

# WaterDrop Machine Instructions

## Introduction

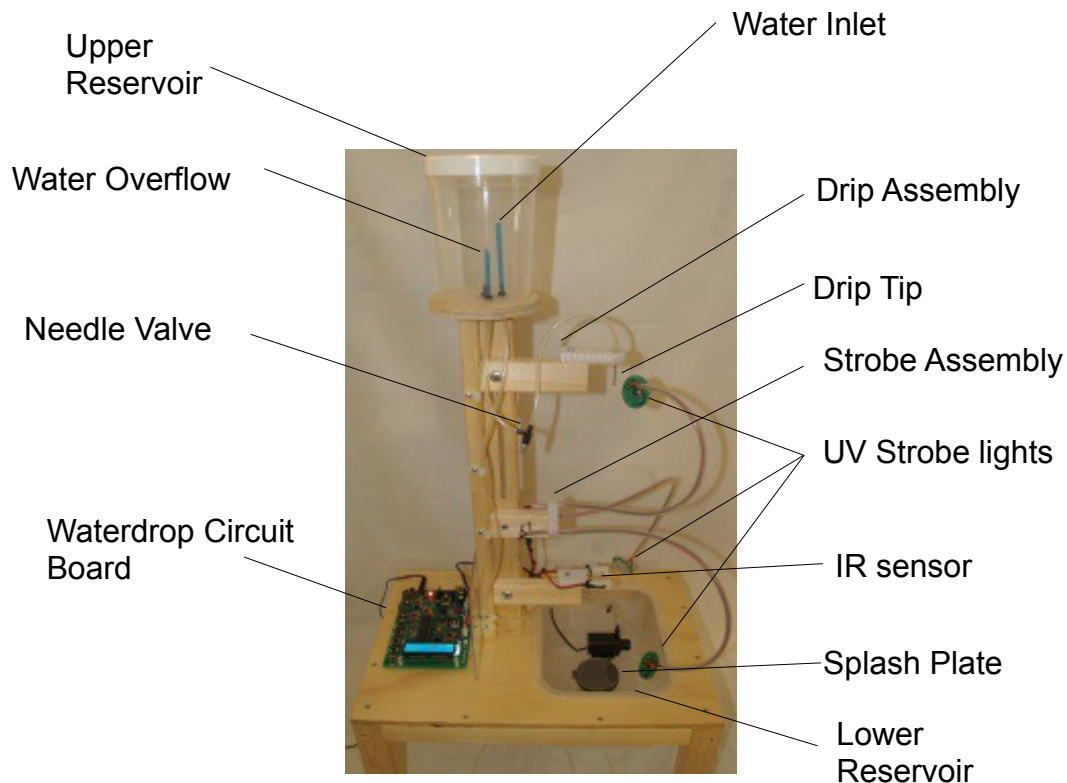
The WaterDrop Machine allows one to study the anatomy, behavior and timing of a falling drop of water and its collision with a surface. It does this using a microcontrolled Ultraviolet LED strobe, Infrared sensor, constant pressure drip system and water with a UV fluorescent dye. The photos below highlight the components and functions of the WaterDrop system.

## Theory of Operation

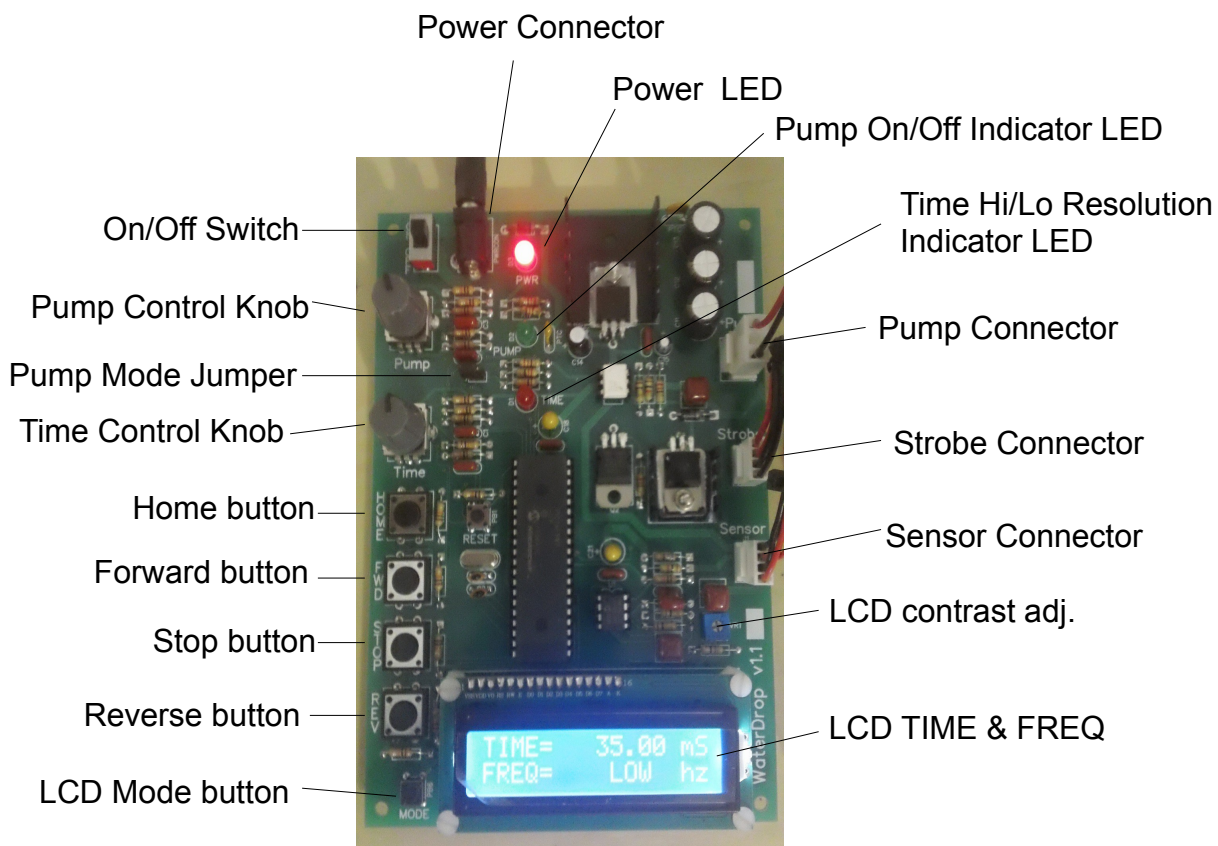
The Waterdrop Machine consists of four main components:

- Water drop delivery system which generates water drops of consistent size and frequency.
- Electronic system which detects the falling water drops and generates a short burst of UV light as well as measuring and displaying water drop time and frequency information. The electronics also act to control the water pump.
- Splash plate system which allows for the water drop to impact a hard surface as well as different depths of water.
- Structure system which mechanically supports the water drop delivery, electronic and splash plate systems.

The systems basically function together as follows. A water drop is generated at the drip tip and falls downward. As it passes thru the IR sensor it is detected and a variable delay is generated. When the delay expires the control electronics fire the UV strobe lights for a brief pulse of approx. 200 microseconds. This UV light illuminates the falling drop which contains a UV fluorescent dye and causes it to glow, which also makes it visible to the viewer. This process is repeated for every drop that falls, and if the frequency is high enough it appears to be a single drop suspended in space or impacting a surface.



**FIG. 1 Water Drop Machine**



**FIG. 2 WaterDrop Circuit Board**

## SET\_UP

1. **Positioning the WaterDrop Machine.** The waterdrop machine is best set-up on a even, level surface that does not shake. Visibility of the water drops is best in a dimly lit or darkened environment, although you will need light for the set-up and occasionally to make adjustments. **IMPORTANT** – splashes from the drops falling will scatter around the base so be sure to place unit in an area where you don't mind water with fluorescent dye landing i.e. away from food, pets, furniture etc.
2. **Filling with water.** With the upper reservoir empty, fill the lower reservoir with cool, clean tap water to about ½ inch from the top of tank rim, you can fill to a lower water level if desired to reduce overspray from splashes, but do not go below pump intake . Shake bottle containing dye then add required amount of dye solution to water and mix completely (see instructions with dye for amount). During normal operation water will have to be refilled periodically due to water lost by splashes and evaporation. Dye should also be added as needed to maintain water drop visibility.
3. **Plugging in Power.** Plug the power adapter into a wall socket and also into WaterDrop Machine circuit board power adapter jack. Use only supplied power adapter.

## OPERATION

**CAUTION: Strobe lights may effect persons with photo-epileptic condition**

**CAUTION: Running pump without water may damage pump**

**CAUTION: Do not bend strobe supports at sharp angle, will damage support**

**CAUTION: Do not expose Waterdrop PCB to Static Electricity, may damage circuit**

### 1. Priming water system.

- Make sure to remove Pump jumper on circuit board so pump is in fixed mode.



Pump jumper removed, fixed mode



Pump jumper in place, variable mode

- When jumper is in place the two jumper pins are electrically connected, this places the pump in variable mode where the user can change pump speed using the Pump control knob. This is an option included should the need arise to vary pump output (careful not to overflow upper reservoir). Otherwise the pump output defaults to a preset value when jumper is removed. Before removing or replacing jumper, turn off waterdrop machine.
- Turn on on/off switch. Red power LED should light and LCD should show Waterdrop System and Firmware version momentarily. Then the LCD should show TIME = 35ms and FREQ = LOW.
- Adjust needle valve clockwise until gently closed.
- Turn on pump by pushing PUMP knob down once. Green pump LED should light and water will begin filling upper reservoir. As water level in upper reservoir reaches height of lower straw, the overflow inlet, place finger over air hole in cover of upper reservoir. This helps starts water flow into overflow inlet, remove finger once water is flowing into overflow inlet.

### 2. Getting water drops flowing

- Open needle valve fully by turning counter clockwise
- Remove drip tip from holder and lower tip toward lower reservoir as water flows
- Use finger to tap out any air bubbles from needle valve, tubing and drip tip. This is important because trapped air bubbles will interfere with stability of water drops.
- Put drip tip back into holder and close needle valve.

### 3. Aligning and Adjusting waterdrop flow

- Open needle valve slightly so water drops are flowing.
- Adjust drip assembly and IR sensor assembly positions until water drops are flowing directly in IR sensor path. Assemblies are adjustable side to side and back and forth. Looking down on IR sensor assembly one can see the water stream path through sensor, it should pass directly between the IR emitter and detector. Turn delay knob CCW until drop is at sensor level and check alignment.
- Adjust the needle valve for the most stable drip flow for FREQ = 10 to 16 Hz. Do this by using the LCD frequency display and observing the water drop. The water drop is stable when it is not jiggling about, this requires slowly adjusting the needle valve for best results.
- Needle valve may need periodic adjustment for stable drop flow.

#### **4. Controlling the water drop**

- To move drop up or down turn the TIME knob CW or CCW. Pressing TIME knob toggles the resolution of adjustment between 1ms and 0.1 ms per knob click, this allows user to adjust drop position faster or slower. Red Delay LED lights when adjust mode is 1ms per click.
- Water drop position can also be changed by using HOME, FWD, REV or STOP buttons. HOME returns the water drop to position TIME = 35ms, FWD and REV increment drop position up or down in 0.2 ms steps, and the STOP button stops the movement of drop.

#### **5. Displaying water drop info on LCD**

- The TIME display is the current time in the fall of the water drop in milliseconds (thousandths of a second), with TIME = 0 the time when the water drop passes thru the IR sensor.
- The FREQ display is the current number of water drops falling through the IR sensor in drops per second or hertz (Hz).
- By pushing the STOP button and the REV button at the same time the LCD can be made to display  $\Delta T$  or relative time. This sets the origin TIME = 0 to the current position of the water drop and displays the difference between that and any further adjusted position. This is useful for measuring the time between water drop events. Pressing the STOP button and the REV button at the same time toggles this feature on and off.

#### **6. Adjusting the Splash Plate**

- The splash plate allows the user to create a collision between the water drop and a hard surface and also various depths of water. Using the control syringe the plate can be moved up and down in the lower reservoir. Just note that when the plate is adjusted to the surface of the water, the splash overspray tends to be more and builds up on the platform and may need to be wiped off periodically. The platform is coated with a waterproof sealant.

#### **7. Single Shot strobe Mode**

- Using the Single shot mode with variable strobe brightness levels allows the user to experiment with capturing images with a digital camera. The camera should have a manually controlled shutter time and light sensitivity. By setting the shutter to open in a darkened room with the appropriate sensitivity, images of the water drops can be captured when the single shot strobe is fired.
- The single shot strobe mode is activated by first pressing the mode button. The menu then displays normal and single shot selections with an arrow on the left side of the LCD showing the current selection. Pressing the REV button will select the single shot mode and pressing the STOP button selects the Normal strobe mode. If the REV button is repeatedly pressed it will scroll the single shot mode thru Lo, Med, and Hi strobe brightness levels. The Lo brightness is a very short pulse while Med and Hi are increasingly longer pulse times, (Lo-200us, Med-500us, Hi-1ms).
- After selecting mode normal or single shot, press the mode button to reactivate drip machine. If the single shot mode is selected a asterisk symbol will appear on the LCD Freq display line. Pressing the REV button once will fire the strobe on the next drop of water detected.

## TROUBLESHOOTING

**Symptoms:** Water drops are not flowing well, even with needle valve open fully

**Possible Problem:** Drip tip assembly is too high and not generating enough pressure to get water drops flowing.

**Solution:** Loosen wingnut and lower drip tip assembly until drops are flowing.

**Possible Problem:** The needle valve or drip tip is fully or partially clogged

**Solution:** Clean needle valve and or drip tip. Remove and clean needle valve with small wire and water, Needle valve can be disassembled by unscrewing completely. Drip tip can be cleaned with small wire and water.

**Symptoms:** Water drops are not stable but jitter, can't stabilize by adjusting needle valve.

**Possible Problem:** Air is trapped in drip tip, needle valve or hose.

**Solution:** Remove drip tip from holder and tap out air from valve, hose and tip.

**Possible Problem:** Problem: Drop sensor is not aligned

**Solution:** Check and align water drop to sensor

**Possible Problem:** Water on sensors causing malfunction

**Solution:** Check to see if there is water on the IR sensor and emitter lenses and clean if necessary.

## CARING FOR WATERDROP MACHINE

- Avoid introducing dirt or contamination into water reservoirs
- Keep lower reservoir covered when not in use so dirt/dust does not build up in water
- Empty water reservoirs when stored for long periods, water can be stored in a jug.  
***(Water can be siphoned out of lower reservoir with included SIPHON TOOL and syringe. Press siphon tool suction cup to smooth area on bottom of lower reservoir then use syringe to start siphon process by inserting into tube then drawing water into tube from reservoir, remove syringe and water will flow as long as tube end is lower than reservoir)***
- Don't run pump without water
- Periodically apply thin coat of silicon grease to needle valve o-ring, careful only a thin film is required on o-ring a large amount will clog needle valve.

## ACTIVITIES

**Before doing activities first read and complete the SET-UP and OPERATION sections**

**1. Viewing the suspended water drop** – In this activity the user views and interacts with the water drop as it floats in space.

- Adjust the drip rate to a frequency in the 10 to 16 Hz range with a stable drop
- Observe the suspended water drop, is this the same drop or more than one drop you are seeing? How does the color of the strobe light compare to the color of the water drop, same or different?
- Using clean straws or toothpicks poke and interact with the drop.
- Try placing the straw or toothpick ahead of the drop and notice the result.

**Whats happening:** As the water drops fall the ultraviolet strobe light flashes for a very short time, about 200us or 0.000200 seconds on the falling drop. It does this for every drop in the same place and if the drops are repeating fast enough your eye and brain puts these images together so they appear to be the same drop suspended in space. You will notice that the water drop color is different than the strobe color that is because of fluorescence. The dye in the water is absorbing the strobe light as one color or frequency and giving it off or glowing at another color or frequency.

**2. Viewing Demos 1,2 and 3** – In this activity we will view three built-in demonstration patterns of the WaterDrop machine.

- Adjust the drip rate to a frequency in the 10 to 16 Hz range with a stable drop
- Press the HOME and FWD button at the same time for the “PAC-MAN” demo you can press any button (HOME, FWD, REV or STOP) to return to normal mode.
- Press the HOME and STOP buttons at the same time for the “ROLLING STONES” demo
- Press the HOME and REV buttons at the same time for the “STRING OF PEARLS” demo

**3. Observing water drop collision with plate and measuring collision time** – In this activity the user observes the water drop colliding with a solid object in slow motion and measures the time it takes for this event to unfold.

- Adjust the drip rate to a frequency in the 10 to 14 Hz range with a stable drop
- Raise the splash plate to the water surface level or slightly above
- Adjust a strobe head to illuminate the splash plate surface
- Press the HOME then FWD button
- Observe how the water drop collides with the surface and forms a splash
- Press REV to watch the splash form in reverse motion
- Press HOME, then use the TIME knob to move the drop to just above the plate
- Press the MODE button and note the TIME at this point is now 0ms
- Use TIME knob to move the drop to show the crown forming while noticing TIME info displayed. You should be able to measure the time it takes for the splash to form.

**4. Measuring speed of water drops** – In this activity we will calculate the speed of a falling water drop using measured values of distance and time.

- Adjust the drip rate to a FREQ in the 10 to 16 Hz range
- Press the HOME button
- Press the MODE button
- Using a ruler and the TIME knob move the water drop a distance of 1 inch up or down and note the TIME displayed on the LCD. This is the time it takes the water drops to fall one inch. Note each ms is 0.001 seconds

to calculate speed in (feet per second)

$$\text{speed} = 1 / (12 \times \text{time (in seconds)})$$

to calculate speed in (miles per hour)

$$\text{speed} = 3600 / (12 \times 5280 \times \text{time (in seconds)})$$

an average speed for people walking is 3.4 miles per hour, how does that compare with the falling water drop?

**5. Observing the whole drop** – In this activity we will observe the process of the whole drop formation when impacting the water surface.

- This activity is best viewed in darkness or very low light
- Adjust the drip rate to a FREQ of 2 to 3.5 Hz
- Lower the splash plate all the way
- Adjust strobe head to illuminate the water surface
- Press the HOME button
- Press the TIME knob so the RED delay LED is on
- Begin adjusting the TIME knob CW to view the entire splash formation process which takes up to 250 ms
- Try raising the splash plate and see how varying the water depth effects the splash formation.

**6. Standing Wave Collision** – This activity generates a standing wave pattern in the lower reservoir and we then view the water drop collision with that pattern

- Adjust the drip rate to a FREQ in the 10.5 to 11.5 Hz range approximately until a stable standing wave pattern is generated in the lower reservoir.
- Adjust the strobe head to illuminate the water surface
- Press the HOME button
- Now use the TIME knob or the FWD, REV and STOP buttons to cause the water drop to collide with the standing wave.
- Observe the collision but this time look thru the side of the lower reservoir to see the collision from underwater.

**7. Viewing drop at Tip** – In this activity we will observe the water drop as it forms leaving the drip tip.

- Adjust the drip rate to a FREQ in the 10 to 14 Hz range
- Position a strobe head to illuminate the drip tip.
- Adjust the TIME control knob to observe the formation of the water drop as it leaves the drip tip.

## **8. Photographing Water drops**

- By using the Single shot strobe mode you can experiment with taking high speed photos of falling water drops and splashes.
- You will need a digital camera with manually controlled shutter time and light sensitivity, a tripod stand and a lens for close up photos. You may also want a transparent lens cover to prevent splashes from getting on your camera lens.
- In a room that can be darkened set-up camera and waterdrop machine
- Adjust drop FREQ to 2hz or less
- Select Single Shot strobe mode. The strobe brightness level you select will depend on your camera sensitivity and the the part of the water drop event you are trying to photograph. The splash and rebound parts of the drop are slower events and can be captured with a Med-Hi strobe setting while while this would cause a blur in photographing the faster falling drop event, which needs a faster strobe pulse to freeze the motion.
- Set camera shutter to open for a around 2 seconds with a high light sensitivity.
- Adjust TIME on water drop to the desired event.
- Trigger camera, then trigger strobe by pressing REV button once.
- Check image and strobe power, adjust shutter times and sensitivity for best results.

## **ADDITIONAL RESOURCES**

An interesting book on water drops published in the early 1900's, A Study of Splashes by A.M. Worthington, a PDF version is available online at:

<http://archive.org/details/studyofsplashes00wortrich>

Resource on high speed imaging, M.I.T. Edgerton Center

<http://web.mit.edu/edgerton>