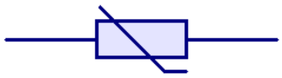
June 2014 – Model Solution

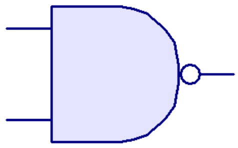
1a. A thermoplastic is a material which can be worked into new shapes when heat is applied, such as acrylic or HIPS.

1b. A semiconductor is a material whose ability to conduct electricity can be varied, such as silicon.

2a. A Thermistor:



2b.



3. Shaft B gear ratio is 20:60, which is 2:6, or 1:3. If shaft A is rotating at 360rpm, then B will rotate at 360/3 = <u>120rpm</u>.

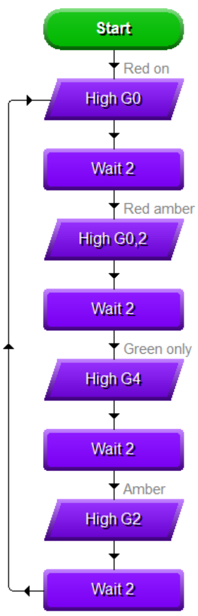
Shaft C gear ratio is 25:100, or 1:4. If shaft B is rotating at 120rpm, then shaft C will rotate at 120/4 = <u>30rpm</u>.

4. <u>Step 1:</u> When A is closed, RL1 is energised. Due to the way the relay is wired up, this causes RL1 to latch, holding the relay in an energised state even after the user releases the button.

<u>Step 2:</u> On the second half of the circuit, the effect of RL1 latching is to energise RL2, and L2 will illuminate.

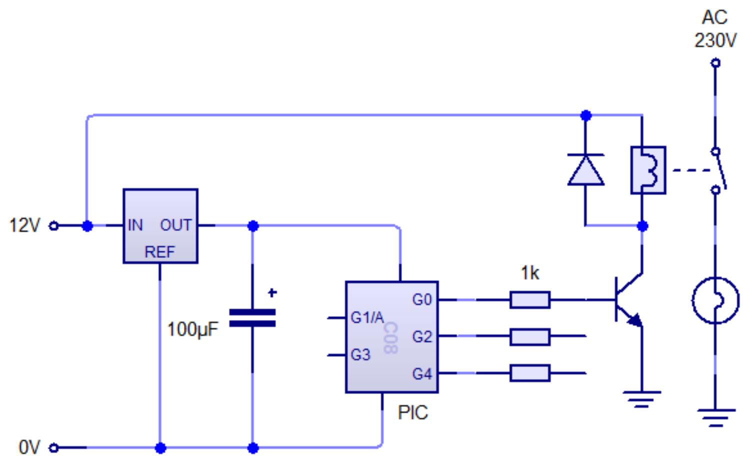
<u>Step 3:</u> When RL2 energises, the throw of its pole causes the relay to de-energise, breaking the circuit, and extinguishing L2. The relay will then repeatedly oscilate between energised and de-energised, causing lamp L2 to flash rapidly.

4b. When B is pressed, RL1 is released, resetting the system to its starting state. L1 is illuminated.



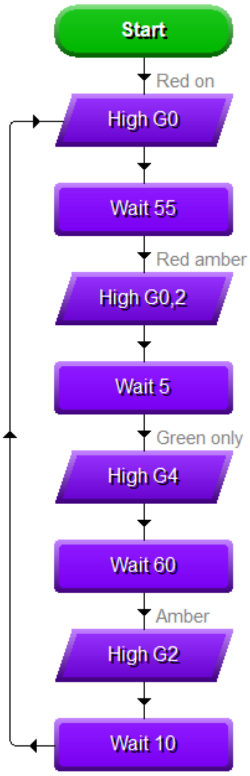
5a. To control 230V AC electricity, two power supplies will be needed. To isolate them from one another, relays can be used, something like the circuit shown here.

(*for clarity, I have only drawn one transistor, relay, flyback diode and lamp. The actual circuit would include two more of these, connected to the shown output current limiting resistors*)



To control the system, I'd need a PIC program, which would work along the lines of the one shown here to the left.

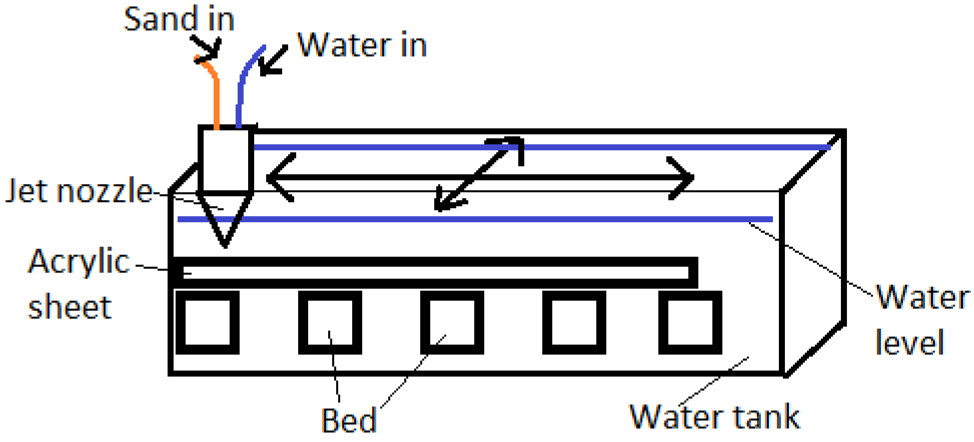
5b. To modify the system, the timings in the previous flowchart program can be modified, and a new program pushed to the PIC.



5c. Two advantages of using LEDs are:
i. LEDs work with DC current, and so the need for relays is removed.
ii. LEDs have a vastly longer operating life compared to incandescent lamps, and so system maintenance is reduced.
iii. LEDs make more efficient use of power, as less energy is converted to heat in their operation.

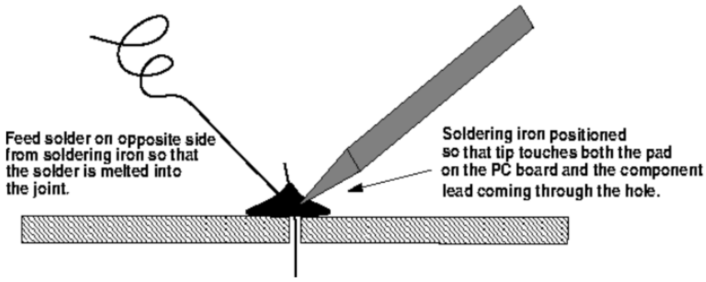
6a. I would use a water-jet cutter to produce the 100 parts, as follows:

Step 1: The shape would be drawn up in any 2d vector graphics package, which would allow precise creation of the flat (pre-bent) shape shown in the question.
Step 2: For batch production, a cutting sheet would be designed to maximize the yield of 70x20x1mm mild steel pieces. They won't tessellate perfectly on the sheet due to the rounded edge, but wastage won't be excessive for this design.
Step 3: A water jet cutter is used. The machine is set up by raising the machine bed above the water bath, then placing the steel 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. Appropriate jet power settings are entered for 1mm mild steel, and the machine is activated.

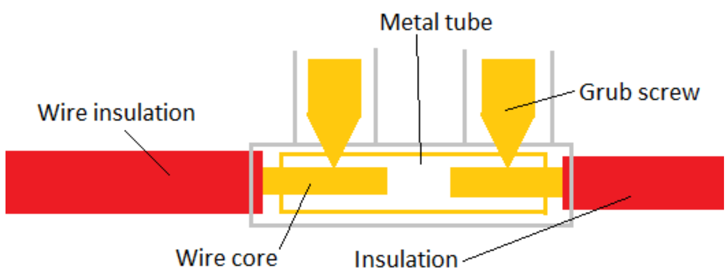


Step 4: The pieces can be removed when the process is finished, and any burrs (unlikely to be an issue) can be removed with a metal file.
Step 5: Using a caliper, the location for the fold can be located and marked with a pencil. The fold can be lined up and created using a brake-press., which will neatly create a pre-set 90˚ bend. Alternatively, a jig could be bolted in place on the back of the jig, so that the part is automatically bent at the correct point.

6b. Permanent method: Soldering. Prior to soldering, both metals need to be clean, and free from oxidation and grime. The two surfaces (e.g. PCB pad and component leg) are both heated with a soldering iron (@ 250-350˚C) for approximately 3s, then solder is fed in, until a volcano-shaped peak is formed by the solder flowing over the two parts. The solder is then removed, followed by the soldering iron. The unwanted leg part is then trimmed off with side-cutters. Continuity can then be tested with a multimeter to confirm the connection has been made.

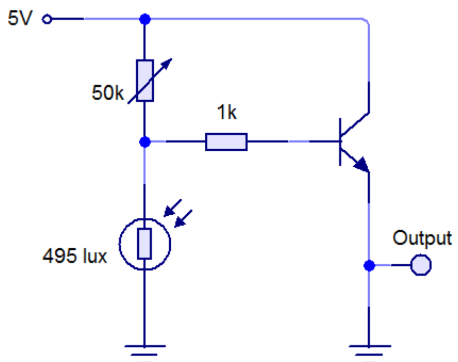


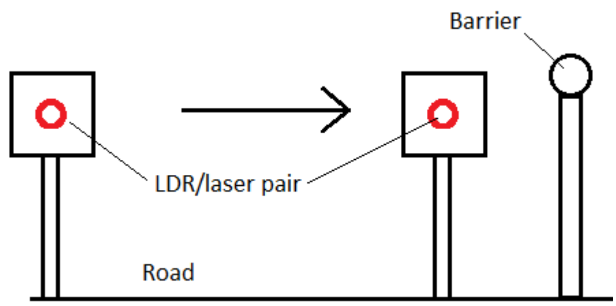
Temporary method: Terminal block. Prior to joining the wires, the terminal block screws should be checked to ensure they are all present, and that they can all be tightened (some are manufactured poorly, and cannot be tightened). The wires to be joined should have sufficient insulation removed so that no bare wire can be seen outside the block when the wires are inserted, nor any bare wire protrude from the far end of the block. It is desirable to have as large a surface area as possible inside the block, so as to ensure continuity once the connection has been made.



To make the connection, the wires to be joined are inserted into the block one at a time, and then a small (usually flat-headed) screwdriver is used to pinch the wire against the bottom of the terminal block. Continuity can then be tested with a multimeter to confirm a good result.

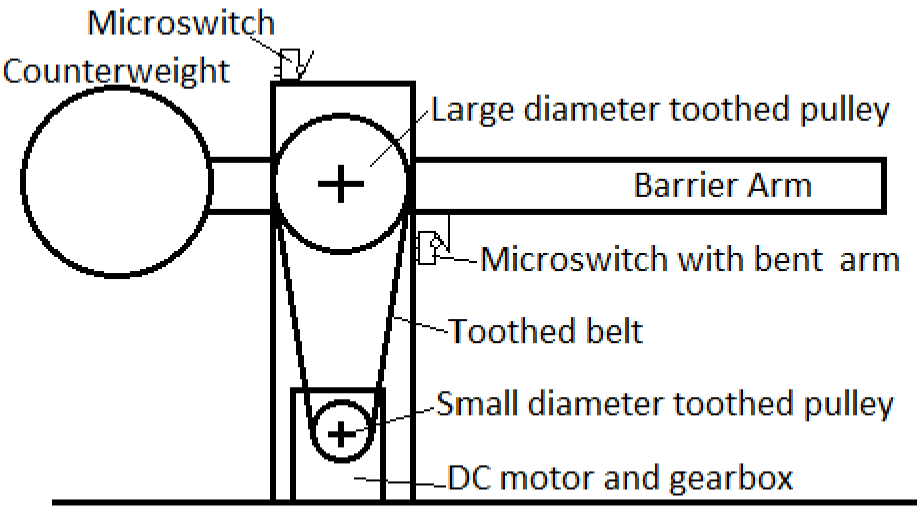
7a. Car bodies are longer than bicycles and people, so I would detect the presence of one at my barrier through the use of a pair of laser-beams, focussed onto a pair of LDRs, 2.0m apart, and 500mm from the ground. When each beam is broken, this can be detected by the circuit shown below (I'd need two of these). When the light level drops, the circuit produces an electronic output that can be fed into a PIC.





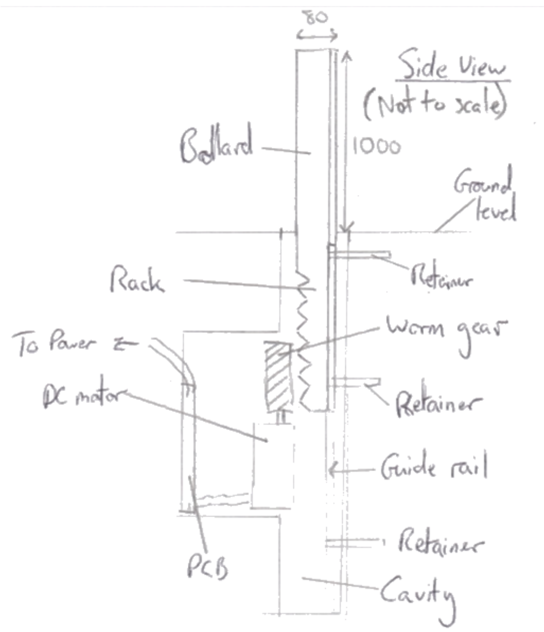
7b i. <u>Design 1.</u> This uses a swing-barrier, mounted to a belt and pulley system, run from a high-power DC motor and gearbox. A pair of microswitches can be discreetly mounted to indicate end-of-travel when the arm has been fully opened/closed. The counterweight serves to reduce the work the motor has to do, by balancing the arm.

The system pivots about the larger of the pulleys, and the barrier can be opened/closed by driving the motor either forwards or backwards.



<u>Design 2</u>. This uses a rising / sinking bollard, which comes out of the ground when traffic is to be blocked. In this design, a modified rack and pinion is used, using a worm gear in place of the spur gear. This is so that in the event of a power failure, the bollard will not fall into the ground and become damaged and also to reduce the output speed from the DC motor.

The diagram is not to scale in the interests of fitting it on the page – the motor should be lower down, and the rack extended in order to bring the bollard down so it is flush with the ground.



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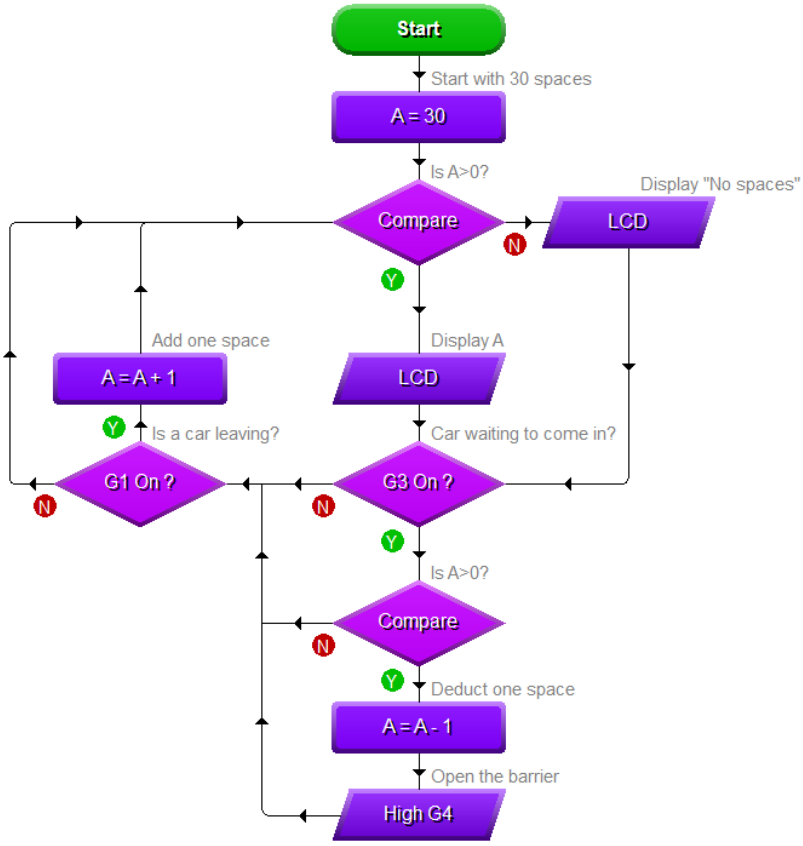
7b ii. This system would use a PIC program with a variable to store the number of available spaces in the car park. At the start of the day when the system is initialised, 30 spaces are available. As the cars enter, A is decremented, and the new total number of spaces displayed on a large LCD panel outside the car park.

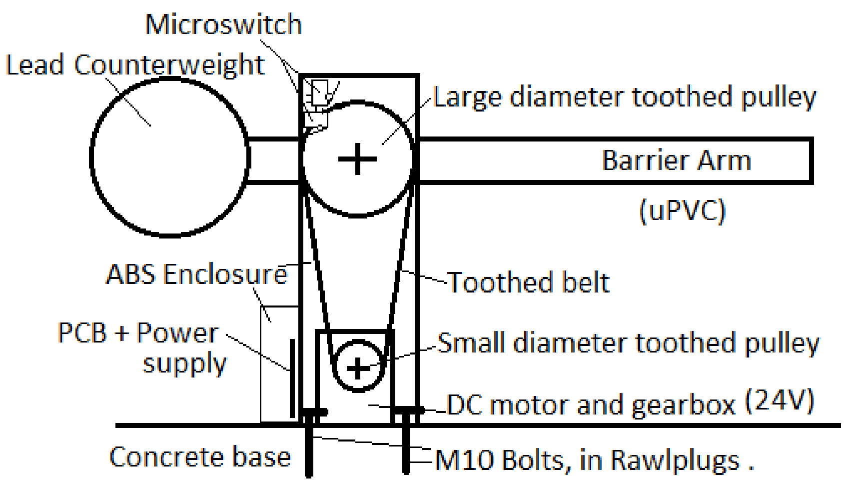
As cars leave, A is incremented, so that a live score is always visible.

If a car tries to enter, but no spaces are available, the car won't be allowed to enter the car park.



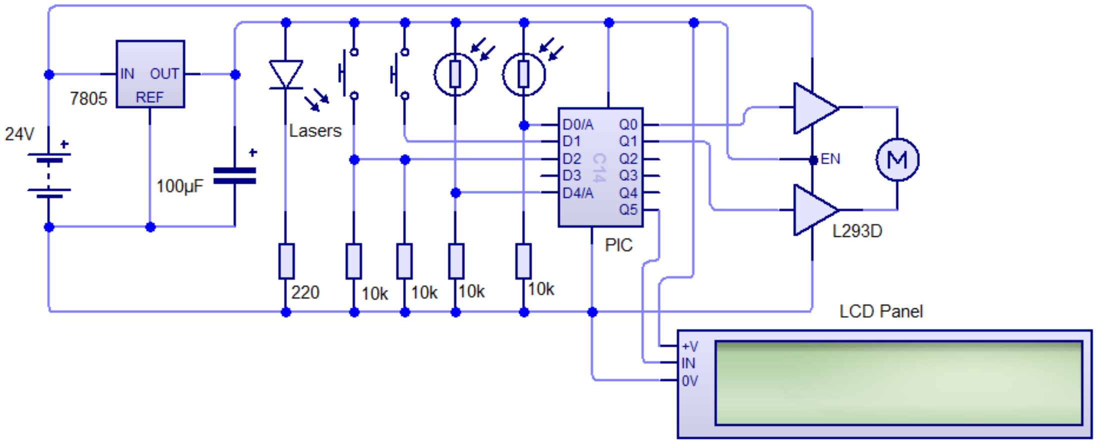
7c. Building on the previous answers, my design uses a PIC-based solution to control the car park.

Barrier and drive system: A 24V DC motor is controlled with a H-bridge for output (so that the barrier can be opened and closed). Through the use of a high-ratio gearbox, the arm can be slowly raised and lowered in a controlled manner, and the gearbox will provide the necessary torque needed to handle the mass of the barrier.

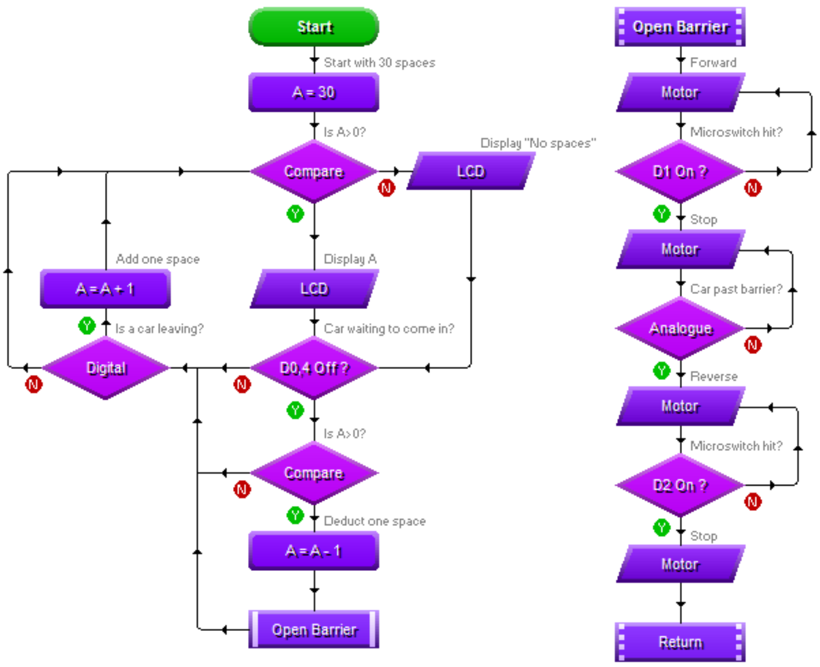


How Movement of the barrier is limited: Movement of the motor is limited by the use of microswitches (connected to the PIC), as the edge of the barrier will close these when the barrier is fully opened/closed. These are drawn as PTM switches on my circuit diagram.

<u>Sensing and Control system:</u> The system uses a pair of LDR/laser beams for inputs, then a PIC for processing. Building on the design from the previous part of the question, I'd use the sensing system from part a, but rather than using the potential divider to energise the base of a transistor, I'd send the output into the analogue input of a PIC (*shown on the circuit diagram*). My flowchart program shows the full logic needed to operate the system.



The PIC will use a modified version of the program from part b of the question. Using a variable to count the remaining spaces available. Building on the previous question, I've added a subroutine to operate the barrier, so that the program's functionality is improved without adding too much complexity to the main program flow.



<u>Assembly of sub-systems:</u> All the individual parts of the system are inter-linked through the PIC circuit, so that the inputs feed the process, which in turn can control the system outputs (display and barrier). The outputs provide feedback to the inputs, ensuring smooth and reliable operation.

Materials and components: I've kept the weight down by using hollow uPVC (for weather resistance and low weight), counter-balanced with a small amount of painted lead (steel could be used instead).

I've moved the end of travel microswitches so they can be mounted on the ABS enclosure with machine screws. I've also used large bolts to secure the assembly to the concrete floor of the car park. The top pulley would need to be securely mounted in place, so a steel supporting frame would be placed inside the main housing, and also secured with bolts. My pulleys could be made from stainless steel and painted, so that they won't corrode quickly in the outdoor environment.