June 2013 – Model Solution

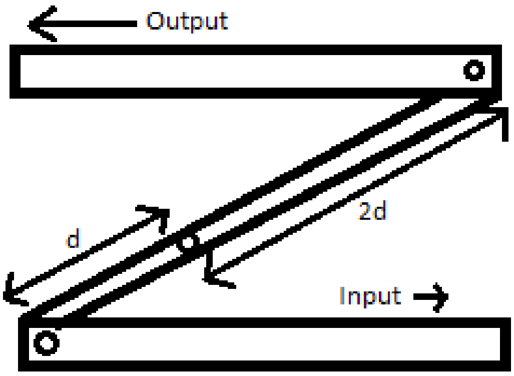
1a. A material which resists the flow of electrical current, for example wood or plastic.

1b. A ferrous metal is one which contains iron, such as stainless steel.

2a. Frequency is the number of cycles of a wave that happen in one second, and is measured in Hertz (Hz).

2b. Fabrication is the process of assembling parts to make a new product or system.

3. To amplify linear motion by a factor of two, a reverse motion linkage could be used. If the distance from the pivot to the output is double the distance from the input, the linear motion will amplified by two.



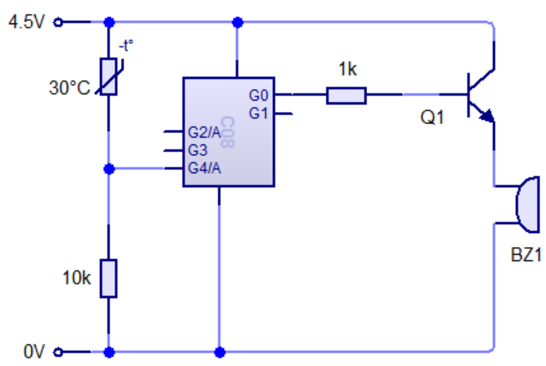
4a. Truth table

A	B	C	Q
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

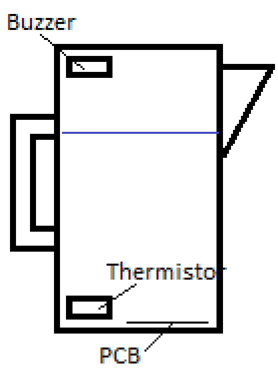
4b. In this solution, a thermistor is connected as a potential divider, the output from which is connected to the analogue input pin on a PIC.

The PIC handles the processing, and is programmed with a simple loop program to say that when the temperature reaches 100˚C, the output pin is turned on.

The output is connected to the base of an NPN transistor, which will provide the buzzer with sufficient current to operate.

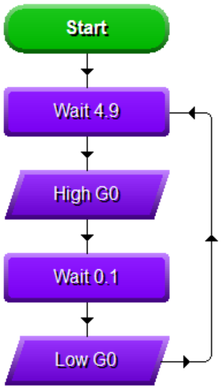


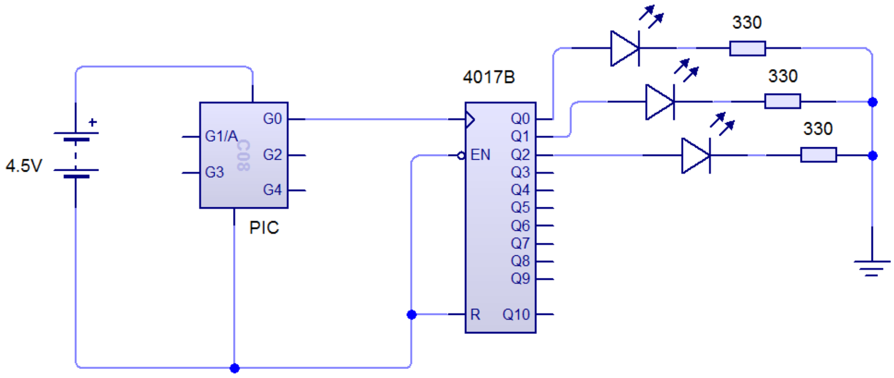
I have mounted the PCB inside the base of the kettle, the thermistor would be mounted inside the plastic body of the kettle, and the buzzer would be mounted near the top of the unit.



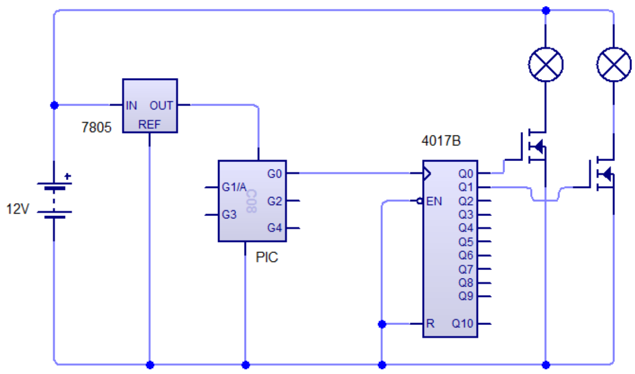
5a. I could use an astable 555 timer IC to accomplish this, but for simplicity, I will use a PIC in this design, and take one output from the PIC, which is fed into a decade counter IC. Each decade pin can then be connected to an LED and resistor.

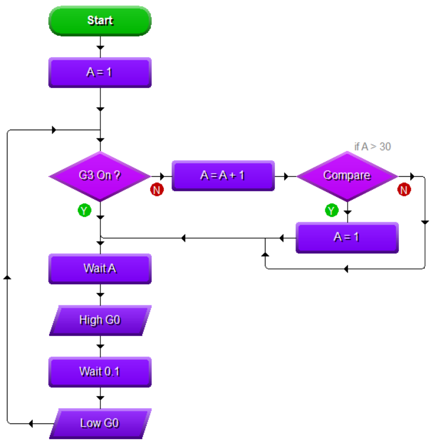
A simple PIC flowchart program can then be used to pulse the output pin once every 5s, which will give the desired output.



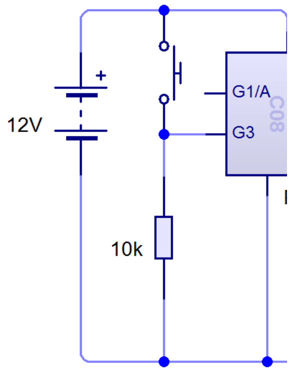


5b. To handle the additional current requirements, I would use a MOSFET (Metal Oxide Field Effect Transistor). I chose this component because they have a larger current-carrying capacity than most NPN transistors, (but are more susceptible to damage from static electricity). I have connected the gate to the decade counter output, the drain to the lamp and the source to 0V.

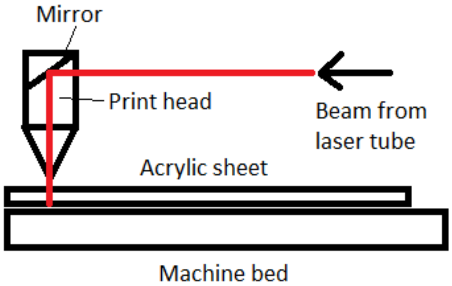




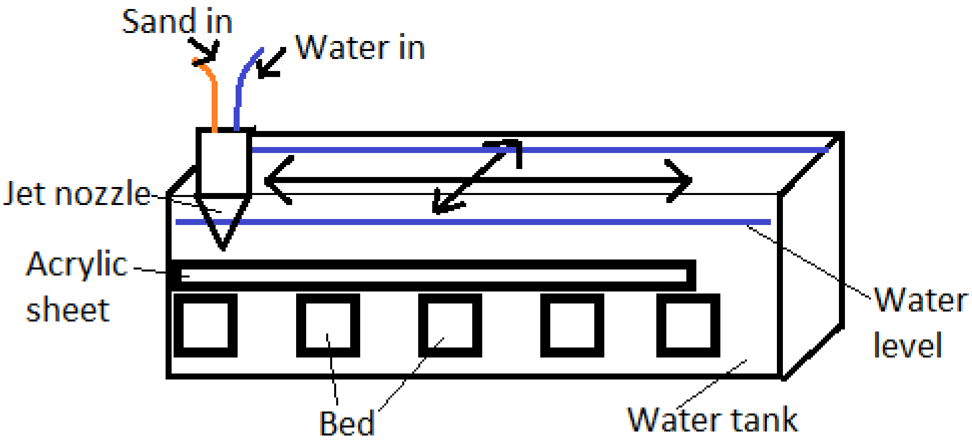
5c. To provide a variable time delay from 1-30s, I would add a PTM switch to the input, with a 10k pull-down resistor (top prevent the pin from floating). Each time the PIC input is triggered, I would modify my program to increment a variable (up to 30, when it would be reset). I would use this variable as my time delay in my program.



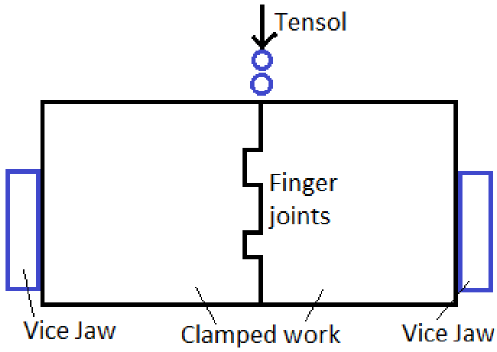
6a i. One method of cutting a 50mm x 20mm rectangular hole in 3mm acrylic would be to use a laser cutter. First, the shape would be drawn to the correct dimensions on 2D CAD software (e.g. AutoCAD or Techsoft 2D Design), then the file sent to the laser cutter control software. The correct power, Z-axis and speed settings would be entered, before the acrylic sheet is placed onto the machine bed. The extractor pump and air-assist (where present) would be turned on, to avoid fumes, and the machine energised.



6a ii. The second method would be to use a water-jet cutter. The initial process of designing the part and sending it to the control software remains the same as for laser-cutting. The machine is set up by raising the machine bed above the water bath, then placing the acrylic sheet, and clamping it into place. The bed is then lowered just under the water, and the cutting head Z-axis set to the required height above the work-piece.



6b. One method to permanently joining two pieces of acrylic together would be to use Tensol solvent adhesive, which is specifically designed to bond acrylic. The two pieces of sheet should both first be thoroughly cleaned to be free from grease and grime. In designing the pieces to be joined, the surface area between the surfaces to be bonded should be maximised, using finger joints or dovetails.

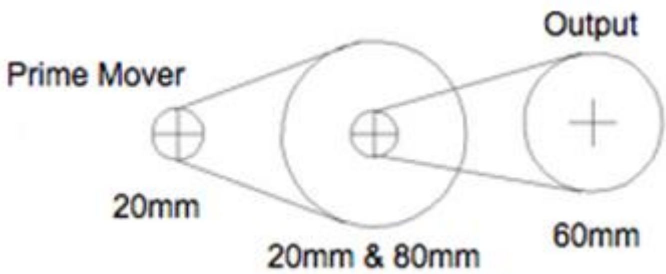


To perform the procedure, the two surfaces should be clamped tightly together, and a syringe-sized dispenser used to run a bead of the solvent down the join. The glue will be sucked into the joint by a capillary action. Excess can then be wiped off with a tissue, and the join left to dry.

7a i. System 1 is to use a belt and pulley system, with a small (e.g. 20mm diameter) pulley connected to a DC motor (prime mover), driving a larger (e.g. 80mm diameter) pulley. This could be mounted to another 20mm pulley, which in turn drives a 60mm pulley to provide an output.

In this specific example…
20:80 = 2:8 = 1:4
The first belt/pulley pair slows the motion by a factor of 4.

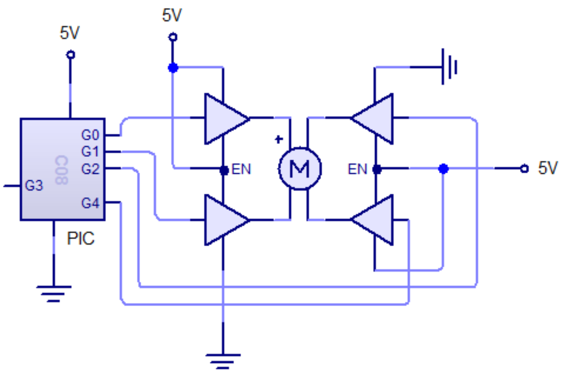
20:60 = 2:6 = 1:3
The second further slows the motion by a factor of 3.



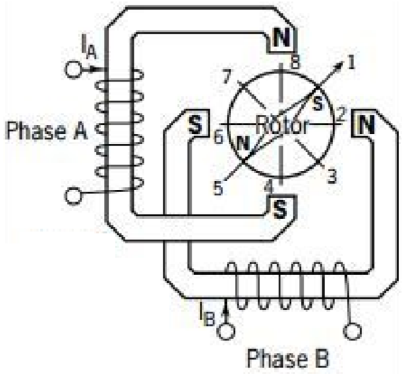
4 x 3 = 12.

Overall, output motion is slowed 12x over.

7a ii. System 2 is to use a stepper motor.



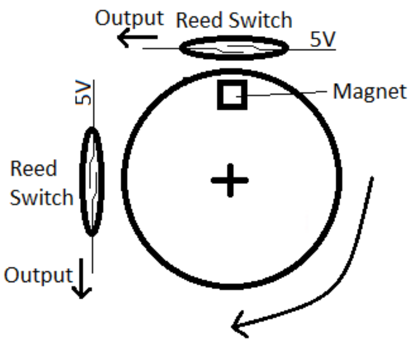
To ensure slow output movement, an L293d H-bridge driver IC would be used, driven by a PIC. The overall speed of the output can be very finely controlled by modifying the pause (usually measured in ms) between steps in the control program.



The stepper has its own output shaft which normally has a spline on it, to prevent slipping.

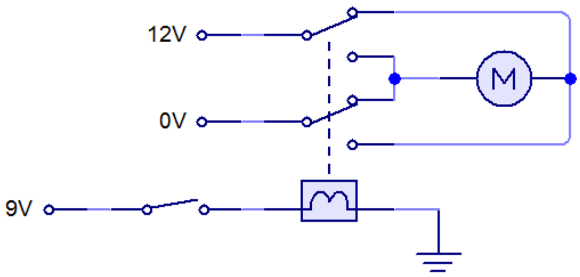
7b i. To create an electronic pulse after a 270˚ rotation of a shaft, I'd use a pair of reed switches, and a magnet attached to the outside of a thin MDF disk attached to the shaft, as shown in the sketch.

The reed switches could be attached to digital inputs on a PIC. Immediately prior to the start of rotation, the first reed switch would be closed. Upon reaching 270˚, the second would be closed, thus providing feedback, so that the system knows the desired amount of rotation has been achieved.



7b ii. To reverse a motor, a half-H bridge driver could be used. For larger motors which require more than 600mA, a DPDT relay could be used instead. In this sketch, I have used a SPST switch to indicate the pulse.

In an actual system, the pulse would most likely be received by a PIC, and the relay triggered by transistor, operated by a PIC.



7c. Complete solution *coming soon…*