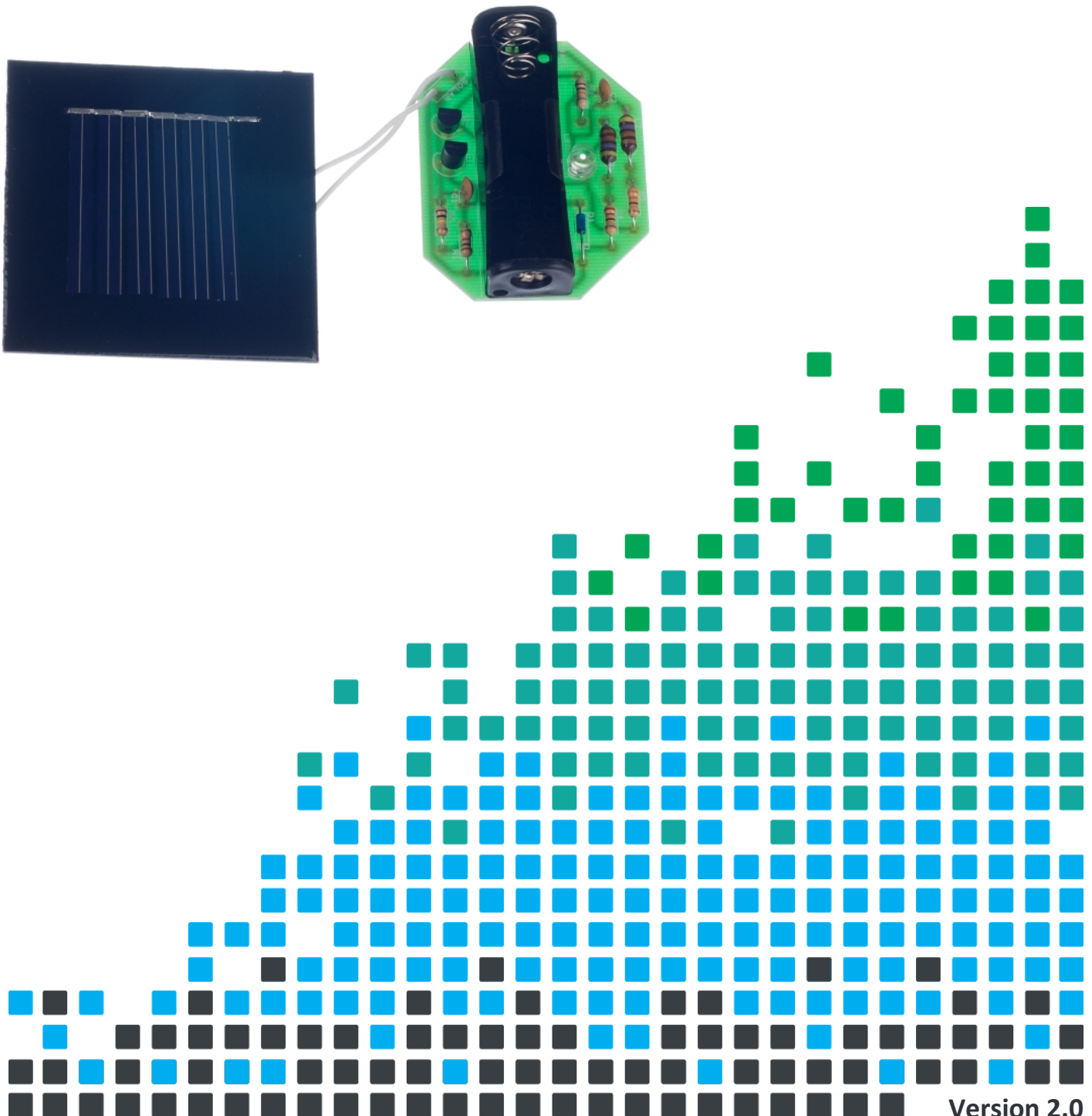


HARNESS THE POWER OF THE SUN WITH THIS

# SOLAR GARDEN LIGHT KIT



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## Introduction

### **About the project kit**

Both the project kit and the supporting material have been carefully designed for use in KS3 Design and Technology lessons. The project kit has been designed so that even teachers with a limited knowledge of electronics should have no trouble using it as a basis from which they can form a scheme of work.

The project kits can be used in two ways:

1. As part of a larger project involving all aspects of a product design, such as designing an enclosure for the electronics to fit into.
2. On their own as a way of introducing electronics and electronic construction to students over a number of lessons.

This booklet contains a wealth of material to aid the teacher in either case.

### **Using the booklet**

The first few pages of this booklet contains information to aid the teacher in planning their lessons and also covers worksheet answers. The rest of the booklet is designed to be printed out as classroom handouts. In most cases all of the sheets will not be needed, hence there being no page numbers, teachers can pick and choose as they see fit.

Please feel free to print any pages of this booklet to use as student handouts in conjunction with Kitronik project kits.

### **Support and resources**

You can also find additional resources at [www.kitronik.co.uk](http://www.kitronik.co.uk). There are component fact sheets, information on calculating resistor and capacitor values, puzzles and much more.

Kitronik provide a next day response technical assistance service via e-mail. If you have any questions regarding this kit or even suggestions for improvements, please e-mail us at:

support@kitronik.co.uk

Alternatively, phone us on 0845 8380781.



## Schemes of Work

Two schemes of work are included in this pack; the first is a complete project including the design & manufacture of an enclosure for the kit (below). The second is a much shorter focused practical task covering just the assembly of the kit (next page). Equally, feel free to use the material as you see fit to develop your own schemes.

Before starting we would advise that you to build a kit yourself. This will allow you to become familiar with the project and will provide a unit to demonstrate.

### ***Complete product design project including electronics and enclosure***

Hour 1	Introduce the task using 'The Design Brief' sheet. Demonstrate a built unit. Take students through the design process using 'The Design Process' sheet. <u>Homework</u> : Collect examples of lighting products, solar products and garden products including some solar lights. List the common features of these products on the 'Investigation / Research' sheet.
Hour 2	Develop a specification for the project using the 'Developing a Specification' sheet. <u>Resource</u> : Sample of garden lights and solar products. <u>Homework</u> : Complete the 'Inventors' worksheet.
Hour 3	Read 'Designing the Enclosure' sheet. Develop a product design using the 'Design' sheet. <u>Homework</u> : Complete design.
Hour 4	Using cardboard, get the students to model their enclosure design. Allow them to make alterations to their design if the model shows any areas that need changing. <u>Homework</u> : Complete the 'Capacitors' worksheets.
Hour 5	Split the students into groups and get them to perform a group design review using the 'Design Review' sheet. <u>Homework</u> : Complete the 'Charging the Battery' sheet.
Hour 6	Using the 'Soldering in Ten Steps' sheet, demonstrate and get students to practice soldering. Start the 'Resistor Value' worksheet and work through the information on 'LEDs & Current Limit Resistors'. <u>Homework</u> : Complete any of the remaining resistor tasks.
Hour 7	Build the electronic kit using the 'Build Instructions'.
Hour 8	Complete the build of the electronic kit. Check the completed PCB and fault find if required using the 'Checking Your Solar Light PCB' section and the fault finding flow chart. <u>Homework</u> : Read 'How the Solar Garden Light Works' sheet in conjunction with the 'How Does a Solar Cell Work' sheet.
Hour 9	Build the enclosure.
Hour 10	Build the enclosure.
Hour 11	Build the enclosure.
Hour 12	Using the 'Evaluation' and 'Improvement' sheet, get the students to evaluate their final product and state where improvements can be made.

### **Additional Work**

Package design for those who complete ahead of others.



## Electronics only

Hour 1	Introduction to the kit demonstrating a built unit. Using the 'Soldering in Ten Steps' sheet, practice soldering.
Hour 2	Build the kit using the 'Build Instructions'.
Hour 3	Check the completed PCB and fault find if required using 'Checking Your Solar Light PCB' and fault finding flow chart.

## Answers

1st Band	2nd Band	Multiplier x	Value
Brown	Black	Yellow	100,000 Ω
Green	Blue	Brown	560 Ω
Brown	Grey	Yellow	180,000Ω
Orange	White	Black	39Ω

## Resistor questions

Value	1st Band	2nd Band	Multiplier x
180 Ω	Brown	Grey	Brown
3,900 Ω	Orange	White	Red
47,000 (47K) Ω	Yellow	Violet	Orange
1,000,000 (1M) Ω	Brown	Black	Green

## Capacitor Ceramic Disc values

Printing on capacitor	Two digit start	Number of zero's	Value in pF
222	22	00	2200pF (2.2nF)
103	10	000	10000pF (10nF)
333	33	000	33000pF (33nF)
473	47	000	47000pF (47nF)

## Battery charging questions

Battery capacity	Charge current	Time taken to charge (hours)
500mAh	100mA	5 hours
500mAh	50mA	10 hours
500mAh	1000mA	Half an hour
750mAh	100mA	7.5 hours
750mAh	75mA	10 hours
1000mAh	40mA	25 hours



## The Design Process

The design process can be short or long, but will always consist of a number of steps that are the same on every project. By splitting a project into these clearly defined steps, it becomes more structured and manageable. The steps allow clear focus on a specific task before moving to the next phase of the project. A typical design process is shown on the right.

### **Design brief**

What is the purpose or aim of the project? Why is it required and who is it for?

### **Investigation**

Research the background of the project. What might the requirements be? Are there competitors and what are they doing? The more information found out about the problem at this stage, the better, as it may make a big difference later in the project.

### **Specification**

This is a complete list of all the requirements that the project must fulfil - no matter how small. This will allow you to focus on specifics at the design stage and to evaluate your design. Missing a key point from a specification can result in a product that does not fulfil its required task.

### **Design**

Develop your ideas and produce a design that meets the requirements listed in the specification. At this stage it is often normal to prototype some of your ideas to see which work and which do not.

### **Build**

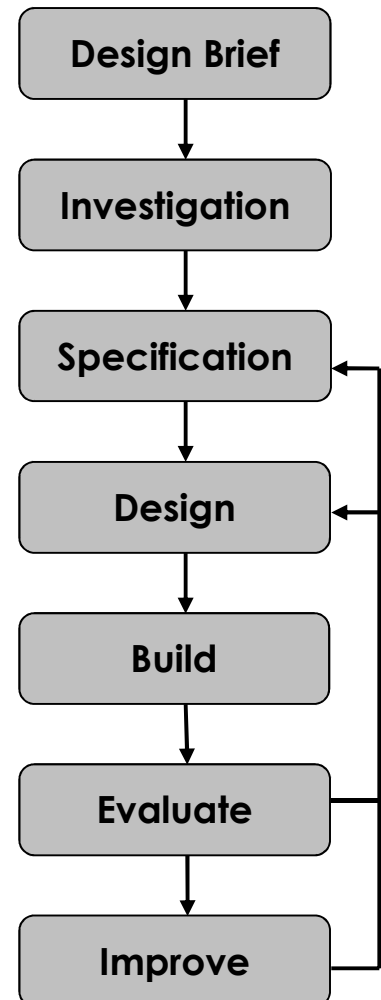
Build your design based upon the design that you have developed.

### **Evaluate**

Does the product meet all points listed in the specification? If not, return to the design stage and make the required changes. Does it then meet all of the requirements of the design brief? If not, return to the specification stage and make improvements to the specification that will allow the product to meet these requirements and repeat from this point. It is normal to have such iterations in design projects, though you normally aim to keep these to a minimum.

### **Improve**

Do you feel the product could be improved in any way? These improvements can be added to the design.

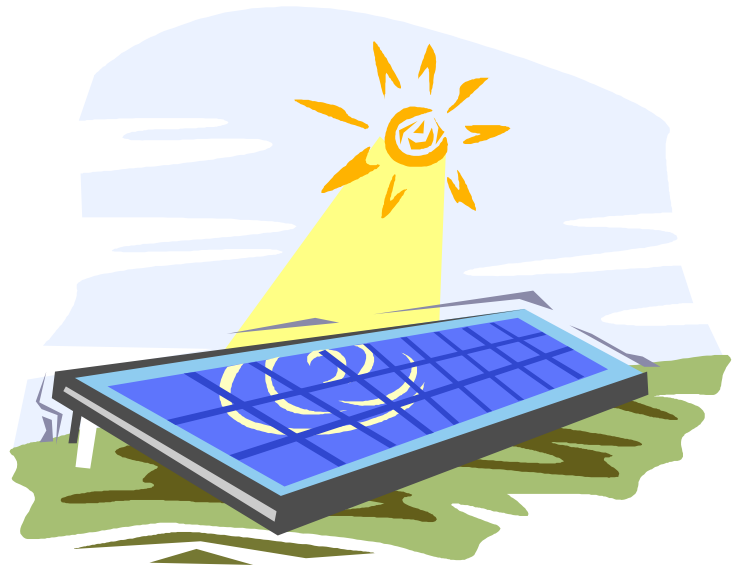


## The Design Brief

A manufacturer has developed a simple circuit for a solar powered garden light. The circuit has been developed to the point where they have a working Printed Circuit Board (PCB).

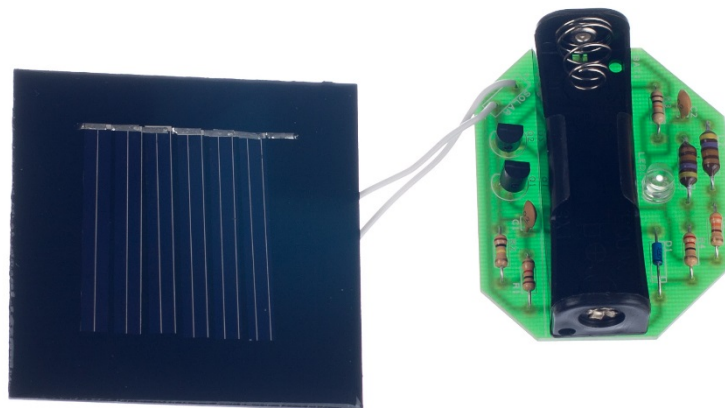
The manufacturer would like ideas for how to design an enclosure for the PCB and, therefore, how the final product might look.

The manufacturer has asked you to do this for them. It is important that you make sure the final design meets all of the requirements that you identify for such a product.



## Complete Circuit

A fully built circuit is shown below.



## Investigation / Research

Using a number of different search methods, find examples of similar products that are already on the market. Use additional pages if required.

Name.....

Class.....





## Developing a Specification

Using your research into the target market for the product, identify the key requirements for the product and explain why each of these is important.

Name.....

Class.....

Requirement	Reason
Example: The solar cell must face upwards.	Example: So that it is exposed to maximum amount of sunlight possible.



## Inventors

There have been many famous inventors that have created products that have changed our way of life. One such inventor is Trevor Baylis. He famously invented a wind up radio that could be used in developing countries that do not have access to mains electricity, which we take for granted in developed countries.

He was inspired to do this after seeing a television programme about the spread of AIDS in Africa and the difficulty of getting information to people about the disease because of the lack of access to TVs and radios due to their cost and the problem in powering them.

Using the internet, library or any other suitable search method, research another five famous inventors. List what they are famous for inventing and how it has improved our way of life.

Name of inventor	What they invented	How has it improved our way of life?



## Design

Develop your ideas to produce a design that meets the requirements listed in the specification.

Name.....

Class.....



## Design Review (group task)

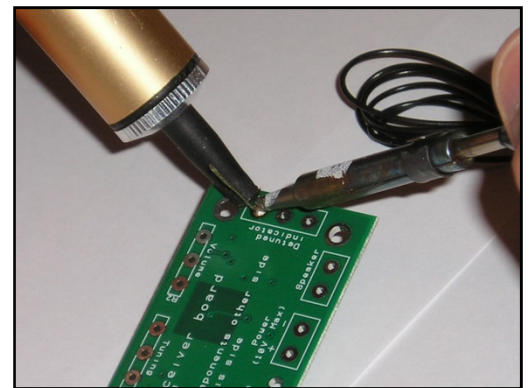
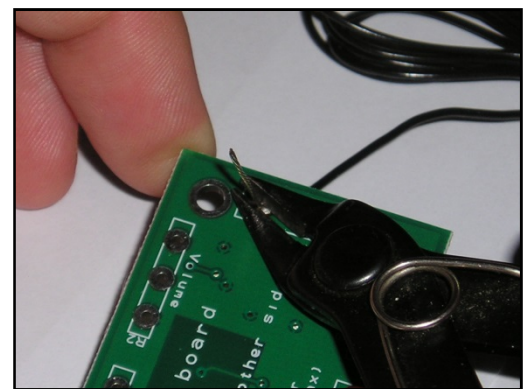
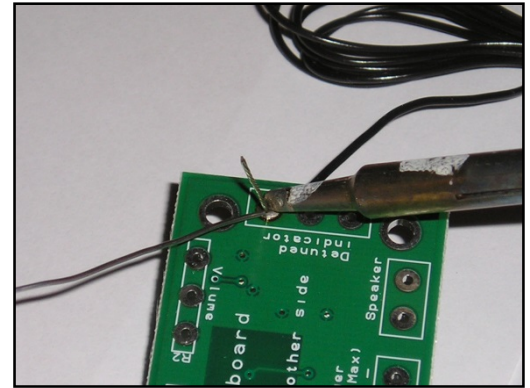
Split into groups of three or four. Take it in turns to review each person's design against the requirements of their specification. Also look to see if you can spot any additional aspects of each design that may cause problems with the final product. This will allow you to ensure that you have a good design and catch any faults early in the design process. Note each point that is made and the reason behind it. Decide if you are going to accept or reject the comment made. Use these points to make improvements to your initial design.

Comment	Reason for comment	Accept or Reject

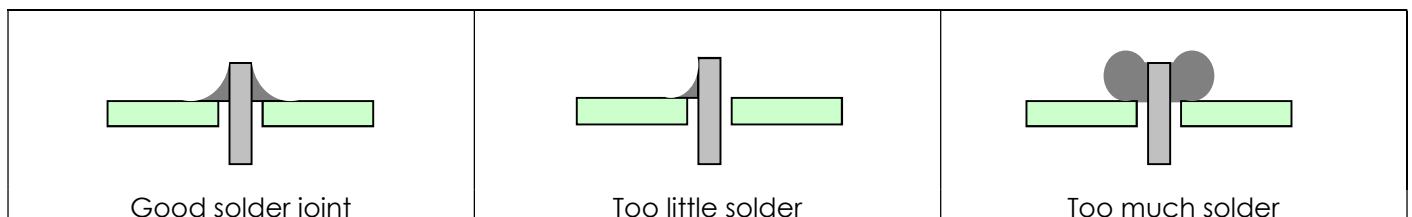


## Soldering in Ten Steps

1. Start with the smallest components working up to the taller components, soldering any interconnecting wires last.
2. Place the component into the board, making sure that it goes in the right way around and the part sits flush against the board.
3. Bend the leads slightly to secure the part.
4. Make sure that the soldering iron has warmed up and if necessary, use the damp sponge to clean the tip.
5. Place the soldering iron on the pad.
6. Using your free hand, feed the end of the solder onto the pad (top picture).
7. Remove the solder, then the soldering iron.
8. Leave the joint to cool for a few seconds.
9. Using a pair of cutters, trim the excess component lead (middle picture).
10. If you make a mistake heat up the joint with the soldering iron, whilst the solder is molten, place the tip of your solder extractor by the solder and push the button (bottom picture).



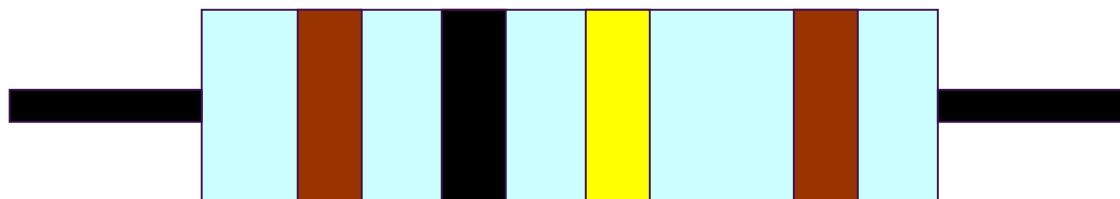
## Solder joints



## Resistor Values

A resistor is a device that opposes the flow of electrical current. The bigger the value of a resistor, the more it opposes the current flow. The value of a resistor is given in  $\Omega$  (ohms) and is often referred to as its 'resistance'.

### Identifying resistor values



Band Colour	1st Band	2nd Band	Multiplier x	Tolerance
Silver			$\div 100$	10%
Gold			$\div 10$	5%
Black	0	0	1	
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7		
Grey	8	8		
White	9	9		

Example: Band 1 = Red, Band 2 = Violet, Band 3 = Orange, Band 4 = Gold

The value of this resistor would be:

$$\begin{aligned}
 & \mathbf{2} \text{ (Red)} \mathbf{7} \text{ (Violet)} \times \mathbf{1,000} \text{ (Orange)} & = 27 \times 1,000 \\
 & & = \mathbf{27,000} \text{ with a 5\% tolerance (gold)} \\
 & & = \mathbf{27K\Omega}
 \end{aligned}$$

#### Too many zeros?

Kilo ohms and mega ohms can be used:

$$1,000\Omega = 1K$$

$$1,000K = 1M$$

### Resistor identification task

Calculate the resistor values given by the bands shown below. The tolerance band has been ignored.

1st Band	2nd Band	Multiplier x	Value
Brown	Black	Yellow	
Green	Blue	Brown	
Brown	Grey	Yellow	
Orange	White	Black	



## Calculating resistor markings

Calculate what the colour bands would be for the following resistor values.

Value	1st Band	2nd Band	Multiplier x
180 $\Omega$			
3,900 $\Omega$			
47,000 (47K) $\Omega$			
1,000,000 (1M) $\Omega$			

## What does tolerance mean?

Resistors always have a tolerance but what does this mean? It refers to the accuracy to which it has been manufactured. For example if you were to measure the resistance of a gold tolerance resistor you can guarantee that the value measured will be within 5% of its stated value. Tolerances are important if the accuracy of a resistors value is critical to a design's performance.

## Preferred values

There are a number of different ranges of values for resistors. Two of the most popular are the E12 and E24. They take into account the manufacturing tolerance and are chosen such that there is a minimum overlap between the upper possible value of the first value in the series and the lowest possible value of the next. Hence there are fewer values in the 10% tolerance range.

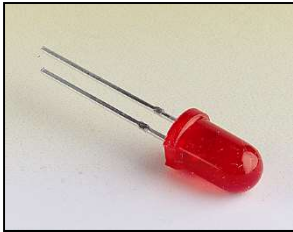
E-12 resistance tolerance ( $\pm 10\%$ )											
10	12	15	18	22	27	33	39	47	56	68	82

E-24 resistance tolerance ( $\pm 5\%$ )											
10	11	12	13	15	16	18	20	22	24	27	30
33	36	39	43	47	51	56	62	68	75	82	91



## LEDs & Current Limit Resistors

Before we look at LEDs, we first need to start with diodes. Diodes are used to control the direction of flow of electricity. In one direction they allow the current to flow through the diode, in the other direction the current is blocked.



An LED is a special diode. LED stands for Light Emitting Diode. LEDs are like normal diodes, in that they only allow current to flow in one direction, however when the current is flowing the LED lights.

The symbol for an LED is the same as the diode but with the addition of two arrows to show that there is light coming from the diode. As the LED only allows current to flow in one direction, it's important that we can work out which way the electricity will flow. This is indicated by a flat edge on the LED.

For an LED to light properly, the amount of current that flows through it needs to be controlled. To do this we use a current limit resistor. If we didn't use a current limit resistor the LED would be very bright for a short amount of time, before being permanently destroyed.

To work out the best resistor value we need to use Ohms Law. This connects the voltage across a device and the current flowing through it to its resistance.

Ohms Law tells us that the flow of current ( $I$ ) in a circuit is given by the voltage ( $V$ ) across the circuit divided by the resistance ( $R$ ) of the circuit.

$$I = \frac{V}{R}$$

Like diodes, LEDs drop some voltage across them: typically 1.8 volts for a standard LED. However the high brightness LED used in the 'white light' version of the lamp drops 3.5 volts.

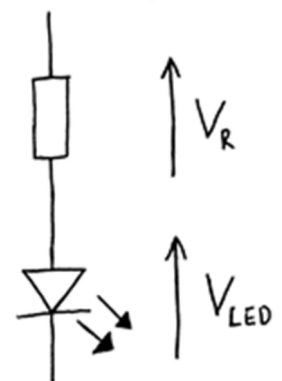
The USB lamp runs off the 5V supply provided by the USB connection so there must be a total of 5 volts dropped across the LED ( $V_{LED}$ ) and the resistor ( $V_R$ ). As the LED manufacturer's datasheet tells us that there is 3.5 volts dropped across the LED, there must be 1.5 volts dropped across the resistor. ( $V_{LED} + V_R = 3.5 + 1.5 = 5V$ ).

LEDs normally need about 10mA to operate at a good brightness. Since we know that the voltage across the current limit resistor is 1.5 volts and we know that the current flowing through it is 0.01 Amps, the resistor can be calculated.

Using Ohms Law in a slightly rearranged format:

$$R = \frac{V}{I} = \frac{1.5}{0.01} = 150\Omega$$

Hence we need a 150 $\Omega$  current limit resistor.





## LEDs Continued

The Colour Changing LEDs used in the 'colour' version of the lamp has the current limit resistor built into the LED itself. Therefore no current limit resistor is required. Because of this, a 'zero  $\Omega$ ' resistor is used to connect the voltage supply of 5V directly to the Colour Changing LED.

### **Packages**

LEDs are available in many shapes and sizes. The 5mm round LED is the most common. The colour of the plastic lens is often the same as the actual colour of light emitted – but not always with high brightness LEDs.

### **Advantages of using LEDs over bulbs**

Some of the advantages of using an LED over a traditional bulb are:

Power efficiency	LEDs use less power to produce the same amount of light, which means that they are more efficient. This makes them ideal for battery power applications.
Long life	LEDs have a very long life when compared to normal light bulbs. They also fail by gradually dimming over time instead of a sharp burn out.
Low temperature	Due to the higher efficiency of LEDs, they can run much cooler than a bulb.
Hard to break	LEDs are much more resistant to mechanical shock, making them more difficult to break than a bulb.
Small	LEDs can be made very small. This allows them to be used in many applications, which would not be possible with a bulb.
Fast turn on	LEDs can light up faster than normal light bulbs, making them ideal for use in car break lights.

### **Disadvantages of using LEDs**

Some of the disadvantages of using an LED over a traditional bulb are:

Cost	LEDs currently cost more for the same light output than traditional bulbs. However, this needs to be balanced against the lower running cost of LEDs due to their greater efficiency.
Drive circuit	To work in the desired manner, an LED must be supplied with the correct current. This could take the form of a series resistor or a regulated power supply.
Directional	LEDs normally produce a light that is focused in one direction, which is not ideal for some applications.

### **Typical LED applications**

Some applications that use LEDs are:

- Bicycle lights
- Car lights (break and headlights)
- Traffic lights
- Indicator lights on consumer electronics
- Torches
- Backlights on flat screen TVs and displays
- Road signs
- Information displays
- Household lights
- Clocks



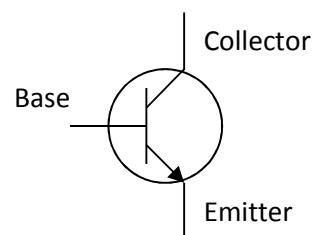
## Using a Transistor as a Switch

### Overview

A transistor in its simplest form is an electronic switch. It allows a small amount of current to switch a much larger amount of current either on or off. There are two types of transistors: NPN and PNP. The different order of the letters relate to the order of the N and P type material used to make the transistor. Both types are available in different power ratings, from signal transistors through to power transistors. The NPN transistor is the more common of the two and the one examined in this sheet.

### Schematic symbol

The symbol for an NPN type transistor is shown to the right along with the labelled pins.



### Operation

The transistor has three legs: the base, collector and the emitter. The emitter is usually connected to 0V and the electronics that is to be switched on is connected between the collector and the positive power supply (Fig A). A resistor is normally placed between the output of the Integrated Circuit (IC) and the base of the transistor to limit the current drawn through the IC output pin.

The base of the transistor is used to switch the transistor on and off. When the voltage on the base is less than 0.7V, it is switched off. If you imagine the transistor as a push to make switch, when the voltage on the base is less than 0.7V there is not enough force to close the switch and therefore no electricity can flow through it and the load (Fig B). When the voltage on the base is greater than 0.7V, this generates enough force to close the switch and turn it on. Electricity can now flow through it and the load (Fig C).

Fig A – Basic transistor circuit

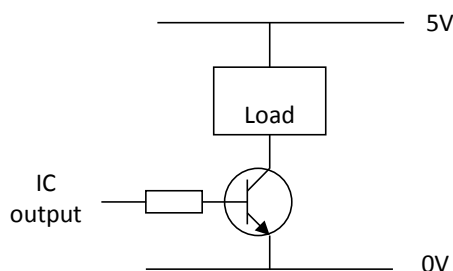


Fig B – Transistor turned off

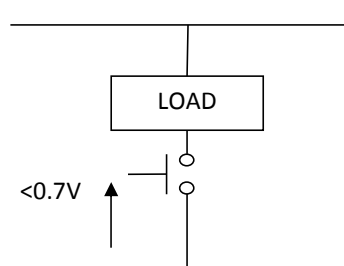
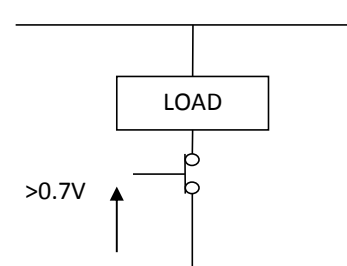
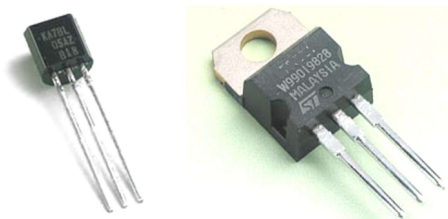


Fig C – Transistor turned on



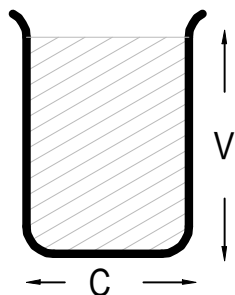
### Current rating

Different transistors have different current ratings. The style of the package also changes as the current rating goes up. Low current transistors come in a 'D' shaped plastic package, whilst the higher current transistors are produced in metal cans that can be bolted onto heat sinks so that they don't over heat. The 'D' shape or a tag on the metal can is used to work out which pin does what. All transistors are wired differently so they have to be looked up in a datasheet to find out which pin connects where.



## Capacitor Basics

### What is a capacitor?

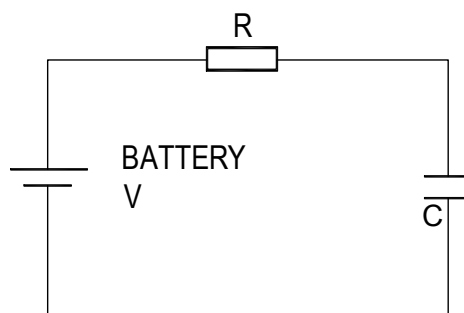
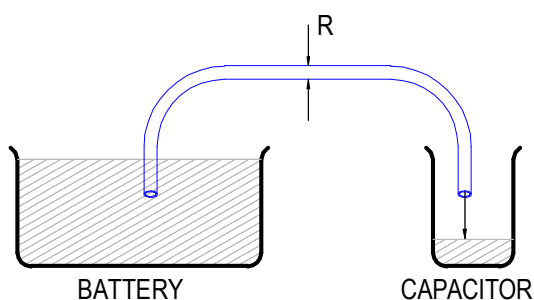


A capacitor is a component that can store electrical charge (electricity). In many ways, it is like a rechargeable battery.

A good way to imagine a capacitor is as a bucket, where the size of the base of the bucket is equivalent to the capacitance ( $C$ ) of the capacitor and the height of the bucket is equal to its voltage rating ( $V$ ).

The amount that the bucket can hold is equal to the size of its base multiplied by its height, as shown by the shaded area.

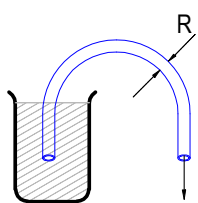
### Filling a capacitor with charge



When a capacitor is connected to an item such as a battery, charge will flow from the battery into it. Therefore the capacitor will begin to fill up. The flow of water in the picture above left is the equivalent of how the electrical charge will flow in the circuit shown on the right.

The speed at which any given capacitor will fill depends on the resistance ( $R$ ) through which the charge will have to flow to get to the capacitor. You can imagine this resistance as the size of the pipe through which the charge has to flow. The larger the resistance, the smaller the pipe and the longer it will take for the capacitor to fill.

### Emptying (discharging) a capacitor

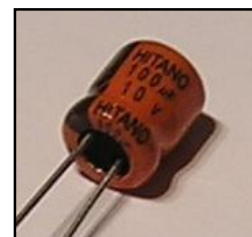


Once a capacitor has been filled with an amount of charge, it will retain this charge until it is connected to something into which this charge can flow.

The speed at which any given capacitor will lose its charge will, like when charging, depend on the resistance ( $R$ ) of the item to which it is connected. The larger the resistance, the smaller the pipe and the longer it will take for the capacitor to empty.

### Maximum working voltage

Capacitors also have a maximum working voltage that should not be exceeded. This will be printed on the capacitor or can be found in the catalogue the part came from. You can see that the capacitor on the right is printed with a 10V maximum working voltage.



## Ceramic Disc Capacitors

### Values

The value of a capacitor is measured in Farads, though a 1 Farad capacitor would be very big. Therefore we tend to use milli Farads (mF), micro Farads ( $\mu\text{F}$ ), nano Farads (nF) and pico Farads (pF). A  $\mu\text{F}$  is a millionth of a Farad,  $1\mu\text{F} = 1000\text{ nF}$  and  $1\text{nF} = 1000\text{ pF}$ .

1F	= 1,000mF
1F	= 1,000,000 $\mu\text{F}$
1F	= 1,000,000,000nF
1F	= 1,000,000,000,000pF

The larger electrolytic capacitors tend to have the value printed on the side of them along with a black band showing the negative lead of the capacitor.

Other capacitors, such as the ceramic disc capacitor shown on the right, use a code. They are often smaller and may not have enough space to print the value in full, hence the use of the 3-digit code. The first 2 digits are the first part of the number and the third digit gives the number of zeros to give its value in pF.



Example:  $104 = 10 + 0000$  (4 zero's) = **100,000 pF** (which is also  $0.1\ \mu\text{F}$ )

Work out what value the four capacitors are in the table below.

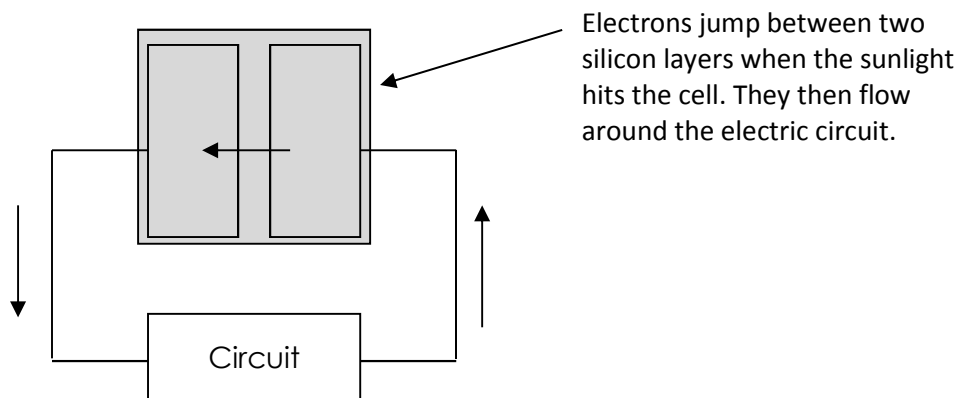
Printing on capacitor	Two digit start	Number of zero's	Value in pF
222			
103			
333			
473			



## How Does a Solar Cell Work?

A solar cell (sometimes known as photovoltaic cells) is a device that converts light from the sun into electricity that can then be used to power other electronic devices.

Most solar cells are made of silicon. The silicon is separated into two parts and each part has another chemical added to it. This is called 'doping'. When sunlight hits the solar cell, it causes electrons to 'jump' between the two doped parts of silicon. The direction that the electrons 'jump' is always the same as this is controlled by the way the two parts of silicon are doped. It is this constant flow of electrons that we think of as electricity.



The sun generates a lot of energy but not all of this can be converted into electricity by the solar cell. The amount of the sun's energy that can be converted into energy is determined by the efficiency of the solar cell. A typical solar cell may have an efficiency of 12%. This means that if 100 Watts of light energy fell on a solar cell, it would generate 12 Watts of electrical energy.

Electrical power (in Watts) is given by:

$$\text{Power} = \text{Volts} \times \text{Amps}$$

The solar cell in the garden light uses a cell that produces 3V and 50mA. Therefore, it produces:

$$3\text{V} \times 0.05\text{A} = 0.15 \text{ Watts.}$$



## Charging the Battery

The time taken to charge the battery depends upon two factors:

- The capacity of the battery (a larger battery will take longer to charge)
- The rate at which current (power) flows into the battery from the charging source

A typical capacity for a rechargeable battery used in a garden light would be 500mAh (milli Amps per hour). This means that the battery can deliver 500mA of current for one hour after which the battery will be empty.

The reverse of this is true for charging the battery. To fully charge the battery you will have to provide it with 500mA of current for a period of one hour.

Most solar cells will not be able to provide 500mA of current (they will supply less). Therefore, the time taken to charge the battery can be calculated using the following formula:

$$\text{Time taken to charge} = \frac{\text{Capacity of battery}}{\text{Charge current}}$$

So if we have a 500mAh battery and a charge current of 250mA, it will take:

$$\text{Time taken to charge} = \frac{500\text{mAh}}{250\text{mA}} = 2 \text{ hours}$$

### Task

Calculate how long it would take to charge the rechargeable batteries listed below.

Battery capacity	Charge current	Time taken to charge (hours)
500mAh	100mA	
500mAh	50mA	
500mAh	1000mA	
750mAh	100mA	
750mAh	75mA	
1000mAh	40mA	



## Renewable Energy

Renewable energy is becoming more important as our demand for energy grows, while, at the same time, traditional forms of generating power such as coal, gas and oil are a finite resource. Once these are used up, they will be gone forever. A renewable energy source is something that is naturally occurring and can be replaced.



Types of renewable energy include:

### **Solar**

Solar energy is energy generated from sunlight. Applications of solar energy include generating power by turning the sun's rays into electricity by using a solar cell and by heating water, which can then be used for showers, baths or for heating radiators.

### **Wind**

Wind power is energy generated from the wind. Normally the wind is used to turn a wind turbine. A wind turbine looks like a large windmill, which rotates when the wind blows on it. This is then used to turn a turbine that turns the rotating movement into electricity. Often a number of wind turbines are located near each other in what is known as a 'wind farm' that can generate enough electricity to power a few thousand houses.

### **Hydroelectricity**

Hydroelectricity uses the power of water falling to generate electricity and is one of the most widely used forms of renewable energy. The force of the water is used to turn a turbine, which generates electricity. Most hydroelectric power plants are created by damming a river and then using the force of the dammed water to turn a turbine.

### **Tidal**

Tidal power is another form of hydropower. Instead of using the power of falling water to generate electricity, it uses the movement of water due to the tides to generate energy. There are currently a lot of different designs for tidal energy devices that are coming into use but they all use the force of the water in some way to turn a turbine, which generates electricity.

### **Geothermal**

Geothermal power comes from heat energy that is stored within the ground. Geothermal power plants are often located near tectonic plate boundaries where there can be large sources of geothermal heat created as two tectonic plates meet. Normally, some form of 'heat engine' is used to convert the heat in to electricity. Sometimes the geothermal heat is used to simply heat water, which can then be used to heat homes and businesses.

### **Bio fuels**

Bio fuels are fuel sources that are derived from some form of biological mass (plants). They are renewable because the plant from which they are created can be re-grown and replaced. Bio fuels can be used to power cars and other vehicles and can be used to power generators, which can be used to create electricity.



## Instruction Manual

Your solar light is going to be supplied with some instructions. Identify four points that must be included in the instructions and give a reason why.

Point to include:

Reason:

Point to include:

Reason:

Point to include:

Reason:

Point to include:

Reason:





## Evaluation

It is always important to evaluate your design once it is complete. This will ensure that it has met all of the requirements defined in the specification. In turn, this should ensure that the design fulfils the design brief.

Check that your design meets all of the points listed in your specification.

Show your product to another person (in real life this person should be the kind of person at which the product is aimed). Get them to identify aspects of the design, which parts they like and aspects that they feel could be improved.

Good aspects of the design	Areas that could be improved

## Improvements

Every product on the market is constantly subject to redesign and improvement. What aspects of your design do you feel you could improve? List the aspects that could be improved and where possible, draw a sketch showing the changes that you would make.



## Packaging Design

If your product was to be sold in a high street electrical retailer, what requirements would the packaging have? List these giving the reason for the requirement.

Requirement	Reason

Develop a packaging design for your product that meets these requirements. Use additional pages if required.



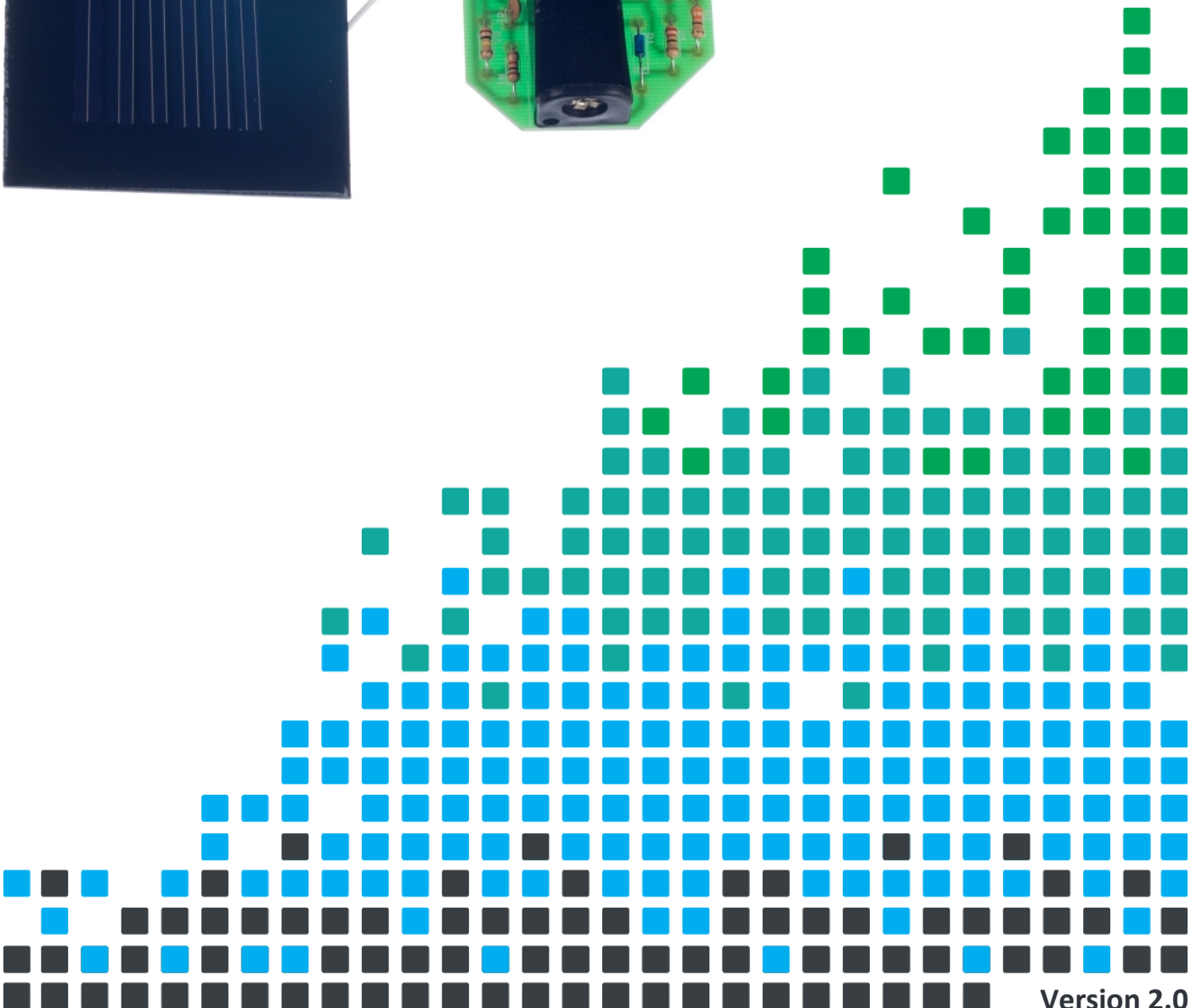
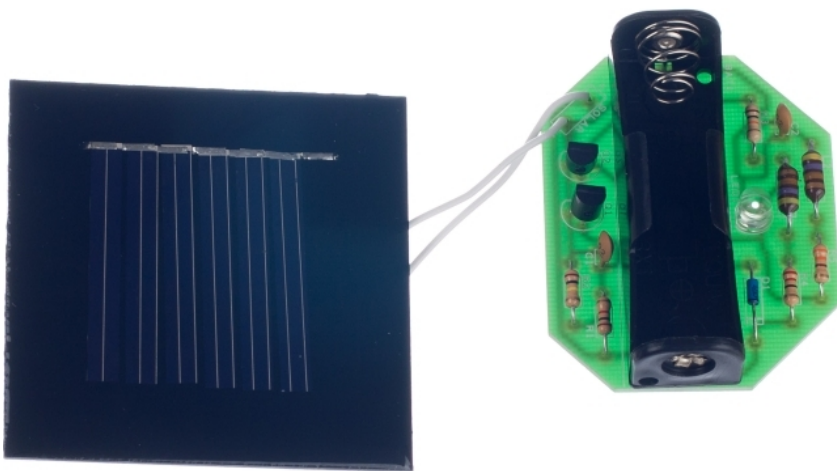


## ESSENTIAL INFORMATION

BUILD INSTRUCTIONS  
CHECKING YOUR PCB & FAULT-FINDING  
MECHANICAL DETAILS  
HOW THE KIT WORKS

HARNESS THE POWER OF THE SUN WITH THIS

# SOLAR GARDEN LIGHT KIT



Version 2.0

## Build Instructions

Before you start, take a look at the Printed Circuit Board (PCB). The components go in the side with the writing on and the solder goes on the side with the tracks and silver pads.

### 1 PLACE RESISTORS

Start with the three resistors:  
The text on the PCB shows where R1, R2 etc go.  
Ensure that you put the resistors in the right place.

PCB Ref	Value	Colour Bands
R1	1K	Brown, black, red
R2	100K	Brown, black, yellow
R3	10K	Brown, black, orange
R4	22Ω	Red, red, black
R5	330Ω	Orange, orange, brown



### 2 SOLDER THE DIODE

Solder the diode into the board where it is labelled D1. It is important that the diode is inserted the correct way around otherwise it will not work. If you look closely at the diode, you will see that it has a black band at one end. This should match the outline on the PCB.



### 3 SOLDER THE INDUCTORS

Solder the two inductors into the PCB where it is labelled L1 and L2. The inductors look like the resistor but are slightly larger. It doesn't matter which way around the inductors go into the PCB.



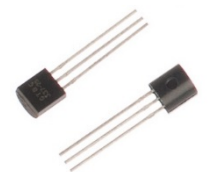
### 4 SOLDER THE CAPACITORS

Solder the two 1nF capacitors into the PCB where it is labelled C1 and C2. The capacitors can be identified by the text '102' which is written on them. It doesn't matter which way around they are put into the PCB.



### 5 SOLDER THE TRANSISTORS

Solder the two transistors into the PCB where it is labelled Q1 and Q2. The transistors have to be inserted the correct way around to work. Make sure that the outline of the component matches the outline on the PCB.



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## SOLDER THE LED

Solder the LED (Light Emitting Diode) into the PCB where it is labelled LED1. The LED has to be inserted the correct way around to work. Make sure that the outline of the component matches the outline on the PCB (the LED has one flat edge). Depending on your enclosure design, you may wish to mount the LED at a specific height above the PCB or on wire leads.



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## SOLDER THE BATTERY HOLDER

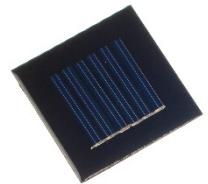
Solder the PCB mount battery holder into the PCB where it is labelled BAT1. The battery holder has to be inserted the correct way around to work. The markings on the PCB show where the 'spring' end of the battery holder goes.



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## CONNECT THE SOLAR CELL

Next connect the solar cell to the PCB. First, look at the back of the solar cell. There are markings to show which are the '+' terminals and which are the '-' terminals. Now look at the PCB and you will see that the terminals labelled 'solar' also have labels to indicate which is '+' and which is '-'. In the kit there is a bundle of wire. Use two lengths of this to connect each of the terminals on the PCB to the corresponding terminal on the solar cell. The solar cell has terminals that have already been tinned with solder and you will find these the easiest to solder to.



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## INSERT THE BATTERY

The last job is to insert the rechargeable battery (the battery holder indicates which way around the battery goes). Before you insert the battery please go through the 'Checking your solar light PCB' section on the right.



## Checking Your Solar Light PCB

Carefully check the following before you insert the battery:

### Check the bottom of the board to ensure that:

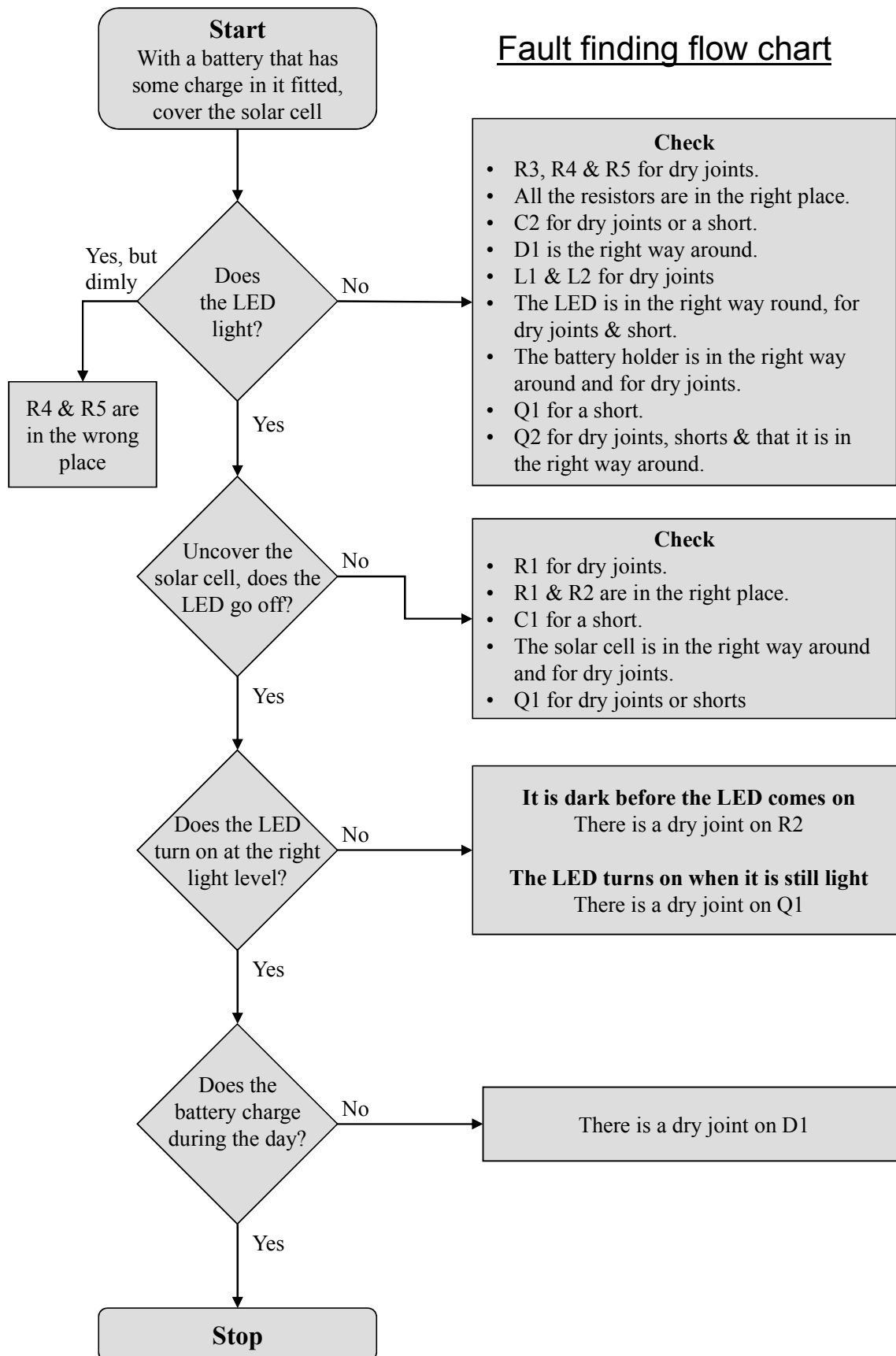
- All holes are filled with the lead of a component.
- All these leads are soldered.
- Pins next to each other are not soldered together.

### Check the top of the board to ensure that:

- The flat edges on the LEDs and transistors match the outlines on the PCB.
- The band on the diode matches the corresponding outline on the PCB.
- The spring end of the battery holder is next the 'BAT1' text on the PCB.
- The positive connection on the solar cell is connected to the positive 'solar' terminal on the PCB and the negative connection on the solar cell is connected to the negative 'solar' terminal on the PCB.



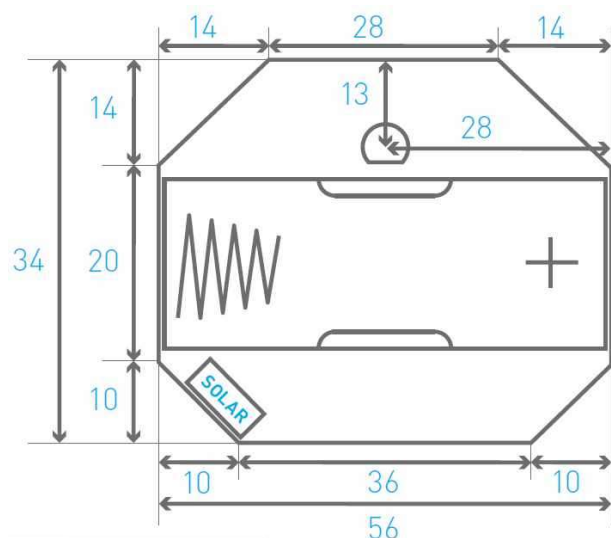
## Fault finding flow chart



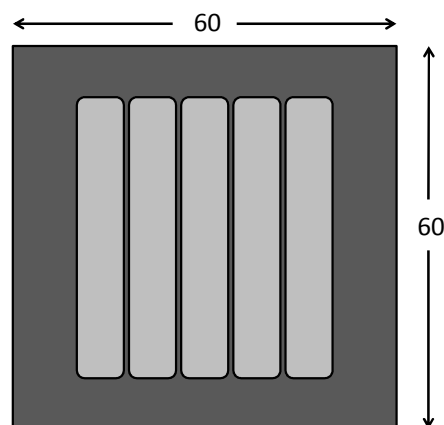
## Designing the Enclosure

When you design the enclosure, you will need to consider:

- The size of the PCB (below left).
- The size of the solar cell (below right).
- Where the LED is mounted (shown in the top middle of the PCB).



Dimensions in mm



All dimensions in mm.

The diameter of the LED is 5 mm and the total height of the unit approximately 15mm.

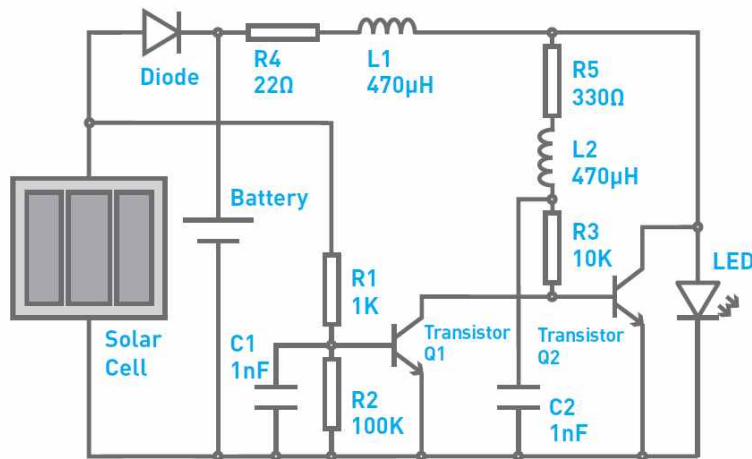
The LED can be mounted on flying leads if you want to position it away from the PCB.

	<p><b>Mounting the PCB to the enclosure</b></p> <p>The drawing to the left shows how a hex spacer can be used with two bolts to fix the PCB to the enclosure.</p> <p><i>Your PCB has four mounting holes designed to take M3 bolts.</i></p>
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## How the Solar Garden Light Works



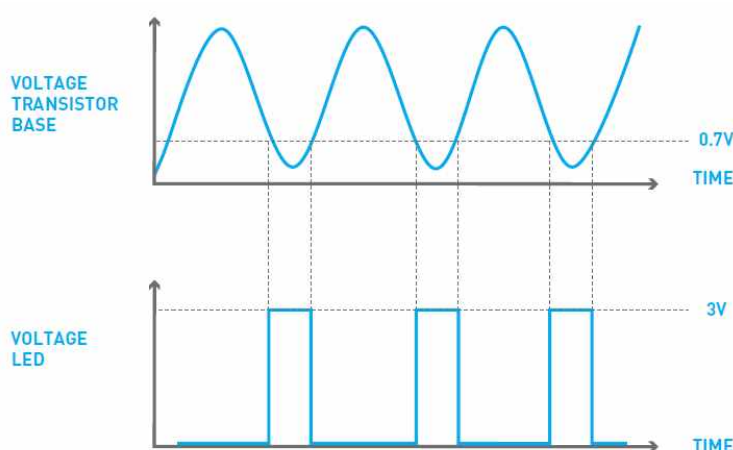
The garden light uses a solar cell to charge a rechargeable battery during the day. At night, when the light level has dropped, the circuit switches from charging the battery to discharging the battery through a high brightness LED.

The solar cell and the diode form the parts used to charge the battery. When sunlight shines on the solar cell, it produces enough power to charge the battery. The diode is used to stop the battery discharging back (as it only allows electricity to flow in one direction) into the solar cell if there is not enough sunlight falling upon (and therefore not enough voltage generated by) the solar cell.

Resistors (R1) and (R2) and transistor (Q1) form the part of the circuit that switches the LED on when the light level has fallen below the desired level.

When there is sunlight on the solar cell, the voltage it produces is enough to turn transistor (Q1) on (this keeps the LED turned off). As the amount of sunlight falls, the voltage it produces falls until there is not enough to keep transistor (Q1) turned on. The resistors (R1) and (R2) form a potential divider, which is used to feed only a proportion of the voltage produced by the solar cell through to the transistor. This allows the point where the LED comes on to be fine-tuned to the desired level.

Once activated, the remaining parts are used to power the LED. The LED requires around 3V to work but the battery can only supply about 1.2V. In order to generate 3V for the LED, the circuit has been designed so that the LED is not always on but when it is, 3V can be supplied.



This happens so fast that to the human eye, the LED looks like it is always on. The inductor (L2) and the capacitor (C2) form a resonant circuit that produces an alternating signal as shown in the picture above. When this alternating signal produces a voltage above 0.7V it turns on the transistor (Q2), which keeps the LED off. When this voltage drops below 0.7V, the transistor turns off and the LED comes on. When it is on the inductor (L1), which has been storing an amount of electricity, discharges into the LED at the same time as the battery which produces the extra voltage needed to give the 3V for the LED.

The resistors (R4) and (R5) have been selected to reduce the amount of power the LED drive circuit uses. This helps to extend the battery life so that the light can last about ten hours from a good days charging in the summer. When there is less daylight in winter, this time will be reduced.



## Online Information

Two sets of information can be downloaded from the product page where the kit can also be reordered from. The 'Essential Information' contains all of the information that you need to get started with the kit and the 'Teaching Resources' contains more information on soldering, components used in the kit, educational schemes of work and so on and also includes the essentials. Download from:

[www.kitronik.co.uk/2134](http://www.kitronik.co.uk/2134)



This kit is designed and manufactured in the UK by Kitronik

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