

DESIGNING AND MAKING AN ELECTRONIC LOCK

WHAT YOU WILL LEARN

After completing this project, you should understand:

- How to design a control system using a block diagram.
- How a sequential control system works.
- How a sequential control system can use electronic memory to help it operate.
- How logic gates can be used to build memory circuits.
- How a field effect transistor (FET) can be used as an electronic switch.
- How a solenoid is used to produce movement.

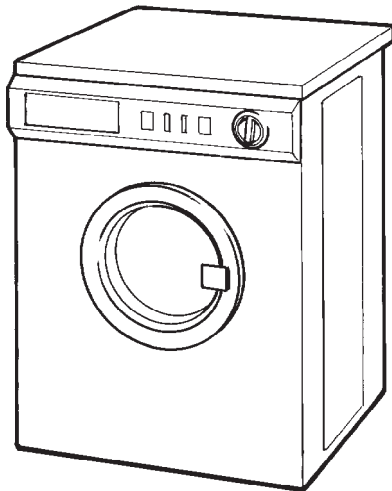
After completing this project, you should be able to:

- Use the following components in control circuits:

FET
IC 4001
Resistor
Solenoid
Switch.

- Build an electronic lock system.

When control systems are used to perform tasks, they are often required to do things in a specific order. One task needs to be completed before the next begins. This is known as a **sequential control**. An automatic washing machine is an example of a sequential control system. Once the wash programme has been set, the machine goes through a preprogrammed sequence of operations.



Automatic
washing
machine

Sequential control systems are very common in the manufacturing industries. Any automated production line will be based on a sequential control system. A traffic control system cannot work effectively unless the lights controlling the flow of cars and pedestrians follows a set sequence of operations. A modern passenger aircraft can follow a predetermined navigational course using an autopilot.

Sequential control can also work in the opposite sense. In the above examples, a set sequence of output operations takes place once the system starts. But sequential control systems can also be designed to make something operate once a set sequence of input operations has happened.

Before a vending machine will operate and dispense goods, the money must be deposited into the coin slot and the selection made.

CONTROL - ELECTRONIC LOCK

Sequential control systems often work in both senses, i.e. a set sequence of input operations causes a set sequence of output operations to happen. To make a phone call, you need to lift the receiver and then dial the correct number. The telephone system rings the telephone you have dialled, stops it ringing when somebody answers and finally makes the connection so you can talk to the other person.

Sequential control systems are very important because they are able to perform complex tasks automatically. This project involves designing and making a sequential control system.

DESIGNING A CONTROL SYSTEM

Control systems can be represented using *block diagrams*. There are three basic building blocks and each block is used to represent a stage in the control system. The three blocks are:



The Input Block - *Enters information into the control system. It will normally contain a switch or sensor.*

The Process Block - *Receives the information from the input block and uses it to control the output block, switching it on or off depending upon the state of the input.*

The Output Block - *Gives out information or makes things happen. The output block would normally contain components that either light up, make a noise or move.*

Control systems can be designed using these basic blocks in a simple and effective way without necessarily knowing too much about the electronic circuits contained in each block. A simple control system would normally contain at least one of each type of block.

YOUR TASK

Design and make an electronic lock that will unlock a door when a number of switches are pressed in the correct sequence. The sequence must contain at least four inputs.

◀ NOTE

To find out more about sequential control see Technology Study File 5 (Investigating Control).

◀ DESIGN BRIEF

CONTROL - ELECTRONIC LOCK

DESIGNING THE CONTROL SYSTEM

The input block needs to contain the 'code' switches that are pressed in the correct sequence to unlock the door. The process block has to contain something to check the sequence in which the switches are pressed and to unlock the door if the sequence is correct. The output block needs to contain a device which can lock and unlock the door when the process block recognises that the correct sequence of switches has been pressed.

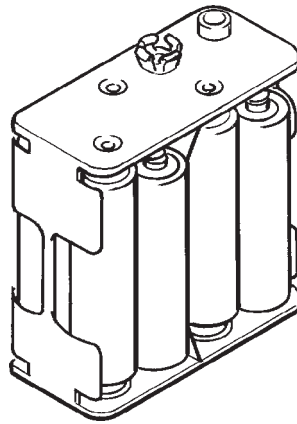
The block diagram for the sequential control system would look like this.



DESIGN CONSTRAINTS

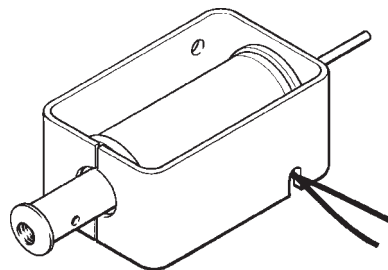
Before you can design and make the electronic lock system you need some more information. You need to know what power supply to use, what components are available and how they are used.

Power Supply - You will be using a 12 Volt power supply. This will be provided by eight 1.5 Volt cells in a cell holder.



OUTPUT BLOCK

The component available for use in the output block is a **solenoid**. Solenoids are used to produce movement that can be controlled electronically.



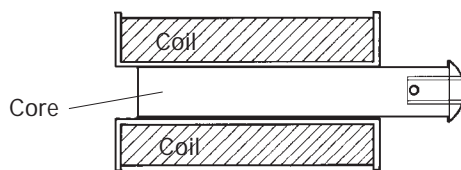
Solenoid

◀ SYSTEM OUTPUT
POSSIBILITIES

CONTROL - ELECTRONIC LOCK

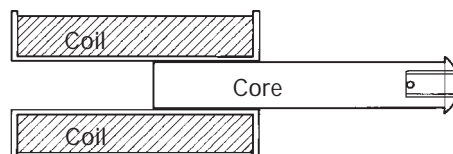
A solenoid consists of a coil of wire wound around a former. There are hundreds of turns on an average solenoid. An iron core fits into the hollow centre of the coil former. It has a spring attached to it which pushes it out of the coil. When an electric current passes through the coil, it becomes magnetic. This property is known as electromagnetism.

The magnetic field around the coil attracts the iron core and it pulls it into the centre of the coil former.



Solenoid energised - core is pulled in by the magnetic field produced by the current flowing through the coil

When the current is switched off, the magnetic field fades away and the spring pulls the core back out of the former.



Solenoid de-energised - magnetic field fades away and core is returned by a spring

In this way, an object can be moved to a desired position by switching an electric current on or off. The more turns of wire around the coil former, or the greater the current flowing through the coil, then the greater the force will be that pulls the core into the former.

When a solenoid has current flowing through its coil, it is said to be **energised**. When no current is flowing through its coil it is **de-energised**.

You will have to use the solenoid to lock and unlock the door. You may need to design some kind of mechanism to add to the basic solenoid to allow you to do this.

◀ NOTE

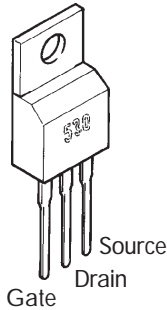
To find out more about solenoids see Technology Study File 15 'Controlling Position and Movement'

PROCESS BLOCK

The main component used in the process block is a Field Effect Transistor or **FET**.

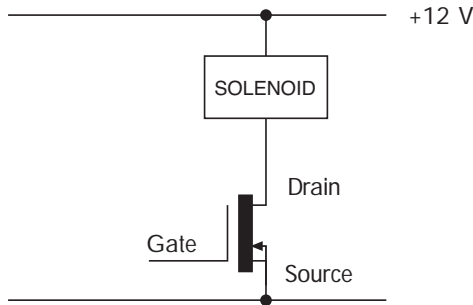
You will be using a type IR530 which looks like this.

The three legs of the FET have names. It is quite easy to see which leg is which from the picture.



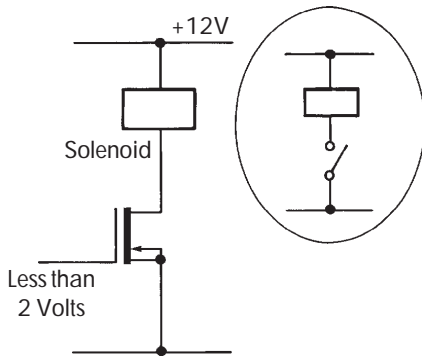
◀ SYSTEM PROCESSING
POSSIBILITIES

You will need to connect the FET and the solenoid like this.

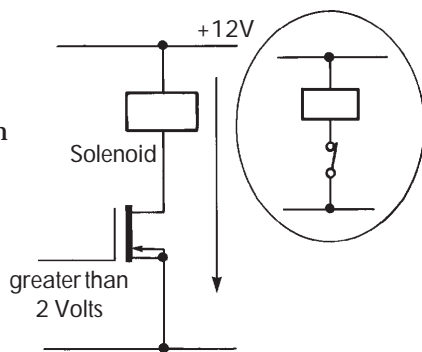


The FET works like an electronic switch. To turn it on, you need to put a positive voltage onto the **gate**. This will allow current to flow through the FET from **drain** to **source**.

A gate voltage of **less than 2** Volts will turn the FET fully off.

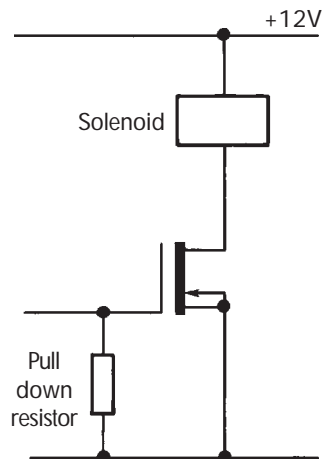


A gate voltage of **greater than 2** Volts will turn the FET fully on.



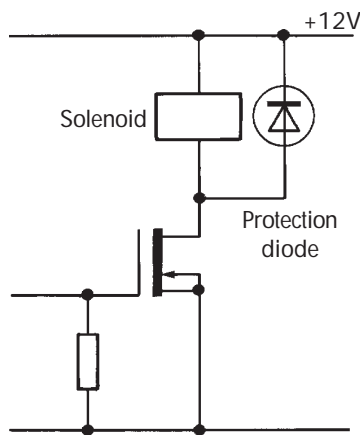
When you use a FET like this you need to connect a *pull down* resistor to the gate:

This makes sure the FET stays switched off when there is no input voltage on the gate.



One final addition to the output circuit is needed. A diode must be connected across the solenoid like this:

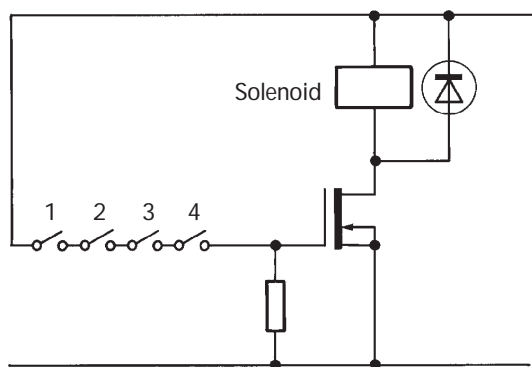
This is necessary because the solenoid can produce a large voltage spike or 'back EMF'. This happens at the point when it de-energises. This back EMF could damage the FET.



INPUT BLOCK

You know that the four input blocks must contain one switch each. When the switches are pushed in the correct sequence the FET should switch on and energise the solenoid. To switch the FET on, you have to put a positive voltage onto the gate that is greater than 2 Volts.

First thoughts might lead you to consider connecting the four input switches like this.



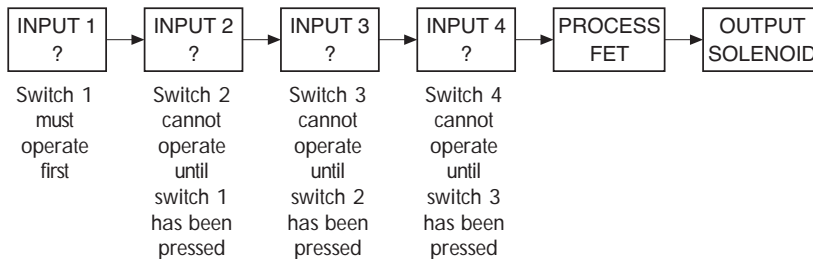
◀ SYSTEM INPUT POSSIBILITIES

CONTROL - ELECTRONIC LOCK

Although the FET would switch on when the correct four switches were pressed, it would not make any difference in what **sequence** they were pressed. So this solution is no good.

What the system needs is some way of remembering which switch has been pressed. If it can do this, it can use the information to prevent any switch from operating until the previous switch has been pressed.

Each input block needs to 'remember' that it has been pressed and pass this information onto the next block



If each input block is going to 'remember' whether it has been pressed, it must have some extra components added to give it this **memory**.

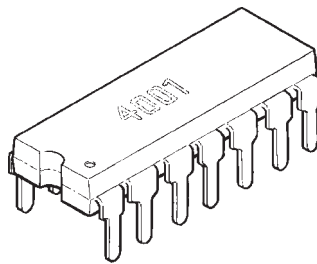
In this project, you will be using an *integrated circuit* (IC).

An IC is a tiny chip of semi-conducting material, usually silicon, that has a whole circuit produced on it. This is why they are also known as a silicon chips or microchips. The chip is normally no bigger than 0.2 mm^2 , small enough to pass through the eye of a needle!

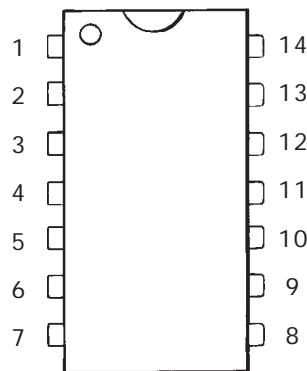


To make them easier to handle and use, they are fitted into larger plastic cases with connecting leads. ICs have revolutionised the electronics industry by enabling engineers to design and make electronic products that are much smaller and consume far less power. The first computers used to take up a whole floor of an office block. The same machines now could be made to fit in your pocket. ICs are an example of a very high technology product, yet they are also very cheap to buy. The majority of ICs cost less than £1. This is because they are made in very large quantities in countries where the workers are paid low wages. The price of a product does not always reflect its true worth!

There are many different types of IC designed to do different jobs. You will be using an IC 4001.

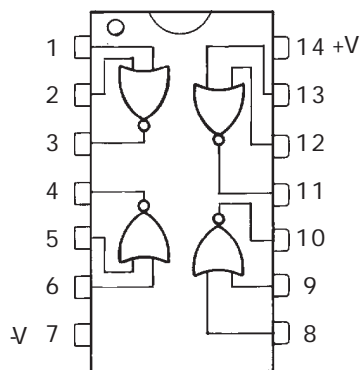


You can see that the IC has got 14 connecting pins. These pins are numbered from 1 to 14. To find out which pin is which, you need to look carefully at the case. On one end there is a notch. To the left of the notch there is a spot. The pin next to the spot is pin 1. The pins then count around in an anti-clockwise direction from pin 1.



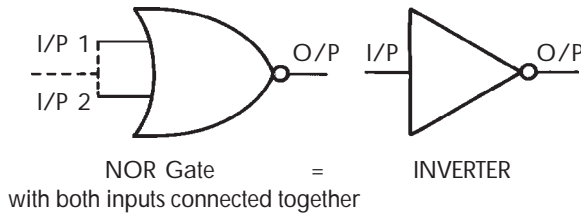
When engineers design electronic control systems that use ICs, they do not need to know much about what happens inside the chip. They mainly need to know what each pin on the IC does. (For example, is it a power supply connection, an input, an output etc?)

The IC 4001 actually contains four separate circuits. Each circuit is a NOR gate.



USING LOGIC GATES FOR CONTROL

To make each input circuit, you will need to use two of the NOR gates connected as inverters. To convert a NOR gate into an inverter, you need to connect the two inputs together.

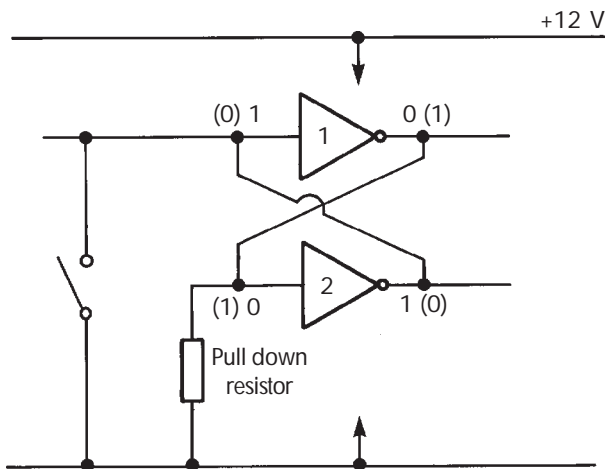


The truth table below will remind you how an inverter functions.

INPUT	OUTPUT
LOW	HIGH
HIGH	LOW

◀ MATHS OPPORTUNITY
Binary systems and principles of logic.

To make the first input circuit, the two inverters are connected together like this using only two external components, a resistor and the switch:



When the circuit is first switched on, the resistor acts as a *pull-down* resistor. This means that the input to inverter two is a 0.

The output of an inverter is always the opposite of the input. This means that the output of inverter two is a 1.

The output from inverter two is *fed back* to the input of inverter one. This means that the input of inverter one must be a 1.

The output of inverter one will be a 0 which is fed back to the input of inverter two.

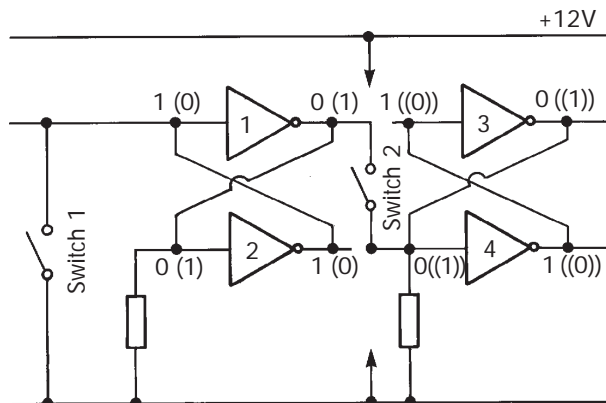
CONTROL - ELECTRONIC LOCK

The circuit is arranged like a figure eight. One inverter is always in the opposite state to the other.

When the switch is pressed, the input to inverter one is a 0. This causes the output to change to a 1. This 1 is fed back to the input of inverter two. The output of inverter two changes to a 0. (These new states are shown on the diagram in brackets.)

Once the switch is pressed, the circuit remains in this state. The circuit has a **memory** as it 'remembers' that the switch has been pressed.

The next three input circuits are made in a very similar way. The only difference is the way in which the switch is connected. You want to prevent the next switch from being able to operate until the previous switch has been pressed. To do this, you connect the first two input circuits like this:



When the circuit is first switched on, the input circuits are in the states shown outside the brackets.

Pushing the second code switch has no effect on the second input circuit as the switch is not changing the state of the input to inverter four.

The second code switch is prevented from doing anything until the first code switch has been pressed. When the first code switch is pressed, the first input circuit changes states to those shown inside the brackets. This means that pressing switch two changes the state of the input to gate four. The second input circuit changes states to those shown inside the double brackets.

The next two input circuits are built and connected in the same way as the second one. Any input switch is prevented from operating until the switch before it has been pressed. The string of input circuits works in the same way as the runners in a relay race. The next runner cannot run until the previous one passes the baton.

CONTROL - ELECTRONIC LOCK

You now have a good basis for designing and making an electronic lock system that operates on the principles of sequential control. There is at least one more thing to add if the control system is going to be practical to use, and several possible optional extras that could be added to improve the system still further.

First, a **reset** facility must be fitted. This is necessary so the system can lock the door again after the lock has been opened. The easiest way to do this is to put a switch into the power supply line. When it is open, the power supply is cut. All of the input circuits reset, the FET switches off and the solenoid de-energises, locking the door.

Some possible optional extras could include:

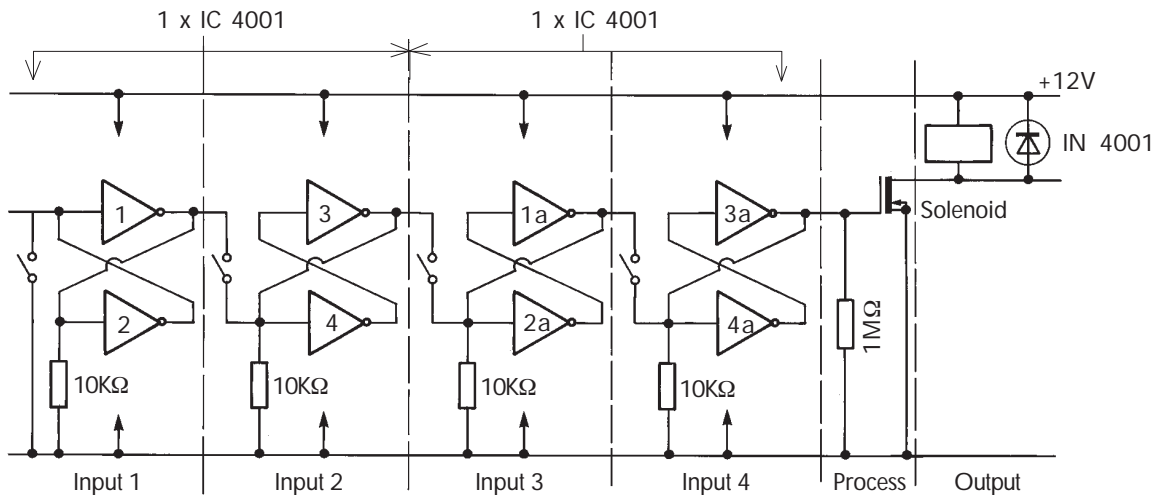
- A set of 'dummy' switches that are not connected to make the sequence harder to guess.
- Mounting the switches in the form of a key-pad to give the system a professional look.
- A 'lockout' facility to prevent the door from opening if any of the dummy switches are pressed.
- An alarm to warn that an unauthorised person is using the lock if any incorrect switches are pressed.
- An automatic reset which operates when the door is opened and closed. This could be done using a micro-switch fitted to the door.
- Some kind of timing circuit to re-lock the door after a certain amount of time.

PUTTING IT ALL TOGETHER



The circuit diagram for the basic electronic lock system is shown below. Because you need a total of eight inverters, you have to use two ICs.

It has been divided into inputs, process, and output. This may help you to understand what each component is doing.

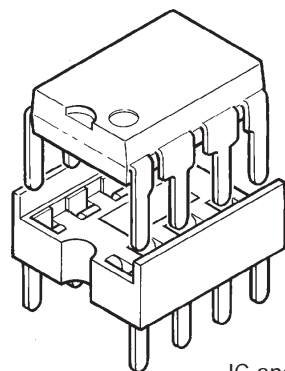


You must make a printed circuit board (PCB) on which to mount the components.



To find out about this see Technology Study File 2 (Making a PCB)

Integrated circuits are delicate devices so they need to be handled with care. Don't remove them from their packaging until you are ready to use them and don't handle them unnecessarily. When using them to build circuits, you mount the chip in a holder. The holder is soldered onto the PCB and the chip simply plugs into it. This means that the chip does not have to be soldered which could damage it and it can be replaced easily should it be defective.



IC and holder

CONTROL - ELECTRONIC LOCK

TESTING

When you have built the circuit, you have to test it to see if it works correctly. The solenoid should energise when the correct sequence of switches is pressed and de-energise when the reset switch is pressed. If the circuit does not work at all, follow this simple fault finding procedure:

1. Check that the PCB layout is correct and that no tracks are bridged or broken. Repair if necessary.
2. Check all soldered joints are good.
3. Check all components are connected correctly. Pay particular attention to the ICs. It is quite easy to plug them in the wrong way round.
4. If all this fails, try a new IC 4001.

◀ NOTE

To find out about this see Technology Study File 2 (Making a PCB)

EVALUATING THE ELECTRONIC LOCK

There are a number of things to consider when evaluating your electronic lock system:

- How well does it work?

Is the solenoid energised when the correct sequence of switches is pressed?

How easy is it to guess the sequence using trial and error?

- Will it work in the situation for which it was designed ?

How effective is the solenoid at locking and unlocking the door?

Is the lock strong enough for its intended use?

- Did you manage to include any extras to improve the basic lock system?

Can you think of any other additions that would improve it still further?