Light activated switch

Build instructions, circuit explanation and example applications

Issue 1.6

Product information: www.kitronik.co.uk/quicklinks/2112/
Introduction

About the project kit
This project kit has been carefully designed for use by teachers in KS3 / KS4 design and technology. They are designed such that even teachers with a limited knowledge of electronics should have no trouble using it.

Using the booklet
This booklet is intended as an aid for teachers when planning and implementing their scheme of work.

Please feel free to print any pages of this booklet to use as student handouts in conjunction with Kitronik project kits. There are no page numbers in this booklet. This means you can feel free to pick and choose which sheets you use whilst still retaining a feeling of continuity.

Support and resources
You can also find resources at 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

Technical specification

Supply Voltage
Minimum = 3V
Maximum = 12V

A supply voltage of 3V to 5V allows for better adjustment.

Output voltage
Vout = Supply voltage less 0.9V

Output current
Maximum = 0.5A

Guidance note
You should ensure that you have a stable power source when using the output to switch on high output loads. This is because if the power source is unable to provide enough power this may result in a supply voltage dip and cause output to switch off. At this point the voltage is likely to recover and turns the output on again. The output would then be in state where it is rapidly switching on and off.
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 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 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 join 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

![Good solder joint](image1)

![Too little solder](image2)

![Too much solder](image3)
LDR (Light Dependent Resistor)

An LDR is a component that has a resistance that changes with the light intensity that falls upon it. They have a resistance that falls with an increase in the light intensity falling upon the device.

The resistance of an LDR may typically have the following resistances:

- Daylight: 5000\,\Omega
- Dark: 2000000\,\Omega

You can therefore see that there is a large variation between these figures. If you plotted this variation on a graph you would get something similar to that shown by the graph to the right.

Applications

There are many applications for Light Dependent Resistors. These include:

Lighting switch

The most obvious application for an LDR is to automatically turn on a light at certain light level. An example of this could be a street light.

Camera shutter control

LDRs can be used to control the shutter speed on a camera. The LDR would be used to measure the light intensity and set the camera shutter speed to the appropriate level.

Example

The circuit shown right shows a simple way of constructing a circuit that turns on when it goes dark. The increase in resistance of the LDR in relation to the other resistor which is fixed as the light intensity drops will cause the transistor to turn on. The value of the fixed resistor will depend on the LDR used, the transistor used and the supply voltage.
Transistors

**Functionality**

A transistor in its simplest form is an electronic switch. It allows a small amount of current to switch on or off a much larger amount of current. There are two types of transistor 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.

The transistor has three legs, these are the base, collector and the emitter. The emitter is always connected to 0v and the electronics that is to be switch on is connected between the collector and the positive power supply. The base of the transistor is used to switch current through the collector and emitter. When the base is between 0V and 0.7V it is switched off and above 0.7V it is switched on allowing the current to flow from the collector to the emitter. 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.

**Schematic symbol**

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

**Values**

Transistors don’t have values, but they do 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 on to heat sinks so 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 catalogue to find out which pin connects where.
Darlington Pair

What is a Darlington Pair?
A Darlington pair is two transistors that act as a single transistor but with a much higher current gain.

What is current gain?
Transistors have a characteristic called current gain. This is referred to as its $h_{FE}$.

The amount of current that can pass through the load when connected to a transistor that is turned on equals the input current $\times$ the gain of the transistor ($h_{FE}$).

The current gain varies for different transistor and can be looked up in the data sheet for the device. Typically it may be 100. This would mean that the current available to drive the load would be 100 times larger than the input to the transistor.

Why use a Darlington Pair?
In some application the amount of input current available to switch on a transistor is very low. This may mean that a single transistor may not be able to pass sufficient current required by the load.

As stated earlier this equals the input current $\times$ the gain of the transistor ($h_{FE}$). If it is not be possible to increase the input current then we need to increase the gain of the transistor. This can be achieved by using a Darlington Pair.

A Darlington Pair acts as one transistor but with a current gain that equals:

Total current gain ($h_{FE_{total}}$) = current gain of transistor 1 ($h_{FE_{t1}}$) $\times$ current gain of transistor 2 ($h_{FE_{t2}}$)

So for example if you had two transistors with a current gain ($h_{FE}$) = 100:

($h_{FE_{total}}$) = 100 $\times$ 100
($h_{FE_{total}}$) = 10,000

You can see that this gives a vastly increased current gain when compared to a single transistor. Therefore this will allow a very low input current to switch a much bigger load current.

Base Activation Voltage
Normally to turn on a transistor the base input voltage of the transistor will need to be greater that 0.7V. As two transistors are used in a Darlington Pair this value is doubled. Therefore the base voltage will need to be greater than 0.7V $\times$ 2 = 1.4V.

It is also worth noting that the voltage drop across collector and emitter pins of the Darlington Pair when the turn on will be around 0.9V Therefore if the supply voltage is 5V (as above) the voltage across the load will be will be around 4.1V (5V – 0.9V).

[Diagram of Darlington Pair with inputs and outputs labeled]
Build Instructions – Light activated

Before you put any components in the board or pick up the soldering iron, just 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.

You will find it easiest to start with the small components and work up to the taller larger ones. If you’ve not soldered before get your soldering checked after you have done the first few joints.

**Step 1**
Start with the resistor (shown left). This is a 220Ω resistor (colour bands red, red, brown), solder this into the board where it is labeled R4.

**Step 2**
The two transistors (shown right) should be placed into Q1 and Q2. It is important that they are inserted in the correct orientation. Ensure the shape of the device matches the outline printed on the PCB. Once you are happy solder the devices into place.

**Step 3**
Solder the LDR (shown left) in to the circle indicated by the text R1. This is next to the ‘light’ text. It does not matter which way around it is inserted.

**Step 4**
Place the variable resistor (shown right) into R2. It will only fit in the holes in the board when it is the correct way around.

**Connecting power**
There are two power terminals on the PCB to allow power to be connected. These are identified by the text ‘power’ on the PCB.
- The positive power connection should be connected to the terminal indicated by the text ‘+’ and ‘red’
- The negative power connection should be connected to the terminal indicated by the text ‘-’ and ‘black’

**Connecting an LED**
The circuit can be used to turn on a LED. The LED should be soldered into the LED1 on the PCB. A current limit resistor must also be placed in the R3 on the PCB. The value of R3 will depend on the LED used and the supply voltage. For a standard LED and a 5V supply voltage a 220Ω would be suitable.

**Connecting an external circuit to the boards output**
The circuit can be used to control another device. To do this the device that is to be controlled should be connected to the terminals labeled output. When the circuit is activated the output turns on and can be used to turn on the device to which it is connected.

Note: This output will be around 0.9V lower that that connected to the PCB.
Build Instructions – Dark activated

Before you put any components in the board or pick up the soldering iron, just 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.

You will find it easiest to start with the small components and work up to the taller larger ones. If you’ve not soldered before get your soldering checked after you have done the first few joints.

Step 1
Start with the resistor shown left. This is a 220Ω resistor (colour bands red, red, brown), solder this into the board where it is labeled R4.

Step 2
The two transistors (shown right) should be placed into Q1 and Q2. It is important that they are inserted in the correct orientation. Ensure the shape of the device matches the outline printed on the PCB. Once you are happy solder the devices into place.

Step 3
Place the variable resistor (shown left) into R1. It will only fit in the holes in the board when it is the correct way around.

Step 4
Solder the LDR (shown right) in to the circle indicated by the text R2. This is next to the ‘dark’ text. It does not matter which way around it is inserted.

Connecting power
There are two power terminals on the PCB to allow power to be connected. These are identified by the text ‘power’ on the PCB.

- The positive power connection should be connected to the terminal indicated by the text ‘+’ and ‘red’
- The negative power connection should be connected to the terminal indicated by the text ‘-’ and ‘black’

Connecting an LED
The circuit can be used to turn on a LED. The LED should be soldered into the LED1 on the PCB. A current limit resistor must also be placed in the R3 on the PCB. The value of R3 will depend on the LED used and the supply voltage. For a standard LED and a 5V supply voltage a 220Ω would be suitable.

Connecting an external circuit to the boards output
The circuit can be used to control another device. To do this the device that is to be controlled should be connected to the terminals labeled output. When the circuit is activated the output turns on and can be used to turn on the device to which it is connected.

Note: This output will be around 0.9V lower that that connected to the PCB.
Checking Your Circuit

Check the following before you connect power to the board:

**Check the bottom of the board to ensure that:**
- All these leads are soldered
- Pins next to each other are not soldered together

**Check the top of the board to ensure that:**
- The body of the two transistors match the outline on the PCB

Testing the PCB

**Light activated circuit**
- In daylight turn the variable resistor $R_1$ fully clockwise (high resistance = 47K$\Omega$). At this point the output should be on (and the LED if fitted).
- Now turn the variable resistor $R_1$ anti-clockwise until the output turns off (and the LED if fitted).
- Turn the variable resistor $R_1$ back clockwise. Note the point at which the output (and the LED if fitted) turns back on. This is the trip point for the current light level.
- If you want the circuit to trip at a lower light level then adjust $R_1$ forward in the clockwise direction.
- If you want the circuit to trip at a brighter light level then adjust $R_1$ back in the anti-clockwise direction.
- Some experimentation maybe required to set the correct trip point.

**Dark activated circuit**
- In daylight turn the variable resistor $R_2$ fully clockwise (low resistance = 47K$\Omega$). At this point the output should be off (and the LED if fitted).
- Now turn the variable resistor $R_2$ anti-clockwise until the output turns on (and the LED if fitted).
- Turn the variable resistor $R_2$ back clockwise. Note the point at which the output (and the LED if fitted) turns back off. This is the trip point for the current light level.
- If you want the circuit to trip at a lower light level then adjust $R_2$ forward in the clockwise direction.
- If you want the circuit to trip at a brighter light level then adjust $R_2$ back in the anti-clockwise direction.
- Some experimentation maybe required to set the correct trip point.
How the light switch works – dark activated

The circuit operation is very simple. When the input to the transistor Q1, which is fed from the connecting point of R1 and R2, is greater than 1.4V the output is turned on. The voltage at the join of R1 and R2 is determined by the ratio of the two resistors. This is known as potential divider.

\[ \text{Voltage at join of R1 and R2} = \text{The supply Voltage} \times \left( \frac{R1}{R1+R2} \right) \]

Normally it requires 0.7V to turn on a transistor but this circuit uses two resistors in a Darlington Pair meaning it requires \( 2 \times 0.7V = 1.4V \) to turn on both transistors.

It is also worth noting that the output, when turned on, will be around 0.9V lower than the supply voltage V+. This is because of the voltage drop across the collector and emitter pins of the Darlington Pair of transistors. Therefore if the supply voltage is 5V then the output voltage will be around 4.1V.

R4 is present to protect the transistor should the variable resistor be set to zero.

**Adjusting the trigger level**

The point at which the circuit is triggered is set by the 47KΩ variable resistor. By varying the value of this resistor the ratio of the resistance of R1 and R2 can be varied to a point where a centre voltage (trip point) of 1.4V is achieved at the desired light level.

**LED (if fitted)**

If LED1 and R3 are fitted the LED will light at this point. The value of R3 should be selected for the relevant supply voltage on LED used. A standard LED would require around 10mA (0.01A) producing a normal brightness. As stated a 5V supply would give 4.1V across LED1 and R3. The LED1 would use 1.9V leaving around 2.2V (4.1V-1.9V) across R3.

\[ \text{Using } R = \frac{V}{I} \quad R3 = \frac{2.2}{0.01} \quad R3 = 220\Omega \]
How the light switch works – light activated

The circuit operation is very simple. When the input to the transistor Q1, which is fed from the connecting point of R1 and R2, is greater than 1.4V the output is turned on. The voltage at the join of R1 and R2 is determined by the ratio of the two resistors. This is known as potential divider.

Voltage at join of R1 and R2 = The supply Voltage x (R1/(R1+R2))

Normally it requires 0.7V to turn on a transistor but this circuit uses two resistors in a Darlington Pair meaning it requires 2 x 0.7V = 1.4V to turn on both transistors.

It is also worth noting that the output, when turned on, will be around 0.9V lower than the supply voltage V+. This is because of the voltage drop across the collector and emitter pins of the Darlington Pair of transistors. Therefore if the supply voltage is 5V then the output voltage will be around 4.1V.

Note: R4 is only present to protect the transistor in the dark activated version (when the variable resistor is set to zero).

Adjusting the trigger level

The point at which the circuit is triggered is set by the 47KΩ variable resistor. By varying the value of this resistor the ratio of the resistance of R1 and R2 can be varied to a point where a centre voltage (trip point) of 1.4V is achieved at the desired light level.

LED (if fitted)

If LED1 and R3 are fitted the LED will light at this point. The value of R3 should be selected for the relevant supply voltage on LED used. A standard LED would require around 10mA (0.01A) producing a normal brightness. As stated a 5V supply would give 4.1V across LED1 and R3. The LED1 would use 1.9V leaving around 2.2V (4.1V-1.9V) across R3.

Using R = V/I  \[ R3 = \frac{2.2}{0.01} R3 = 220\Omega \]
Applications

*All prices shown relate to the 2009/2010 Kitronik catalogue

**Garden lamp that switches on automatically at night**

As shown to the right, by simply adding a battery holder and light bulb to a PCB built in the 'dark activated' configuration you can create a garden light that automatically comes on in the dark.

Parts list to build 100 garden lights:

<table>
<thead>
<tr>
<th>Part no.</th>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2112</td>
<td>Light activated switch</td>
<td>100</td>
</tr>
<tr>
<td>2232-25</td>
<td>2 x AA battery cage with leads, pack of 25</td>
<td>4</td>
</tr>
<tr>
<td>3517</td>
<td>MES lamp holder economy, pack of 50</td>
<td>2</td>
</tr>
<tr>
<td>3519</td>
<td>MES lamp 2.5V, pack of 50</td>
<td>2</td>
</tr>
<tr>
<td>2201-40</td>
<td>Zinc Chloride AA batteries, box of 40</td>
<td>5</td>
</tr>
</tbody>
</table>

**Draw alarm, which sounds when a dark draw is opened**

As shown to the right, by simply adding a battery holder, switch and buzzer to a PCB built in the 'light activated' configuration you can create an alarm that sounds when a dark draw is opened and the PCB is exposed to light. The switch is to allow the alarm to be activated or deactivated.

Parts list to build 100 draw alarms:

<table>
<thead>
<tr>
<th>Part no.</th>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2112</td>
<td>Light activated switch</td>
<td>100</td>
</tr>
<tr>
<td>2232-25</td>
<td>2 x AA battery cage with leads, pack of 25</td>
<td>4</td>
</tr>
<tr>
<td>3404</td>
<td>Miniature DPDT slide switch, pack of 10</td>
<td>10</td>
</tr>
<tr>
<td>3301</td>
<td>Pack of 10 piezo buzzers</td>
<td>10</td>
</tr>
<tr>
<td>2201-40</td>
<td>Zinc Chloride AA batteries, box of 40</td>
<td>5</td>
</tr>
</tbody>
</table>
**Line following buggy (using 2 light activated boards)**

As shown below, by using two light activated boards and two motors it is possible to make a line following buggy. The boards just need to be mounted close to the ground with the light sensor facing down. Normally the buggy will travel in a straight line. If one of the sensors crosses the dark line it turns off the motor on that side. This will steer the buggy away from the line. Once it has been steered away from the line the motor will turn back on. This circuit could be used with lego motors.

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**Parts list to build 100 buggies:**

<table>
<thead>
<tr>
<th>Part no.</th>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2112</td>
<td>Light activated switch</td>
<td>200</td>
</tr>
<tr>
<td>2234-25</td>
<td>3 x AA battery cage with clip, pack of 25</td>
<td>4</td>
</tr>
<tr>
<td>2238-25</td>
<td>PP3 Battery clip lead, pack of 25</td>
<td>4</td>
</tr>
<tr>
<td>2501</td>
<td>Pack of 10 motors</td>
<td>20</td>
</tr>
<tr>
<td>2503</td>
<td>Pack of 10 motor clips</td>
<td>20</td>
</tr>
<tr>
<td>2201-40</td>
<td>Zinc Chloride AA batteries, box of 40</td>
<td>8</td>
</tr>
</tbody>
</table>

Note: No gear box parts included
Reordering information

Description          Stock code
Light activated switch 2112

Sales
Phone: 0845 8380781
Fax: 0845 8380782
Email: sales@kitronik.co.uk

Technical support
Email: support@kitronik.co.uk

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