Microcontrolled Water Fountain: a Multidisciplinary Project*

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Water fountains have been used for thousands of years for utilitarian and aesthetic purposes. Fountain design provides an excellent opportunity for multidisciplinary projects for engineering and art students. In this paper, detailed design of an indoor fountain with a special effect feature is presented to exemplify what can be done with fountains in educational settings. Comprising of nine individual jets, the fountain produces letters of the alphabet, simple shapes, and symbols with water jets. A microcontroller is used and programmed to create and sequence through interesting arrangements of water displays. With a total material cost of $550, this design, or variations of it, can be adapted for various implementations in fluid mechanics and engineering design courses. Suggestions for student design projects are made.

INTRODUCTION

THE EARLIEST RECORD of water fountains dates back to 4000 BC in Iran according to *The Encyclopedia Americana* [1]. Since then fountains have been used for many purposes such as evaporative cooling in arid climates, producing spectacular water displays, serving as a focal point in an urban or a garden setting, masking traffic noise, creating soothing sounds, etc. Among the most popular fountains have been those that create special effects such as surprising people in water jokes, moving statues by flowing water, producing unusual and playful water jets, combining water and fire in dramatic shows, and adding music and/or lighting to create mesmerizing water displays.

Special effect fountains have a long history, and this alone, could provide stimulating educational opportunities for students to determine how the ancient fountains operated, to analyze their performance, and possibly to construct scaled models of those fountains. Excellent sources are available to learn about trick fountains which were designed in the 1st century, during the Middle Ages, and the Renaissance [2–6]. The author has written about some of the modern-day fountains that utilize computerized control schemes to produce special effects that delight visitors to theme parks, shopping malls, and resort areas [7, 8].

Due to its nature, the design of a successful fountain, especially one with special effects, requires careful consideration to both artistic and engineering features. By way of an example, this paper will show that fountain design provides an excellent opportunity for a practical, affordable, and multidisciplinary project for students. This project is challenging and rewarding for engineering and art majors. Sufficient details are provided in the next section so that this design, or variations of it, could be implemented in other universities for the purpose of enhancing educational experiences of students in fluid mechanics, engineering design, and arts classes.

MICROCONTROLLED WATER FOUNTAIN

Problem statement

Design a small-scale dynamic water fountain that creates shapes, letters, and symbols with water jets.

Educational objectives

The main objective is to provide students with a multidisciplinary project incorporating engineering and art. The next objective is to expose students to applied electronics and computer interfacing, and to engineering catalogs and the wealth of information contained in some of them. Most products today incorporate 'smart' components, namely microprocessors. It is important that engineering graduates, at least, know how microcontrollers are used and applied to meet different needs. Other equally important objectives are to develop students' creative abilities and to enhance their desire to engage in lifelong learning.

Design features

The fountain should have several outlets or nozzles to allow the formation of different characters by using water jets from selected outlets. These outlets should be individually controllable. The characters should be easily created, arranged, and sequenced to produce pleasing water displays. Furthermore, the fountain should be made from

readily available materials and components, although minor fabrication is permissible. And, it should run on the ordinary line power (110VAC in the US) and be safe to operate.

As indicated above, the outlets are to be individually controlled; this feature can be easily met by utilizing a microcontroller. Today, there are a wide variety of inexpensive microcontrollers for various applications in industry, consumer products, and hobbies. Some of the microcontrollers are offered in kit form so that the user can quickly set them up for the application at hand.

Microcontroller selection

The criteria to select the microcontroller for this project included the following considerations. The microcontroller should be easy to (a) setup and require no soldering, (b) interface with high voltage devices such as pumps, and (c) program (e.g., most students are familiar with or can easily learn BASIC language). It is important to meet these criteria so that the learning curve to implement the microcontroller in the fountain project is kept to a reasonable level. Furthermore, the microcontroller should be flexible, allowing for addition of features to the fountain in the future.

Based on the listed criteria, a *Basic Stamp 2* (BS2) microcontroller was selected [9]. The BS2 is programmed with a special version of BASIC called PBASIC. There are a wide variety of free educational materials associated with this microcontroller and its applications that make it a suitable choice for educational projects [10]. Based on the author's estimate, typical engineering students should be able to learn the basic operation and programming of BS2 in about 8 hours of self-guided study.

Design details

In this section design details are provided to enable the reader to reproduce the design. Electrical and general safety rules must be followed as this project deals with water and electricity. Figure 1 shows the overall diagram of the fountain, schematically representing the wet side and the dry side of the design. The dry side includes the microcontroller and associated circuitry and the wet side includes the fountain's basin, which is a 10-gal. plastic container. Notice that the electrical outlet is equipped with a ground-fault-circuit-interrupter (GFCI). All electronics and wiring connections are placed in a box for safety and neatness. A complete parts list is provided in the Appendix.

In order to keep the size of the project reasonable, it was decided that nine individual outlets would be sufficient to produce a range of characters and simple shapes such as squares and triangles, etc. Specifically, the outlets are arranged in a three-by-three matrix, with a 0.05-m (2-inch) spacing between adjacent outlets. Each outlet is simply a 0.13-m (5-inch) long piece of plastic tubing (0.5 in OD) attached to a small submersible pump (100 gph). Thus, there are nine (110 VAC) pumps used, which are individually controlled by the microcontroller. Of course, one could use just one larger pump and nine solenoid valves instead. However, a small submersible pump costs less than a solenoid valve. Furthermore, a small submersible pump that runs on AC power is much less costly than a DC powered pump.

A squared shaped plate (0.125-inch thick Plexiglas) with nine carefully drilled holes is used to hold the plastic tubes in an upright position. A piece of window screen is neatly cut and placed over this plate to reduce fountain splash. The screen is held in place with six small spacers. Another Plexiglas plate serves as a platform to support the pumps with their suction cups. This arrangement is a neat way to package the pumps and the plastic tubes, and provides for easy access to each tube to ensure that the water flows out vertically during the operation.

As mentioned above, a BS2 was selected as the microcontroller. The BS2 has 16 ports that can be configured as either inputs or outputs. Given the nine pumps for the current design, seven ports are thus left unused and available for future expansion of the project. In order to turn the AC powered pumps on and off by the BS2, driver circuits are
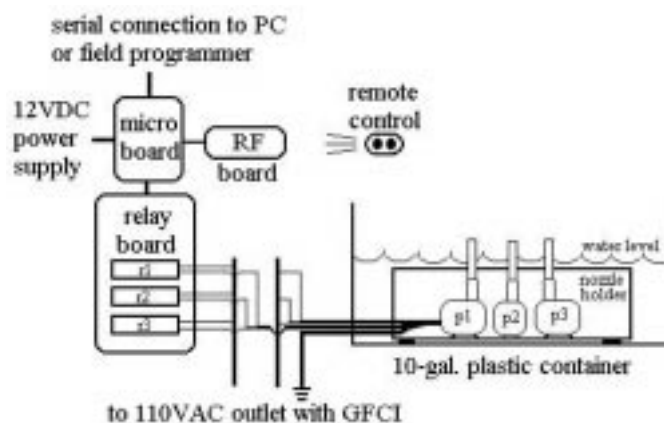

Fig. 1. Schematic of microcontrolled water fountain. Only three pumps/relays are shown for brevity.

needed to amplify the BS2 output currents to enable activation of relays. A circuit board was purchased that has the BS2 as well as the driver circuits in one assembly. A 12 VDC adapter powers this board.

For the relays, optoisolators were selected as they electrically isolate the high voltage circuit (i.e., the pump side) from the low voltage circuit (i.e., the BS2 side); and this is a nice safety feature. A circuit board was purchased to neatly hold the nine optoisolators; however, the board has seven more slots for future expansion. This board conveniently attaches to the microcontroller board, which supplies the power to operate the optoisolators.

In order to program the BS2, a serial connection is made between its board and a personal computer (PC). Programs are written in the PBASIC editor on the PC and downloaded to the BS2 via the serial cable. (The editor software comes with the purchase of BS2 or could be downloaded for free.) Once a program is downloaded to the BS2 there is no need to have the PC connection. The program is permanently stored on the BS2, even in the absence of power, until rewritten.

Alternatively, up to fifteen programs can be written on a PC and uploaded for storage onto a field programmer called Stache (through a serial connection). Then, the Stache is connected to the BS2 board, and any of the fifteen programs could be downloaded to the BS2 in the field. In other words, the Stache allows a user the convenience of having several programs at hand in the field without requiring availability of a PC. The Stache is small, about the size of a matchbox, and runs on a 9 V battery. As shown in Fig. 1, one can add other components, e.g., radio frequency (RF) receiver and RF remote (transmitter), to enable remote control of the fountain. Adding such components would require students to perform some extra research on their own, and in doing so, to practice and appreciate the need for lifelong learning.

Creating characters and shapes

An example is provided here to explain how letters and simple shapes could be generated.

Fig. 2. Viewed from the top. water jets resemble letter U. Note pumps #2 and #5 are off. Count numbers from left to right, top to bottom. Jets are spaced 2 inches apart.

Suppose we want to create letter 'U' with the water jets; this is shown in Fig. 2.

To achieve this, the BS2 is programmed to turn on pumps 1, 3, 4, and 6–9. This operation is elegantly represented by %111101101 in the PBASIC programming language. Notice that there are nine digits in this code, representing the nine used output ports of the BS2, each of which is connected to a pump via an optoisolator. Digit 0 means the output is low (0 VDC), the optoisolator is not affected, and the pump is off. Digit 1 is high output (5 VDC), meaning the optoisolator is engaged to turn on its pump. The numbering order in the code is from the right to the left, i.e., the right most digit is associated with pump #1.

Programming

A simple programming sample is shown below to illustrate how a sequence of water displays can be executed. The program creates the three letters U-O-P (the author's university acronym), displays them for 0.5 s each, and then repeats the sequence. The program comments follow the apostrophe and they are self-explanatory. Note the argument for statement 'pause' is in milliseconds.

```
'Program to flash 3 letters U-O-P for 0.5 s each and
  repeat.
pumps var outs       'define variables
dirs = %111111111    'designate ports as outputs
main:                'marker in the program

pumps = %111101101   'jets # 1, 3-4, 6-9 are on to
                     'form U.
pause 500            'pause 0.5 seconds.
pumps = %000000000   'jets off
pumps = %111101111   'jets # 1-4, 6-9 are on to
                     'form O.
pause 500            'pause 0.5 seconds.
pumps = %000000000   'jets off
pumps = %010110110   'jets # 2, 3, 5, 6, 8 are on to
                     'form P.
pause 500            'pause 0.5 seconds.
pumps = %000000000   'jets off

gotomain             'go to main and repeat
```

Figure 3 shows three snapshots of the water display resulting from running this program. Other examples are shown in Figs 4 and 5. It should be noted that with the current design some letters such as B, G, Q, etc. could not be created; i.e., more outlets are needed to create a wider range of characters.

Educational activities

In the fluid mechanics laboratory, besides rearranging the pumps and developing programs to create numerous water displays with the micro-controlled fountain, a number of simple yet educational exercises related to pumps and pipe flow can be performed. Three examples are briefly presented:
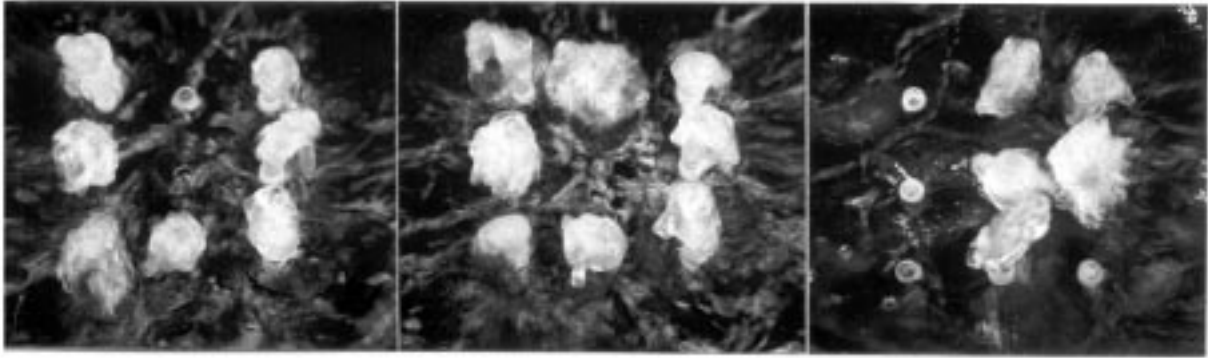
Fig. 3. Water jets display (from left) three letters U-O-P.
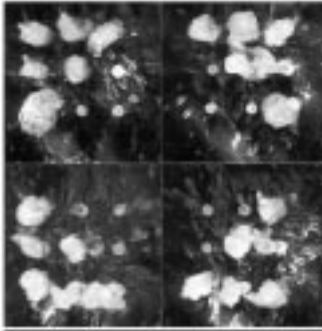

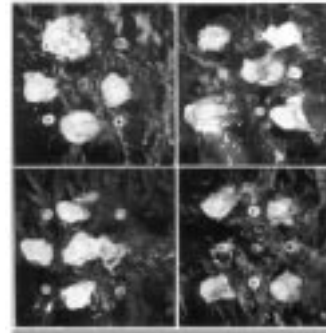Fig. 4. Water jets display a rotating triangular shape.

Fig. 5. Water jets display (clockwise from top left) diamond, crosses, and square shapes.

1. Predict the jet height based on the pump's specification and the length of plastic tubing/nozzle assembly, compare with actual result, and explain.
2. Experimentally generate the head vs. flow rate curve for the pump used in the fountain.
3. Use different materials besides plastic tubing (e.g., aluminum), observe the difference in jet height, and explain.

Educational outcomes

Upon completion of this or similar design projects students will have become familiar with microcontroller and other electronic components (e.g., relay), and their applications. They will have learned how to use engineering catalogs to choose pumps, relays, microcontrollers, etc. In many such catalogs the manufacturers provide application notes, which could be used as supplementary educational materials to further understanding. Above all, the students will have engaged in a project that *integrates* fluid mechanics, electronics, creativity, and artistic expressions.

Ideas for student projects

Up to this point a few suggestions were made for student projects (e.g., analysis and reconstruction of scaled models of ancient trick fountains). Several ideas are listed below that could serve as potential student design projects. Of course, there are many other possibilities, only limited by the imagination of students:

1. Modify the present design to make the fountain operate interactively, for example, by adding infrared sensors to detect the presence of onlookers to start a fountain show.
2. Expand the present design to create a wider range of characters.
3. Modify the present design to synchronize the water jets with music. The author suggests experimentation with a joyful waltz music piece.
4. Modify the present design to add lighting to enhance the water display.
5. Create a fountain design inspired by the Rube Goldberg 'Invention Machines' [11].

CONCLUSIONS

Detailed design of a novel water fountain that creates characters and shapes with water jets was presented to provide an example of a multidisciplinary project, suitable for design and fluids courses. The fountain is controlled by a microprocessor that is relatively simple to implement in the project. The inclusion of a microcontroller enables (non-electrical engineering) students to be exposed to the applied electronics and learn a few fundamental applications. Design and construction of such a fountain provides an opportunity for students to exercise their technical and artistic abilities in an affordable and practical project. Several ideas were presented as potential student projects.

The author would greatly appreciate hearing about any project developed based on the ideas disseminated in this paper.

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11. M. F. Wolfe, *Rube Goldberg*, Simon & Schuster, New York (2000) pp. 122, 138.

Appendix—Parts List
Microcontrolled water fountain (USA retail prices in 2002)

Item #	Part number, catalog description	Source	Quantity	Unit price ($)	Cost ($)
1	P80 Cal Pump, 100 gph max. flow, 2′ max. Head, 110 VAC, 0.09 A	www.eponds.com	9	16.49	148.41
2	BS2-IC, BASIC Stamp 2 Module	www.parallaxinc.com	1	49.00	49.00
3	27945, BASIC Stamp Control Interface Board	www.parallaxinc.com	1	69.50	69.50
4	750-00007, Power supply, 9–12VDC	www.parallaxinc.com	1	10.00	10.00
5	28004, RF Keychain Receiver (optional)	www.parallaxinc.com	1	69.00	69.00
6	28005, RF Keychain Transmitter (remote) (optional)	www.parallaxinc.com	1	21.00	21.00
7	27330, Stache-BASIC Stamp Field Programmer (optional)	www.parallaxinc.com	1	139.00	139.00
8	G4OAC5, AC Output 12–140VAC, 5VDC Logic. This item is the optoisolator.	www.opto22.com	9	8.90	80.10
9	G4PB16, 16-Channel I/O Module Rack	www.opto22.com	1	62.00	62.00
10	Adapter cord with GFCI outlet	Hardware store	1	29.99	29.99
11	1/8′ thick. Plexiglas, 4ft^2	Hardware store			50.00 approx
12	½′ I.D. plastic tubing, 2′ long	Hardware store			
13	½′ O.D. plastic tubing, 5′ long	Hardware store			
14	10 gal. plastic container	Hardware store	1		
15	Terminal strip	Radio Shack	2		
16	Other parts (screws, nuts, window screen, etc.)	Hardware store			
17	Tax and shipping	10% of the price			72.80
	Total cost				**800.80**
	Total (without optional items # 5–7)				**548.90**

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