PrimeBox PX4 Controller

Functional specification

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# Functional Overview

The PrimeBox Certified PX4 Controller is a compact digital environment controller. It was designed to automate indoor horticulture systems, but could be repurposed for a variety of applications requiring the use of an intelligent digital timer (ventilation control, sprinkler systems, ambient lighting, holiday decorations). The controller operates as a stand-alone device. Besides access to a common power outlet, no external components are necessary for complete operation.

Users interact with the device through one or more controls (buttons, dials, sensors) and a small display. The controller will call attention to itself both visually (Display Indication), and audibly (buzzer), when immediate attention is required by a user.

User defined settings allow the controller to precisely control of up to four independent environmental parameters including but not limited to air temperature, air circulation, humidity, liquid nutrient temperature, liquid nutrient feeding schedules, and artificial lighting.

An onboard real-time clock enables timed task invocation and variable duty-cycling of attached power peripherals. Thermal electrical overload protection and a persistent memory configuration ensures both a level of safety and functional reliability. The PX4 maintains a compact footprint allowing it to be placed in a variety of places and orientations.

# Functional Non-goals

* This device will not support networked communication
* This device will not support high power peripherals
* This device will not support sensor input beyond air temperature and humidity
* This device will not support timed events requiring timing precision at less than one second intervals
* This device will not be designed for outdoor use or use in harsh environments
* This device will not be designed to support hardware modifications or upgrades
* This device will not be designed to work with AC power adapters other than 120v NEMA 5-15 type plugs
* This device will not support humidity control (monitoring only)

# Similar Devices

The PX4 controller while unique in design is not a unique product type. Functionally comparable devices available in the market today include:

* Autopilot APCTMDT Controller (<https://www.hydrofarm.com/p/APCTMDT>)
* Titan Hades 2 Controller (<http://www.titancontrols.net/shop/product/titan-controls-hades-2-digital-recycle-and-light-timer-with-high-temp-shut-off>)
* Bayite Temperature Controller (<https://www.amazon.com/bayite-Temperature-Controller-Thermostat-Pre-wired/dp/B01KMA6EAM/ref=pd_lpo_201_bs_tr_t_2?_encoding=UTF8&psc=1&refRID=JK9GHBVREFKMGFZPMN3B>)
* Bluepoint BCT-1 Cycle Timer (<https://www.amazon.com/Blueprint-Cycle-Timer-120V-BCT-1/dp/B00FY3PX00>)

# Open Issues

**Issue#\_S\_0250\_1 – Task edit menu changed such that edit options are consolidated**Status: OPEN  
Action items to create/track:

* Remove ‘Set Task’ option in the ‘Scheduled Task Configuration’ sub menu
* Remove ‘Set Task’ View from controller creation

**Issue#\_S\_0250\_2 – Refactor set time view to remove set/back redundancy**Status: OPEN  
Action items to create/track:

* Remove ‘SET’ option text at bottom of view
* Replace ‘BACK’ menu item text at top with ‘SET’

# User Interface Constraints and Assumptions

## Accessibility

This device will assume users have the ability to both see a fixed resolution text based display and activate simple control features.

## Localization

Interface text will be presented in English only. Alternate localizations are not planned for this release.

## Interface and control availability

The interface and controls for this device must maintain a high level of availability at all times of operation. Users must experience interface feedback similar to or better than mainstream embedded devices.

# System Requirements

## Personas

Philbert Phellows – aspiring cook and fan of eating healthy

* Lives in a small place
* Buys organic veggies and herbs from premium groceries
* Limited technical knowledge

Jenny Jalapanos – Tech savvy tinkerer, avid gardener, mother of hungry & curious kids

* Lives in a place with yard
* Has applied knowledge of both gardening and computers
* Has two kids (1 and 5 years of age), one of whom likes experimenting in the garden
* Is known for growing unique and tasty things

## Functional Requirements

### Primary use cases

#### User observes system initialization (without errors or warnings)

***UC#FR\_P\_0100***

After dawning his ninja costume, Philbert sneaks onto his neighbor’s balcony to reclaim possession of his PX4 controller that was creatively borrowed. Upon returning with his controller, Philbert double-wall-jumps back to his garden and plugs it in. As it powers up, the controller makes a few beeps and the display lights up showing the current time as well as the current air temperature, relative humidity, system mode, and recent system events.

#### User observes system initialization error (RTC error)

***UC#FR\_P\_0110***

Philbert returns his garden to the balcony after temporarily moving it in order to host a cat pedicure party. After plugging the controller in, it emits an unusual sound indicating a critical part of the system isn’t operating correctly and that the system was unable to start. The controller display shows text indicating the system time device was not available and that the system could not start

#### User observes system initialization warning

In order to host a dog manicure party on his balcony, Philbert decides to unplug and temporarily relocate his garden. After moving it, he powers the PX4 controller back up and hears it emit an unusual sound.

##### Scenario A: Display initialization failure

***UC#FR\_P\_0120a***

* Notification description**: *one long tone followed by one short tone***
* Notification explanation: During controller startup, the system reported an initialization error while using the display.
* Notification recovery action: Philbert verifies the display is not functional (text or backlight is not functioning) and upon hearing only one initialization warning decides the system is operating sufficiently without a display.

##### Scenario B: External memory access failure

***UC#FR\_P\_0120b***

* Notification description**: *one long tone followed by two short tones***
* Notification explanation: During controller startup, the system reported an initialization error while using the external memory (SD) card.
* Notification recovery action: Philbert reseats the SD card and restarts the controller.

##### Scenario C: External environment sensor failure

***UC#FR\_P\_0120c***

* Notification description**: *one long tone followed by three short tone***
* Notification explanation: During controller startup, the system reported an initialization error while using one or more external environmental sensors.
* Notification recovery action: Philbert checks the connections to all external probes and restarts the controller.

#### User lets system enter inactive state

***UC#FR\_P\_0124***

After interfacing with the system, Philbert goes to make a triple decker avocado bacon sandwich. After a period of time without user interaction, the PX4 controller changes state automatically. First, the display backlight dims, and finally the text shown on the display reverts to the standard system status view. At this point the display is in full standby mode with the backlight off and the status view active.

#### User wakes device from inactive state

***UC#FR\_P\_0126***

While making a triple-decker avocado sandwich, Philbert remembers that he forgot to check the current temperature recorded by the system. He walks over to the controller, which is in an inactive state) and invokes an action on the interface control. The system registers the first action it receives but instead of executing the standard action for that input it simply turns on the display backlight. After the controller’s backlight is enable, additional queued interface actions are processed normally.

#### User observes system status (temp, time, humidity, system status)

***UC#FR\_P\_0130***

Philbert makes a habit of checking his PX4 controller every day when he returns from work. After waking the controller by activating a control, he is able to see a system summary status from a single default view. This system summary view includes, but is not limited to, the following data points:

* External air temperature
* External relative humidity
* Current system time
* Current system mode status - IN (initialization), OK, AL (alert), SB (standby)
* Event summary – the last several events to occur on the controller

#### User overrides a power relay circuit

***UC#FR\_P\_0140***

The artificial lighting in Philibert’s garden is very bright. One night, Philbert comes home from work really tired and decides to go to bed early. The lights from his garden are keeping him awake so he decides to turn them off. To do this, Philbert performs the following:

1. Wakes up the PX4 controller by pushing its navigation control
2. Navigates and selects the ‘MANUAL OVERRIDES’ menu
3. Navigates and selects the circuits tagged as “LIGHT”
4. The relay circuit status changes from “[ON]” to “[OFF]OVR”

Philbert knows that the manual override will remain in place indefinitely (even during power loss), so he sets a reminder on his phone to remove the override the next morning.

#### User sets automatic sunrise/sunset schedule

***UC#FR\_P\_0150***

Philbert decides to grow some herbs in his garden and most herbs require less light then the leafy greens he’s been growing. Philbert plants lemon grass and oregano, then decides to decrease the amount of light his plants get from 14 hours a day to 12. Philbert achieves this by adjusting the default sunrise/sunset time in the ‘Basic Environmental Settings’ menu:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate and select the ‘Sunrise/Set Default’ menu
4. Navigate and select the ‘Sunrise’ menu
5. Navigate to the hour value in the current time setting (arrows appear above hour value)
6. Select the hour value in the current time setting (arrows turn to underscores)
7. Increment the hour value by one hour
8. Press select to return to selection mode (underscores turn to arrows)
9. Navigate to and select ‘<-SAVE’
10. Navigate and select the ‘Sunset’ menu
11. Navigate to the hour value in the current time setting (arrows appear above hour value)
12. Select the hour value in the current time setting (arrows turn to underscores)
13. Decrement the hour value by one hour
14. Press select to return to selection mode (underscores turn to arrows)
15. Navigate to and select ‘<-SAVE’
16. User is returned to ‘Sunrise/Set Default’ menu

#### User responds to system alarm (over temperature)

***UC#FR\_P\_0160***

The Px4 can be configured to signal an alarm if temperatures measured by the external sensors report a value greater than the trigger temperature configured on controller. Philbert accidentally repositioned his garden right next to a wall heater and when the heater tuned on it blew directly into the garden triggering the over temperature alarm. Realizing his mistake, decides to disable the alarm until he can reposition the garden away from the heater. In order to disable the alarm, Philbert performs the following:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate and select the ‘Alarm Thresholds’ menu item
4. Navigate and select the ‘OvrTmp Alarm‘ menu item
5. Navigate to the trigger value (arrows appear above hour value)
6. Select the trigger value (arrows turn to underscores)
7. Increment or decrement the trigger value to 0
8. Press select to return to selection mode (underscores turn to arrows)
9. Navigate to and select ‘<-SAVE’
10. User is returned to ‘Alarm Thresholds’ menu

#### User sets automatic circulation fan duty cycle

***UC#FR\_P\_0170***

Summer is coming and Philbert is switching his skinny jeans for skinny shorts to make the higher temps bearable. The last two days Philbert has come home from work and the PX4 controller is beeping in alarm mode. It appears his garden is reaching the over-temp alarm threshold despite the apartment remaining below the same threshold. Philbert decides he needs to increase the exhaust fan duty cycle to bring more cool air into the garden. He does this by increasing the fan duty cycle during the day.

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate and select the ‘PwrOutlet DutyCycle’ menu item
4. Navigate and select the ‘ExFan’ menu item
5. Navigate and select the ‘Day DtyCyc’ menu item
6. Navigate to the percentage value (arrows appear above value)
7. Select the percentage value (arrows turn to underscores)
8. Increment the percentage value
9. Select the desired percentage value (underscores turn to arrows)
10. Navigate to and select ‘SAVE’
11. User is returned to ‘Fan Selection’ menu

#### User responds to system alarm (over humidity)

***UC#FR\_P\_0180***

Philbert Phellows was flying a dragon kite from his apartment window and forgot to close it before leaving to work. Shortly after he left, the temperature around his garden fell and condensation began forming on the walls as a result. When he returned, Philbert notices a beeping coming from his PX4 controller and realized the humidity inside the garden was 100%, 20% above the alarm trigger threshold. Philbert decides to disable the alarm until humidity dries up.

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate and select the ‘Alarm Thresholds’ menu item
4. Navigate and select the ‘OvrTmp Alarm‘ menu item
5. Navigate to the trigger value (arrows appear above hour value)
6. Select the trigger value (arrows turn to underscores)
7. Increment or decrement the trigger value to 0
8. Press select to return to selection mode (underscores turn to arrows)
9. Navigate to and select ‘<-SAVE’
10. User is returned to ‘Alarm Thresholds’ menu

### Secondary use cases

#### User modifies power outlet designations and alias

***UC#FR\_S\_0200***

The PX4 comes with a pre-set power outlet configuration. Jenny takes a look at the factory outlet assignments and realizes she desires an alternate configuration. Jenny’s garden is located in an enclosed sun porch that does not require artificial lights. To maximize the usefulness of her controller, Jenny decides to use one outlet to control an irrigation valve, two outlets to control two independent circulation fans, and a single outlet to control an exhaust fan. To achieve this configuration Jenny goes to her PX4 controller and performs the following operations:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘PWR OUTLET CONFIG SETTINGS’ menu
3. Navigate and select the ‘PwrOutlet@1’ menu item
4. Repeat selection until the correct outlet alias appears for the desired PwrOutlet

\*Note: To avoid scheduling confusion, changing an outlets alias will immediately erase all independent scheduled tasks assigned to it.

\*Note: Group scheduled tasks will take effect on an outlet immediately after alias change

#### User creates new scheduled task to manage all air circulation fans

***UC#FR\_S\_0210***

The default air circulation duty cycle works ok for Jenny Jalapenos but the fans tuning on and off at night cause the family Schnauzer to bark. To prevent this, Jenny disables the automatic duty cycle settings for circulation fans and creates scheduled tasks to activate the circulation fans manually (on all day, off all night).

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate and select the ‘PwrOutlet DutyCycle’ menu item
4. Navigate and select ‘CrFan’
5. Navigate and select ‘DtyCyc Mode’ (transitions to ‘OFF’)
6. Navigate and select ‘<-Back’ (transitions to ‘PwrOutlet DutyCycle’ menu)
7. Navigate and select ‘<-Back’ (BASIC ENVIRONMENT SETTINGS sub menu)
8. Navigate and select ‘<-Back’ (transitions back to TOP\_LEVEL menu)
9. Navigate and select ‘SCHEDULED TASKS SETTINGS’
10. Navigate and select ‘Create/Delete Task’
11. Navigate and select ‘New Schd Task (+##)’ (## < max tasks)
12. Navigate to the ‘Outlet’ item and select repeatedly until the menu reads ‘AllCrFans’ (can be ‘<circuitAlias>’, ‘AllExFans’, ‘AllCrFans ‘, or ‘AllPumps’)
13. Navigate and select ‘TaskTime’
14. Navigate to the hour time segment (arrows appear above time segment)
15. Select the hour time segment (arrows turn to underscores)
16. Increment or decrement the time segment to the desired value and press select to exit edit mode (repeat as necessary with other segments)
17. Navigate to and select ‘SET’
18. Navigate and select ‘Outlet State’ (selection transitions to ‘ON’)
19. Navigate to and select ‘SAVE NEW TASK’ (transitions to edit task list)
20. Repeat steps 10-17 but instead of setting a time to turn on, set a time to turn off

#### User creates new scheduled task to manage a single water valve

***UC#FR\_S\_0220***

Jenny is growing a rare type of lavender that grows best when watered once a day in the morning. To achieve an optimum watering schedule, Jenny programs her PX4 controller to turn on the water valve (located on outlet #1) only once in the morning at 6am for 15 minutes. She performs the following actions:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Create/Delete Task’
4. Navigate and select ‘New Schd Task (+##)’ (## < max tasks)
5. Navigate to the ‘Outlet’ item and select repeatedly until the menu reads ‘Valve@1’
6. Navigate and select ‘TaskTime’
7. Navigate to the hour time segment (arrows above segment value)
8. Select the segment value (arrows turn to underscores)
9. Increment or decrement the time segment to the desired value (repeat as necessary with other segments)
10. Navigate and select ‘SET’ (transitions to create ‘Set Schd Task’ menu)
11. Navigate and select ‘Outlet State’ (selection transitions to ‘ON’)
12. Navigate to and select ‘SAVE NEW TASK’ (transitions to edit task list)

#### User attempts new scheduled task creation when none are available

***UC#FR\_S\_0230***

Jenny went wild when configuring scheduled tasks and has created 24 individual scheduled tasks to turn on the water valve and fans in her garden. Jenny decides she needs to turn on the fans one more time around dawn but can’t remember if there was a limit on the number of scheduled tasks she could create. Jenny tries to create a new scheduled task by:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Create/Delete Task’
4. Navigate and select ‘New Schd Task (+##)’ (## == ‘0’)
5. User is not able to create a new task (UI ignores select request)

#### User enables or disables a scheduled task

***UC#FR\_S\_0240***

Jenny checks on her garden one night before going to bed. She notices that her fancy Thai basil looks wilted and that the soil its planted in is really wet (signs of overwatering) She decides to reduce the amount of water the system is feeding the plants by suspending the last scheduled watering. She reaches to the PX4 controller and performs the following:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Set Existing Task’
4. Navigate to and select the desired task (latest ‘Valve@1ON’ task)
5. Navigate to the ‘Status’ row
6. Select the row to transition status from ‘Enabled’ to ‘Disabled’
7. Navigate to and select ‘SAVE’

#### User edits start time of a specific scheduled task

***UC#FR\_S\_0250***

Dew forms on leafy vegetation as temperature variations occur between the vegetation and the surrounding air. Jenny has noticed considerable dew buildup on her ornamental flowers in the morning and would like to minimize this buildup. To achieve this, she decides to alter the existing air circulation task so that it turns on one hour earlier. To do this Jenny edits the existing task by:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Edit Existing Task’
4. Navigate to and selects the desired task (earliest ‘\*CrFansON’ task)
5. Navigate and select the ‘TaskTime’ menu item
6. Navigate to the hour time segment value (arrows above value)
7. Select the hour segment (arrows turn to underscores)
8. Decrement the hour time segment
9. Press select to save the new value (underscores turn to arrows)
10. Navigate and select ‘SET’ (transitions to ‘Edit Existing Task’ menu)
11. Navigate to and select ‘SAVE’ (transitions to ‘Scheduled Task Settings’ sub menu

#### User deletes a specific scheduled task

***UC#FR\_S\_0260***

As fall sets in, the average temperature on Jenny’s porch is getting cooler. During the day, the temperature is fine but soon after dusk the temperature on the porch dips quickly, which is undesirable for Jenny’s tomato plants. Jenny plans to keep the heat in her sunroom longer by removing a scheduled task that runs the exhaust fan neat dusk.

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Create/Delete Task’
4. Navigate and select ‘Delete Schd Task’
5. Navigate to and select the desired task (‘ExFan@2ON’ task near dusk)
6. Navigate to and select ‘YES’ to confirm scheduled task deletion (transitions to ‘Task Selection’ menu with ‘BACK’ highlighted)

#### User bulk deletes all scheduled tasks

***UC#FR\_S\_0270***

Leafy greens and herbs require very different environments for optimum growth. Jenny knows this and is planning to harvest all her leafy green plants on the porch and begin growing all herbs. Instead of modifying the existing scheduled tasks on the controller, she decides to simply erase all the existing tasks and create all new tasks. She remembered there was an option on the controller that makes this easy:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select ‘SCHEDULED TASKS SETTINGS’
3. Navigate and select ‘Create/Delete Task’
4. Navigate and select ‘Bulk Delete Tasks’
5. Navigate to and select ‘YES’ to confirm bulk scheduled task deletion (transitions to ‘Scheduled Task Settings’ sub menu with ‘BACK’ highlighted)

#### User sets alarm thresholds for temperature and humidity

***UC#FR\_S\_0280***

Yesterday, Jenny entered her sunporch and realized it was unusually hot. It appeared one of her children unplugged the power cord that runs to the exhaust fan. She remembered seeing an alarm setting during the controller configuration but hadn’t actually set it. Had she set an alarm, it would have notified her that the temperature was too high earlier in the day. Jenny decides to set the temperature alarm as well as the humidity alarm to avoid scenarios like this in the future.

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate to and select the ‘Alarm Thresholds’ item
4. Navigate and select the ‘Ovr Tmp Alarm’ item
5. Navigate and to the temperature value (arrows appear above value)
6. Select the temperature value (arrows turn to underscores)
7. Increment or decrement the temperature value
8. Press select to return to selection mode (underscores turn to arrows)
9. Navigate to and select ‘SAVE’
10. Navigate and select the ‘Ovr RH Alarm’ item
11. Navigate and to the humidity value (arrows appear above value)
12. Select the humidity value (arrows turn to underscores)
13. Increment or decrement the humidity value
14. Press select to return to selection mode (underscores turn to arrows)
15. Navigate to and select ‘SAVE’

#### User enables storage full alarms

***UC#FR\_S\_0290***

The PX4 Jenny has includes an external SD card to save historical data to. By default, when the storage gets full it simply stops recording new information to storage. This scenario will not trigger an audible alarm unless specified in the controller configuration. Jenny removed the card to investigate a recent temperature trend but found no recent data entries because the card was full. To prevent this from happening again, Jenny decides to enable alerting when the SD card is full:

1. Wake the PX4 controller by pushing its navigation control
2. Navigate and select the ‘BASIC ENVIRONMENT SETTINGS’ menu
3. Navigate to and select the ‘Alarm Thresholds’ item
4. Navigate and select the ‘LogFull Alarm’ item (transitions from ‘OFF to ‘ON’)

#### User overloads system power circuit creating circuit protection condition

***UC#FR\_S\_0294***

Because the PX4 was not designed to power high current application, Jenny knows it might trip an internal circuit breaker if too much electricity is drawn through its power relays. On a particular hot day Jenny decides to experiment cooling the sunporch down with a 1500-watt air conditioner. She plugs the air conditioner into the PX4 outlet where a circulation fan was prior. The waits for the circulation fans to turn on and when they do everything turns off including the PX4 controller. The fans and pumps are all off and the controller is completely unresponsive. Jenny notices the built-in power overload breaker on the PX4 has been tripped. She realizes the air conditioner draws way too much power when its plugged into the PX4 and decides to return the controller to its previous arrangement.

1. Unplug the air conditioner from the PX4
2. Plug the previous circulation fan back into its original outlet
3. Manually reset the overload circuit breaker on the outside of the PX4
4. Ensure the PX4 restarts and attached devices resume their previous operations

## Non-functional Requirements

* Manual interface controls must invoke primary (feel) feedback in less than 50ms
* Manual interface controls must invoke secondary (process) feedback in less than 250ms.
* Any user invoked power relay action must execute within 250ms
* Any user invoked action that disables an alarm must complete in less than 500ms
* Scheduled tasks stored on the controller must maintain timed execution configurations accurate to the second
* Scheduled tasks must execute within +/- 1000ms of their configured execution time
* Low-power optimizations (dimming display) shall occur between 25 and 30 seconds after the last user input is measured
* Default view return shall occur between 50 and 60 seconds after the last user input is measured
* System resume (from low-power mode) will return full interface functionality to user within 500ms after the first interface input is received during a low-power state
* The controller will operate continuously granted power consumption never exceeds 10A at the unit
* The controller will manage power overloads to avoid unsafe operating conditions. Specifically, the PX4 controller will automatically trip its primary input circuit if:
  + 15A is drawn for more than 60 minutes
  + 20A is drawn for more than 10 seconds
  + 40A is drawn for more than 2 seconds
* State persistence:
  + Any local configuration elements (externally sourced sensor information is not applicable) used to actively manage controller state must be saved to a non-volatile memory location and restored after an unexpected restart
  + Scheduled task information must be saved to a non-volatile memory location and restored after an unexpected restart
* Power relay circuit naming will be limited to a static nomenclature comprised of a type prefix and an numerical suffix based on logical circuit ordering:
  + Type (‘PwRly’|‘Pump’|’Valve’|’CrFan’|’ExFan’|’Light’)
  + Separator character (@)
  + Logical ordering (‘1’,’2’,’3’,’4’)