DESIGNING AND MAKING AN INFRA-RED LOCK

WHAT YOU WILL LEARN

After completing this project, you should understand:

- How infra-red radiation can be used for remote control.
- How to design an electronic (non-contact) lock using a block diagram.
- What an infra-red LED is.
- What a phototransistor is.
- What a Power MOSFET is.
- How to convert electric current in a controlled mechanical movement.

After completing this project, you should be able to:

- Use the following components in electronic circuits:

  Infra-red LED
  Phototransistor
  IR530 power MOSFET
  Resistor
  Mechanical output devices
  (including Shape memory alloy)

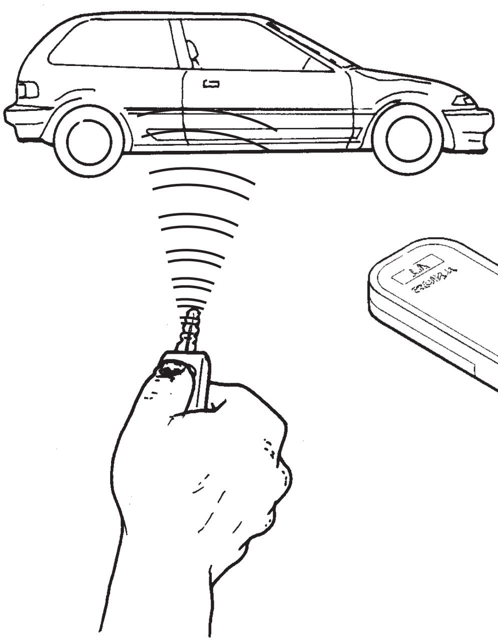
- Select components to make a circuit work in a desired way.

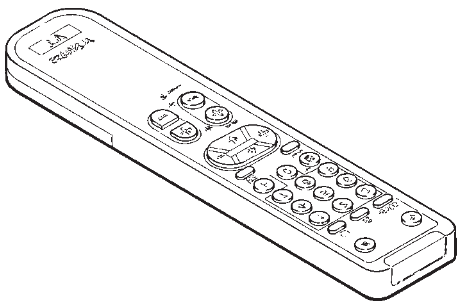
DESIGNING AND MAKING AN INFRA-RED LOCK

It is now quite usual to see people opening and locking their cars from a distance with a remote-control "key". Most of these keys give out an infra-red signal like a TV controller. The big difference is that the lock only responds to the signal (or code) from one key.

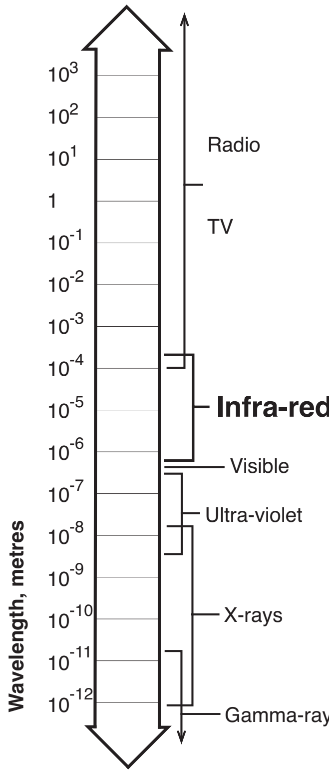
NOTE

Research opportunities - list product examples.

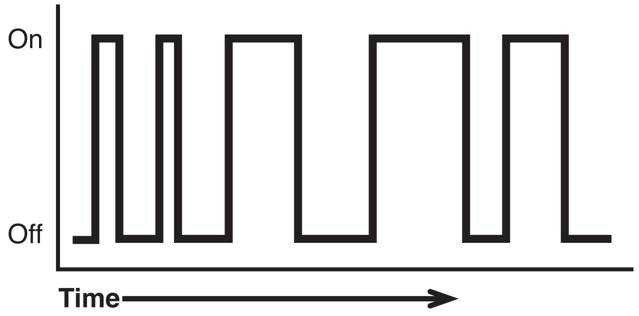




Infra-red radiation behaves like light but it is invisible. (We say that it is just outside the visible part of the spectrum.) You can think of the car key as a small torch which uses an **infra-red LED** (light emitting diode) rather than a bulb.



When the key is used, a small circuit switches the diode on and off in a **series of pulses** of a certain length. This can be shown on a graph. A car lock will only respond to one series of pulses or **code**.



Infra-red locks and keys can be quite complex. Motor manufacturers are always trying to design locks with higher levels of **encryption** - or security. Some locks and keys now change their code each time they are used !

The TEP infra-red lock works in the same way as a car lock but is far simpler and has a much shorter range. There are only three main components: one for the key (transmitter) and two for the lock (receiver).

DESIGNING AN ELECTRONIC SYSTEM

Electronic circuits are systems - something having several parts working together. In many circuits there are three basic parts:

Input Block - Enters information into the system. E.g., a switch which might be turned 'on' or 'off'.

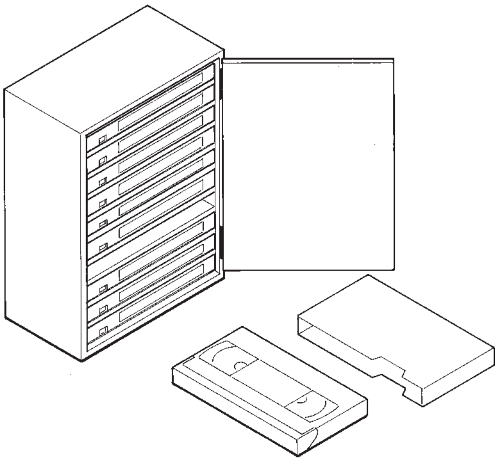
Process Block - Uses information from the input to control the output. E.g., an electronic component such as a transistor.

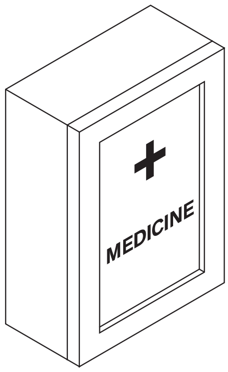
Output Block - Makes things happen. E.g., a bulb lighting up or a motor turning on.

YOUR TASK

DESIGN BRIEF

Design and make an infra-red lock that can be used to secure something. The Lock (and key) must answer a need identified by you - e.g. a medicine cabinet, money safe, video container etc.

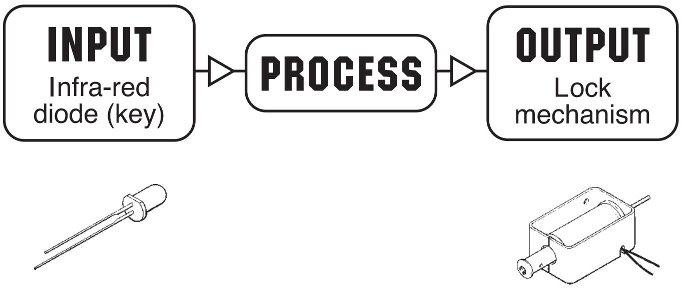




You need to design a system that uses a key (transmitter) and a lock (receiver). The block diagram for the system would look like this:

NOTE

Circuits involving phototransistors cannot be simulated with 'Crocodile Clips'.



DESCRIBING YOUR TASK

DESIGN SPECIFICATION

First, you need to describe in detail what the product will be like, what it will do and who will use it. This is called a design specification and will guide your design work and help you judge how well the outcome works.

Here are some questions to help you with your specification:

- *Is your circuit to be added to an existing product ?*
- *What is it ?*
- *Why does the product need security ?*

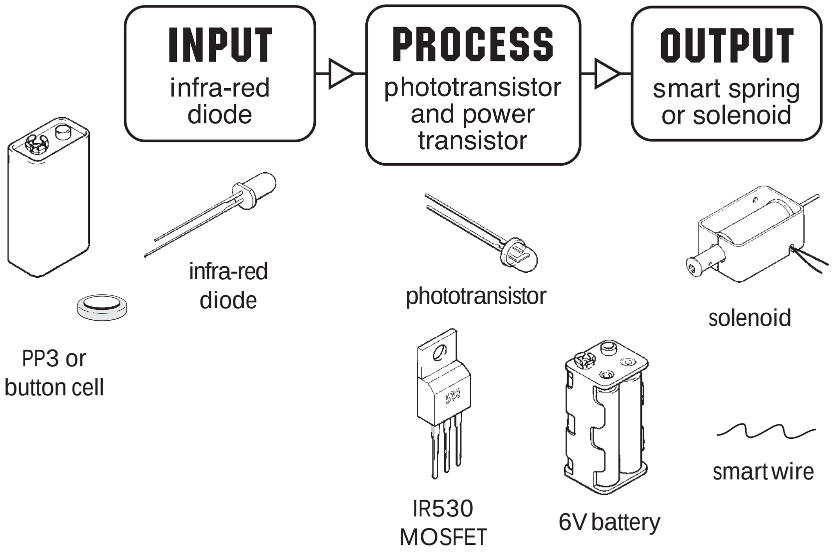
Some additional questions if the product is a new one:

- *Who will use the product with the lock ?*
- *What should it cost ?*
- *What battery will it use ?*
- *What size is the key ?*

MATERIALS AND COMPONENTS PROVIDED

DESIGNING AND MANUFACTURING CONSTRAINTS

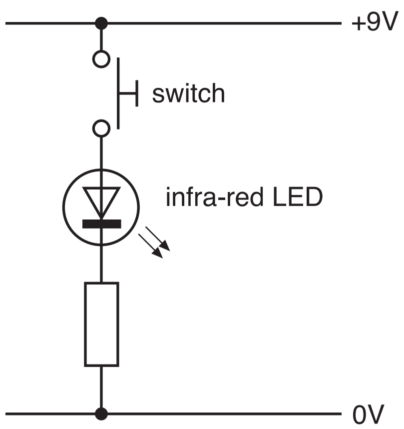
Before you go ahead with designing the lock and key, you need to know what is available. You will also need more information on the components and how they are used.



INPUT BLOCK

SYSTEM INPUT POSSIBILITIES

The input to the lock system is an infra-red LED. This looks like an ordinary LED but it has a purple coloured or black case. Like an ordinary LED it has to be used with a series resistor to prevent it overheating. For a 9v battery, use a 470R resistor. For a 3v battery , use a 180R resistor.



Infra-red transmitter key

The key circuit should include a momentary action press-switch. This is closed or “on” only for as long as you press it. The switch could be a push-button switch or, for example, a membrane panel which you make.

NOTE

For more information, see Technology Study File 11 (Membrane Switches).

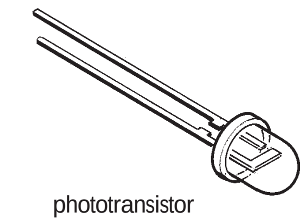
PROCESS BLOCK

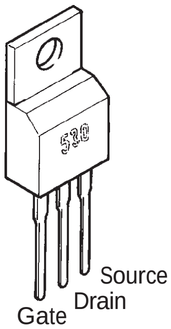
The main components used in the process block are a phototransistor and a power transistor. You can think of the phototransistor as an electronic switch that turns on when infra-red radiation falls on it. This is connected to a power transistor which is another electronic switch able to switch higher currents needed to operate the lock mechanism.

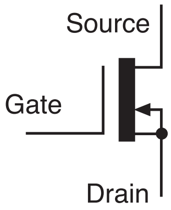
SYSTEM PROCESSING POSSIBILITIES

NOTE

For more information, see Technology Study File 24 (Infra-red Spectrum)



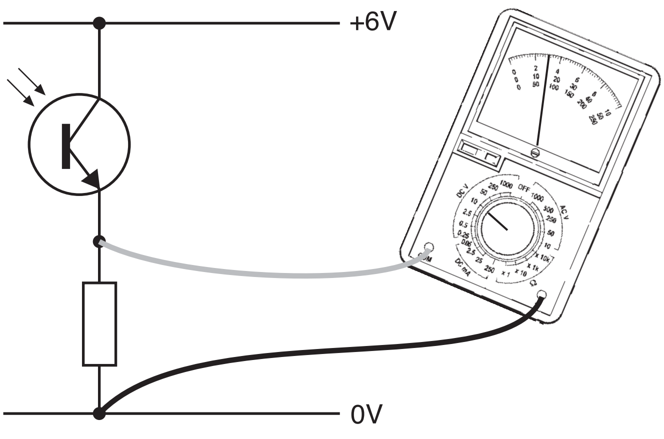




The phototransistor has only two legs called the emitter and collector. It is connected in the circuit as shown with a resistor. Together they form a potential divider. If you measure the voltage where the two join, the meter will read '0' when there is no infra-red radiation. When the infra-red LED is turned on and brought close by, the phototransistor switches on and there will be a voltage reading.

NOTE

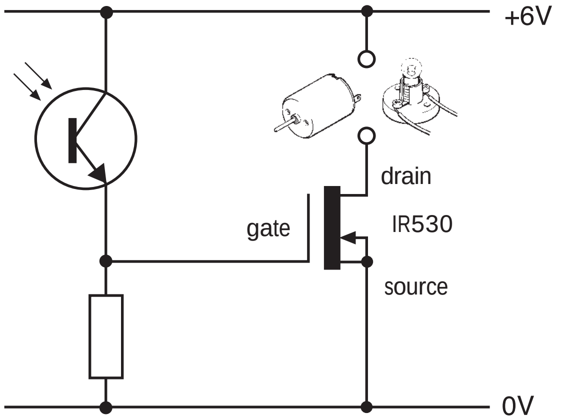
For more information, see Technology Study File 6 (Potential Divider).



The power transistor is a field effect transistor (FET). This has three legs called gate, source and drain and is turned on by a small voltage at the gate leg. When the voltage at the gate is more than 3v, the FET switches on; when it is less the FET switches off. If the gate of the FET is connected to the potential divider as shown, the phototransistor will turn on the FET and this will supply current to anything connected at the place marked "load". (The load is whatever is being switched on or controlled.)

NOTE

For more information, see Technology Study File 15 (Transistors). The FET is one of the most useful devices for single active component circuits.



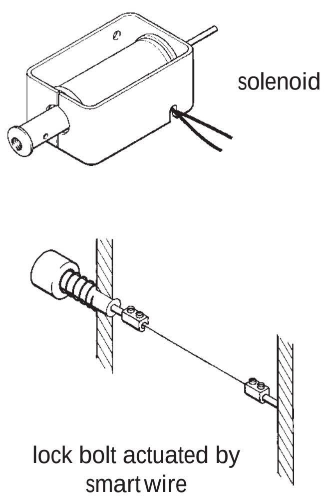
OUTPUT BLOCK

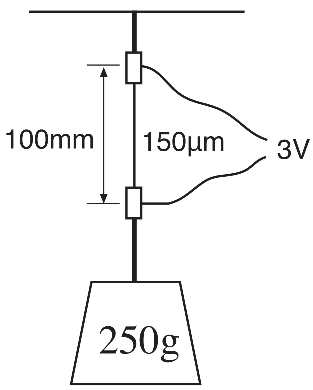
A small motor and gearbox could be connected to the FET so that something turns when the infra-red key is operated. If a lock bolt or catch needs to be moved in a straight line, a solenoid or smart wire can be used. Smart wire is made from a special alloy which "remembers" to contract when hot (about 70°). At room temperature, smart wire can be stretched out by a spring or a small weight. When current is passed through it, the wire heats up and contracts - with a pulling force. When it cools down, it relaxes and stretches out again.

SYSTEM OUTPUT POSSIBILITIES

NOTE

For more information, see Technology Study File 23 (Shape Memory Alloy).

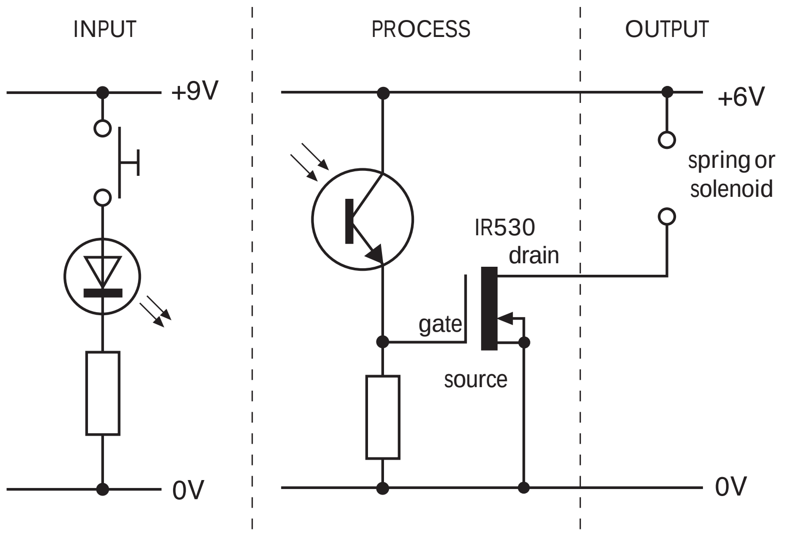




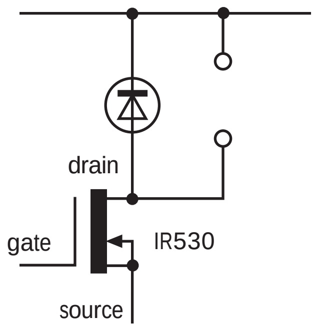
PUTTING IT ALL TOGETHER

SYSTEM SYNTHESIS

The circuit diagram for the complete infra-red lock circuit is shown below. The lock mechanism might be a motor, solenoid or smart spring - providing it does not take more current than the FET can provide (15 amps!).



When connecting a motor or any other output which has a coil (e.g. a solenoid), a diode must be added as shown. This protects the FET against any high voltages that the coil will produce when the current in the coil changes.

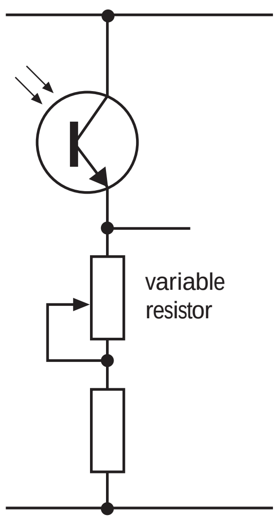


Without any shielding, the phototransistor will be affected by any light falling on it as well as infra-red. Special filters are available that allow infra-red to pass and block out white light. A very cheap filter you can use is black dustbin liner plastic !

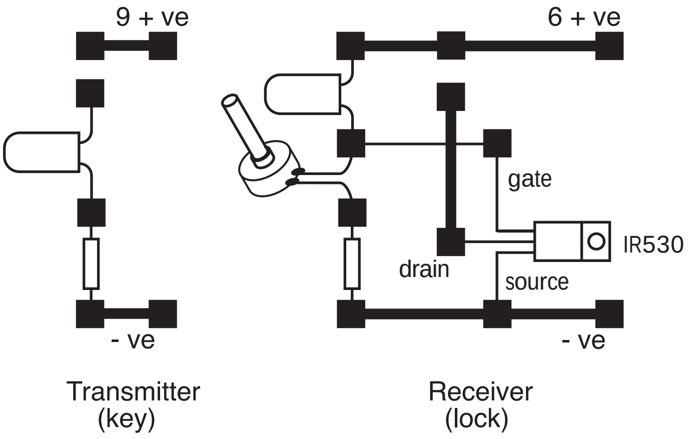
NOTE

Science investigation opportunity.

Ideally, you should be able to adjust the sensitivity of the photodiode. This can be done using a variable resistor in the potential divided as shown. A fixed resistor is also needed to prevent the resistance falling to zero and damaging the phototransistor.



You need to make a PCB. A possible layout is shown here with components in position.



TESTING

SYSTEM DIAGNOSTICS

When you have built the key and lock circuits, you will need to test them. If the system does not work, do the following:

- Check the PCB layouts are correct and that no tracks are bridged or broken.
- Check that all soldered joints are good.
- Check that all components are correctly connected - especially the FET.

If the system still does not work:

Check that the “key” is working. Set up the phototransistor in the potential divider and measure the voltage at the centre. This should increase when infra-red radiation falls on it. If the circuits pass this test, the fault will be with the FET and/or the output.

To test the output, you can switch on the FET directly by connecting with a lead between the gate and +ve. If nothing happens, check that the FET is correctly connected and that the output is working by connecting it directly to the battery supply.

EVALUATING THE INFRA-RED LOCK

EVALUATION

There are a number of things to consider depending on whether you have made something to add to an existing product - or designed the whole thing.

- How well does the lock work ? Is the limited range a problem?
- Will it work for the use for which it was intended?
- Did you choose the most appropriate components and methods of manufacture?
- What did others think of your design?

Note: Do not be disappointed if the range of the lock is very limited in daylight. You will find that with adjustment, it has a much greater range in the dark !

NOTE

Range in total darkness is up to 2m.