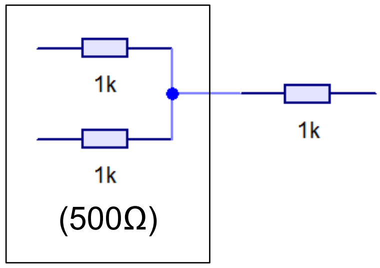
June 2012 – Model Solution

1a. Lamination is the technique of manufacturing a material in multiple layers. Plywood is made by gluing multiple thin layers of wood (called veneers) together. Alternatively, blockboard is made by gluing together multiple solid wooden blocks, which are sandwiches between two thin plywood layers.

1b i. Stainless Steel

1b ii. Iron and carbon

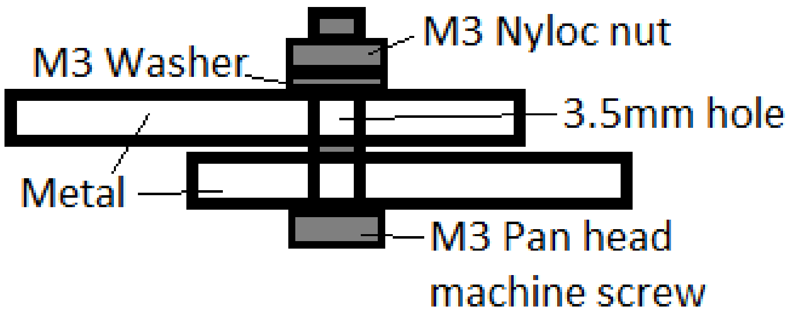
2. Resistors in parallel:
$1/R_T = 1/R_1 + 1/R_2$
$1/R_T = 1/1000 + 1/1000$
$1/R_T = 2/1000 = 1/500$
$R_T = 1/(1/500)$
$R_T = 500$



Resistors in series:
$R_T = R_1 + R_2$
$R_T = 500 + 1000$
$R_T = 1500$

So total resistance is 1500Ω

3. Two pieces of metal could be temporarily joined thus:

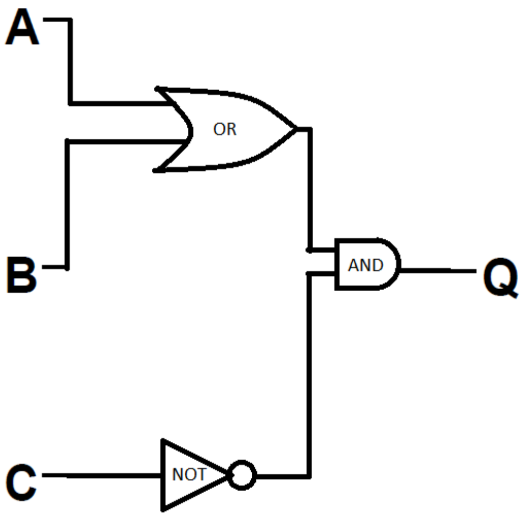


Step 1 – Use a pillar drill to make a 5mm hole through both pieces of metal. Remove any burrs (sharp edges) using a metal file.

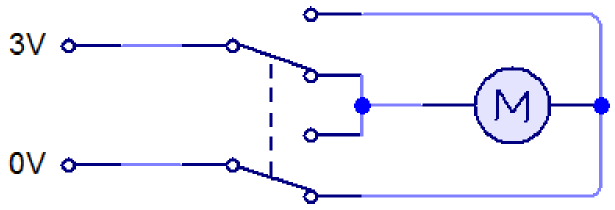
Step 2 - Pass an M3 machine screw through the holes, then place an M3 washer over the top (to distribute the compressive force exerted), and then secured with a Nyloc locking nut.

This way, the pieces of metal would not work loose over time, but could be disassembled for maintenance when required.

4a. Logic network:

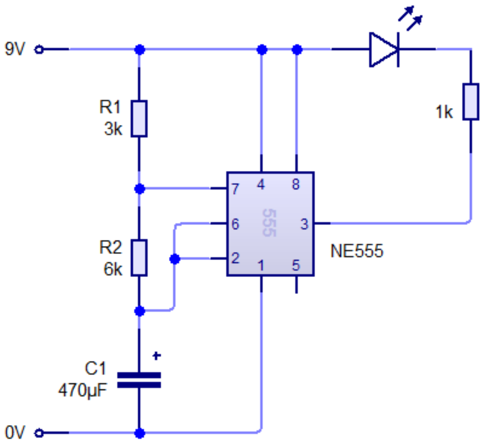


4b. DPDT switch to reverse a motor…



5a i. *(Option Question)*

Solution 1: Astable 555 timer IC



By modifying the values of resistors R1 and R2, as well as capacitor C1, the high and low interval can be changed.

The duty cycle can never be lower than 50%, and I need 40% (2s+3s = 5s. 2/5 = 40%). To make the LED flash at the correct rate, I use pin 3 to sink (rather than source) current.

I chose 470µF for my capacitor value, as it is a standard size, and would lead to being able to use smaller resistor values than I'd need with a smaller capacitor.

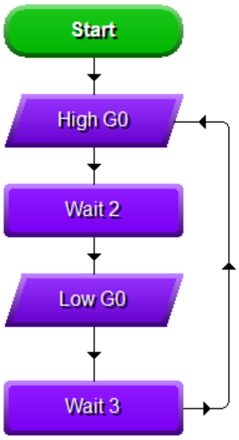
High = 0.7 * (R1 + R2) * C
3 = 0.7 * (R1 + R2) * 0.000470
3 = 0.000329 * (R1 + R2)
3/0.000329 = R1 + R2
9118.5 = R1 + R2
R1 = 9118.5-R2

Low = 0.7 * R2 * C
2 = 0.7 * R2 * 0.000470
2 = 0.000329 * R2
2/0.000329 = R2
R2 = **6079.0**

R1 = 9118.5 – 6079
R1 = **3039.5**

To achieve the required time, I would need to use a 3039Ω resistor for R1, a 6079 resistor for R2 and a 470µF capacitor for C1. I could use preset potentiometers as variable resistors to achieve the precise values needed.

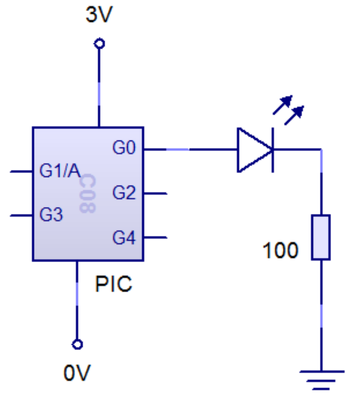
Solution 2: PIC chip



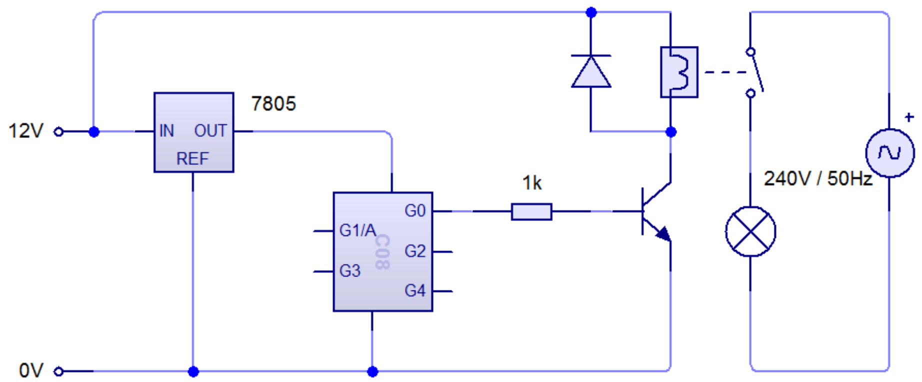
By using a simple PIC program with a WAIT command set up on a loop, the LED can blink precisely.

The program instructs the output pin to go high, wait 2 s, then go off and wait 3s before looping back to the start of the program.

A small resistor on the LED protects the LED from blowing.

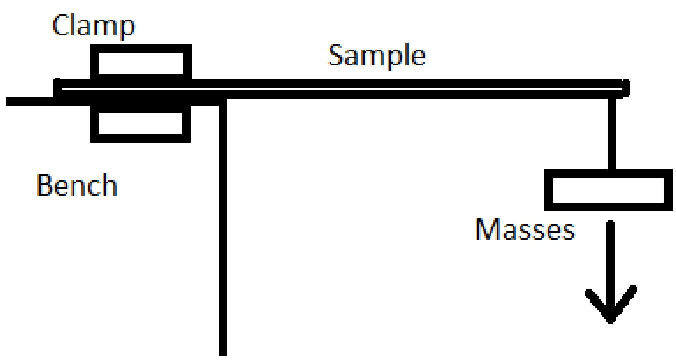


5b. To modify my PIC solution to use 240V AC, I'd need to add a transistor driven relay to the output pin, protected by a fly-back diode (to protect against back-EMF). I'd also need to uprate my power supply (12V should be sufficient for most relays).



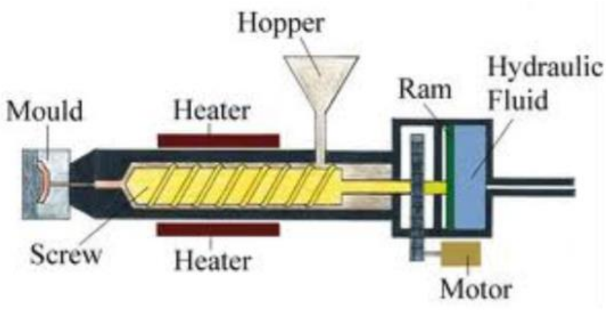
6a. To measure bending forces of plastics, I would obtain 200mm x 20mm x 3mm samples of each material, and use a G-clamp to secure each sample so that it hangs 150mm off the edge of a table top. I would then incrementally suspend masses (200g at a time) from the end of the sample. After each mass is added, I would measure the distance that the end of the sample has moved down by until the sample either snapped, or moved more than 45˚ from horizontal.

Each displacement would be recorded on a spreadsheet. Once the test was completed, I would plot a line graph with a line for each material, so that the relative resistance to bending forces could be compared easily.



6b. A plastic bucket body could be made using injection moulding, as follows:

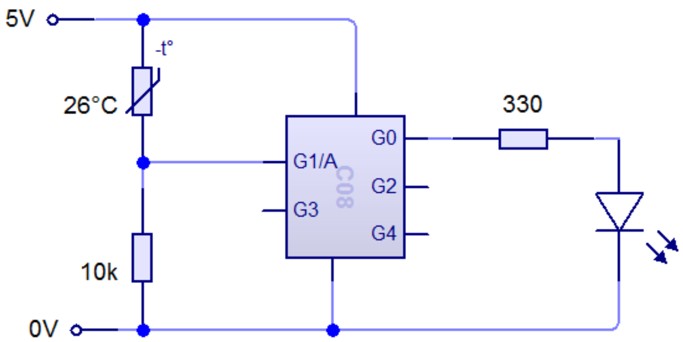
A hopper is filled with granules of the thermoplastic to be used (e.g. ABS), which are released into the main chamber. They are driven along towards the mould by an Archimedean screw, passing along a heated section, which melts the plastic to its molten state. The plastic is driven into the mould under pressure, and then allowed to cool. Once set, the mould is opened, and the bucket body can be removed.



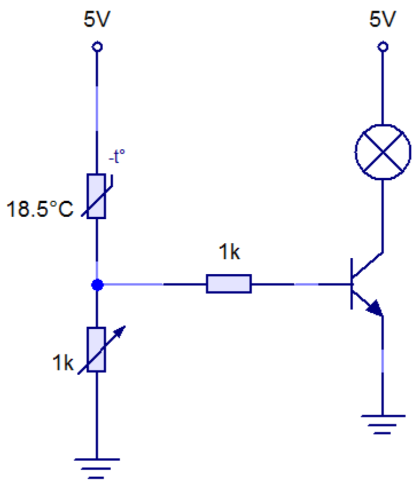
7a i. My first system uses a PIC chip…

By using a 5V supply, and a thermistor set up as a potential divider which is connected to an analogue input, an output of between 3-4V can be obtained from the output.

I've drawn an LED on the output I'm using purely for illustrative purposes, but any other output component could be used.



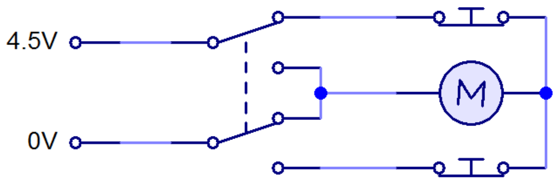
7a ii. My second system uses a transistor…

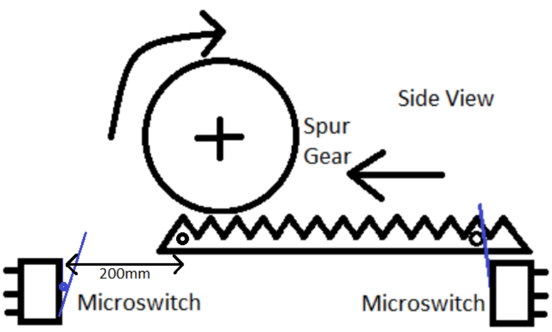


I could use a thermistor set up with a potential divider and a variable resistor (for calibrating to the required temperature), connected to an NPN transistor.

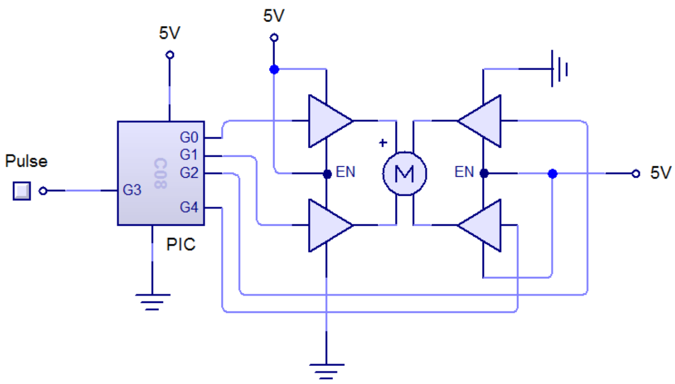
The 1k resistor on the base is a current limiting, to protect the NPN transistor.

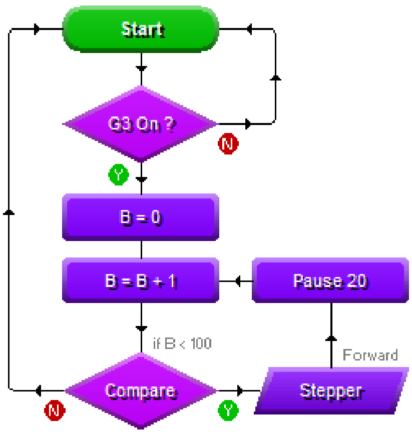
7b i. Rack and pinion
In this configuration, the spur gear (connected through a gearbox to a DC motor – not shown) is triggered by the throw of a DPDT relay (*drawn as a switch for brevity here*). This energises the motor, causing the rack gear to move in a linear direction, as shown in the sketch. Once the rack hits the M3 machine screw protruding from the rack, it opens the PTB (micro)switch, stopping the movement. The DPDT relay can reverse the direction of motion.



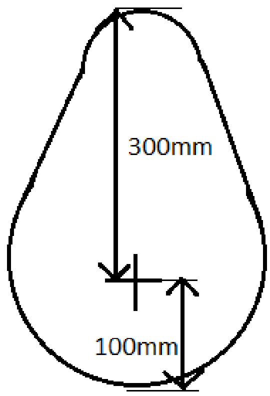


7b ii. Cam and Follower
In this design, a pear cam is connected to a stepper motor. Triggered by a pulse arriving at a digital input on the PIC, it works by moving 100x 1.8˚ steps (so the cam will rotate 180˚), making the follower to rise by 200mm. It is stopped by the PIC microcontroller, and the process is repeated upon receipt of the next pulse.

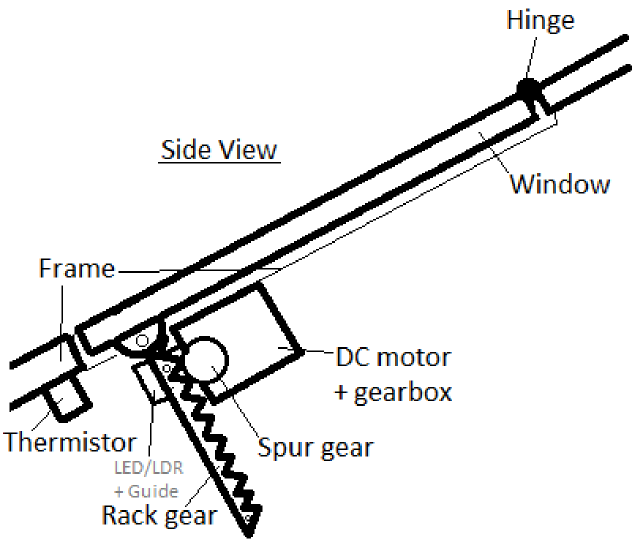




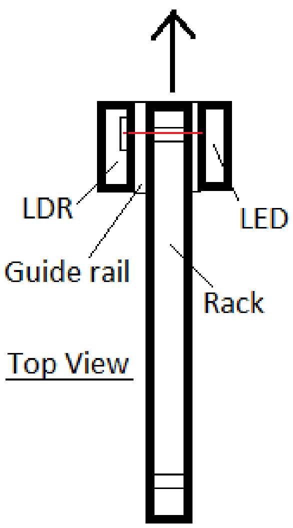
The program uses a variable (B) which counts 100 times, moving the stepper, then pausing momentarily before stepping again. The variable is reset each time a new pulse is received on the PIC input.



7c. For my final design, I've improved on the stages developed in the previous questions, choosing to develop the rack and pinion idea. The window, window frame and hinge can be seen in the side view sketch.

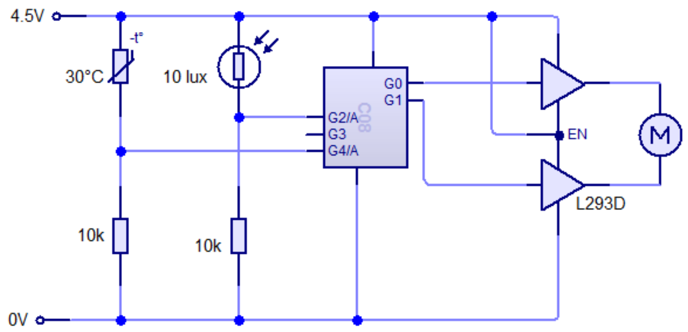


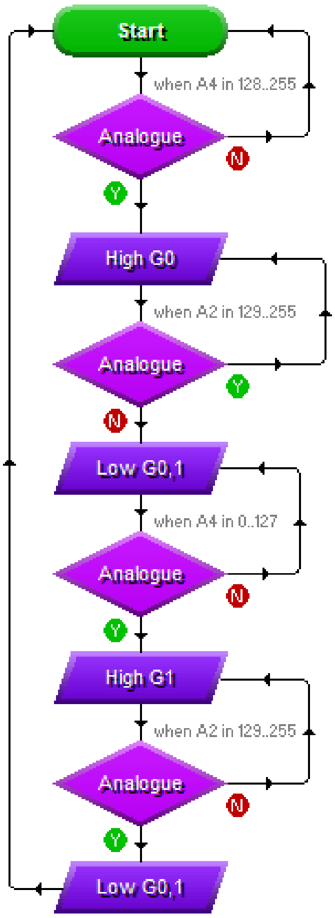
The thermistor is placed on the inside of the frame. It can be mounted by using self-tapping screws straight into the uPVC window frame. From here, wires can be run down to an ABS enclosure holding the control PCB, which can be secured to the wall using walk plugs.



The DC motor (output) and gearbox can also be stored in an ABS enclosure (selected for durability), and again mounted with self-tapping screws. To mesh the rack gear (which would fall away if not held in place) to the spur gear, an aluminium guider is be placed around it, and bolted into place. It is attached to the window itself with an aluminium bracket so it can pivot as the window opens.

Rather than microswitches to limit movement, an LDR/LED pair are used, with small holes drilled through either end of the rack, so that end of travel can be detected on an analogue input pin.





In terms of electronics, I've put both my LDR and thermistor as a potential divider into two analogue inputs in a PIC chip (the process). I've then used an L293d half-H bridge driver to control the DC motor, so that I can handle the additional current required for the motor, and can reverse the motor direction.

The program waits for the temperature to pass 25˚C (this would need calibrating after installation), then it energises the DC motor to move the window. While it is moving, the PIC constantly checks the analogue value of the LDR, until the level goes up (as the LED shines onto it at the limit of travel). The motor is then stopped, and the PIC then repeatedly monitors the temperature drops, when the above process is reversed. The PIC program then loops back and starts again.