add a graph image that displays min/max/ave/alarm over time.
- Can the display be interpolated or the sensor upgraded to improve detail? Would CircuitPython be agile enough to maintain a reasonable frame rate?
- Store snapshots to the SD card as comma-delimited or JSON files.
- Image transfer to a phone via Bluetooth LE.
- Jazz up the button labels.
- 3D printed enclosure designed for mounting permanently.


THERMAL CAMERA
HOLD
THERMAL
CAMERA
IMAGE
FOCUS
SET