



Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

WARNING !

The kit comes with a data sheet included which suggests the relay can be used for 240 V AC.

This is NOT suitable for Australian School students!

Only a qualified Electrician should deal with 240 V AC.

We STRONGLY urge all teachers to explain that the relay is designed to handle only 12 V DC or 24 V DC loads!

LEARNING OUTCOMES:

During the construction of this kit, the students will be exposed to the following learning elements:

<u>Description</u>	<u>Activity</u>
Heat transfer (by conduction)	Soldering
Energy transference	Electricity to Light (LED) Light sensitivity of Photo Transistor (Technically: this is light to electron energy which in turn stimulates a “base current” in the Transistor) Electricity to magnetic force (inside the relay).

Transfer of Energy through an electrical circuit Entire KIT!

The kit comes with:

- Solder included
- A circuit Diagram
- Instruction sheet (which is aimed at experienced users)



Teacher Resource Guide

for FK401 (*Light Activated Switch*)

Extra resources recommended to be used with the kit:

- A copy of the locally written “Student Instruction Sheet” (provided as a soft copy with class sets, and included below).
- A copy of the locally written guide “Towards Better Soldering” (provided as a soft copy with class sets).
- Soldering Iron
- Soldering Iron Stand with a damp cloth or sponge
- Diagonal Pliers (“Side-cutters”)
- Solder sucker or Solder wick (for removing unwanted solder)
- Power source (e.g. 12 V DC plug pack, or battery. If necessary, a fresh 9 V DC battery will work).
- We recommend teachers should also have a “Magnifying Glass” available for helping to identify the different Transistors used in this kit.

Extension activities for this kit:

- 1) Consider changing the way that the light can enter the Photo Transistor.
See notes at the end of this document for suggestions .
- 2) Adjust the sensitivity of the system by carefully adjusting VR1 .
- 3) Practice different soldering techniques, to study affect of heat flow by conduction.
- 4) Discuss what could be switched on and off via the relay. (Keep any tests to 12V DC loads and under 10 Amps)
 - a. If you do this, take note of the two connection Posts which are joined together under the PCB. (The relay is actually only switching one of the lines.)
 - b. Although the PCB is marked with “AC IN” and “AC OUT” , the relay will readily work with a DC load.

Student Sheet with notes inserted:

Below is a copy of the student notes, with some comments and suggestions for teachers. Our comments are inserted in RED font.



Teacher Resource Guide

for FK401 (Light Activated Switch)

What it does:

This circuit responds to the level of ambient light which it senses. If the light level goes above a threshold, then the module will switch on a relay as well as a small indicator LED.

What we are making:

The finished circuit will have a Photo Transistor which changes it's characteristics depending upon how much light it can detect. This Photo Transistor is connected to an Amplifier which in turn can turn on a relay. The relay can be used to switch much larger Electrical loads, such as motors, lights, etc. The input to the amplifier can be easily adjusted so that the system will switch at different light levels.

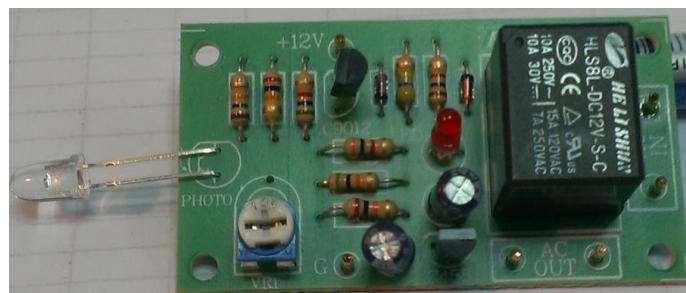


Fig 1: Finished Product

Technical Specs:

- Power supply: 12VDC
- Consumption: 46mA max.
- Maximum Relay Load: 10A , 12V DC
- PCB dimensions: 32.8 x 60.0 mm



Teacher Resource Guide

for FK401 (Light Activated Switch)

Comments for teachers:

The module will work from a fresh 9V DC battery if this is the only power source you have available. HOWEVER... the relay will soon start to behave unreliably if the voltage falls much below 8.8V (As when a battery starts to go flat).

If you elect to supply the students with a 9V battery... please give a warning on this, so as to minimize disappointment once the module leaves the classroom.

How it works:

The Photo Transistor has a semi-conductor junction which is sensitive to visible light. The more light it detects, the lower the “resistance” the Photo Transistor presents to the outside world.

Comments for teachers:

This statement is not technically accurate! The actual mechanisms occurring are:

- *The Photo Transistor has an internal reverse biased Collector-Base junction.*
- *Any light falling onto that junction will slightly stimulate the electrons in the semiconductor.*
- *This “Stimulation” will give rise to a small electron flow (Current).*
- *The Transistor is a powerful amplifier, which will magnify the small current created.*
- *The more light received on the semiconductor will create more “Stimulated Current”.... Which will in turn create more current flow from the Collector to the Emitter.*
- *In “simplified” terms... it is often much easier to consider the Photo Transistor as if it was like a light sensitive Resistor... the more light it receives, the lower the “apparent” resistance of the device ...*
- *Refer to “Appendix 1” for more detailed comments on identifying the correct orientation of the Photo Transistor in this kit.*



Teacher Resource Guide

for FK401 (Light Activated Switch)

The circuit is designed so that VR1 , R1 and the Photo Transistor form the input to an amplifier. The amplifier uses TR1 as it's main active element. The amplifier does not do much until it's input reaches a threshold, at which time it then turns on TR2. TR2 is designed to control the Relay.

The input to the amplifier can be adjusted for different “sensitivity” of light levels, but adjusting VR1.

Comments for teachers:

Technically what is happening:

- *The Photo Transistor is forming a “Current source” which then flows through (R1 + VR1) to give a voltage at the input of the amplifier (R2).*
- *As the light level changes on the Photo Transistor, so it changes the current flowing through the Photo Transistor.*
- *As the current changes, so then does the voltage at the input to the Amplifier.*
- *When the voltage at the amplifier input exceeds approx 2.5 Volts, then TR1 will switch on and will in turn trigger the relay.*
- *Note that the operator can change the total resistance of (R1 + VR1) by adjusting VR1.*
- *Using Ohm's law ($V = I \times R$) you can see that by increasing VR1 , the voltage at the amplifier input will be higher for a given amount of current flow.*
- *Since the current flow is proportional to the light level, this appears to be adjusting for different light sensitivity levels!*

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

Circuit Diagram:

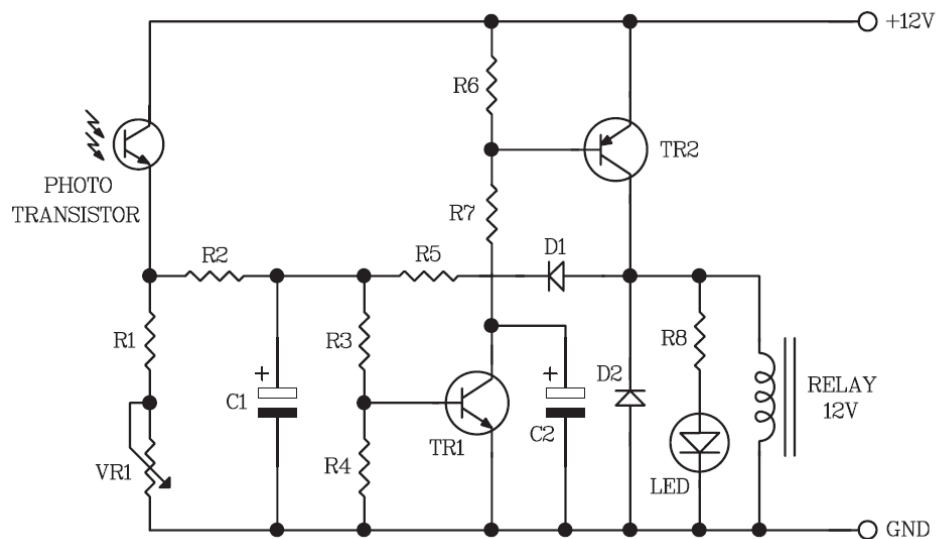


Fig 2: Circuit Diagram

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

How to build it:

Step 1. Installing the Diodes.

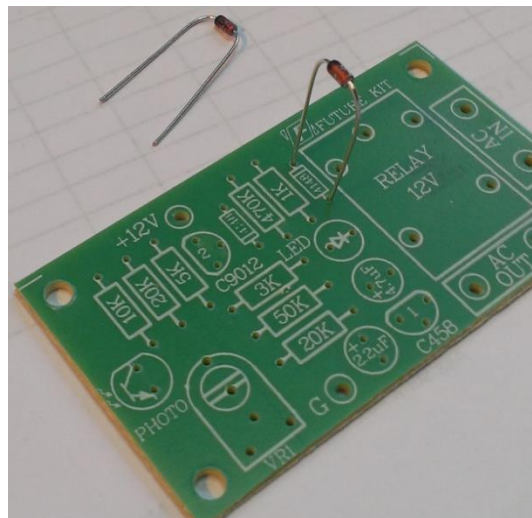


Fig 3.1 Installing the Diodes

By referring to *Fig 3.1* identify the position and orientation (Polarity) of each Diode.

Note that each diode has a clearly marked band around its body at one end. The PCB will also have one end of the diodes marked with an extra stripe. Make sure you align the diodes banded end with the marked end on the PCB.

Insert the diodes in their correct positions as indicated on the printed circuit board (PCB). Do this by carefully bending their wires down to form a 'U' shape and poke through the holes in the PCB as shown in *Fig3.1*. Once



Teacher Resource Guide

for **FK401 (Light Activated Switch)**

they are in the correct positions solder them into place and trim the excess wire.

Step 2. Installing the resistors.

<u>RESISTORS</u>		
R1	10k Ω	- brown-black-orange-gold
R2, R4	20k Ω	- red-black-orange-gold
R3	50k Ω	- green-black-orange-gold
R5	470k Ω	- orange-violet-yellow-gold
R6	5k Ω	- green-black-red-gold
R7	3k Ω	- orange-black-red-gold
R8	1k Ω	- brown-black-red-gold
<u>TRIMMER POTENTIOMETER</u>		
VR	=	10k or 15 or 100k Ω
<u>ELECTROLYTIC CAPACITOR</u>		
C1	=	2.2 μ F
C2	=	4.7 μ F
<u>TRANSISTOR</u>		
TR1	=	C458, C828, C945, C1815
TR2	=	C9012
<u>DIODE</u>		
D1, D2	=	1N4148

Fig 3.2 Component Values

By referring to *Fig 3.2* determine the value of each resistor and place them in their correct positions as indicated on the printed circuit board (PCB). Do this by carefully bending their wires down to form a 'U' shape and poke through the holes in the PCB as shown in *Fig3.3*.

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

Try to install the resistors so that their “Colour Codes” are aligned in the same direction. *(This is not mandatory, but highly recommended).* Once they are in the correct positions solder them into place and trim the excess wire.

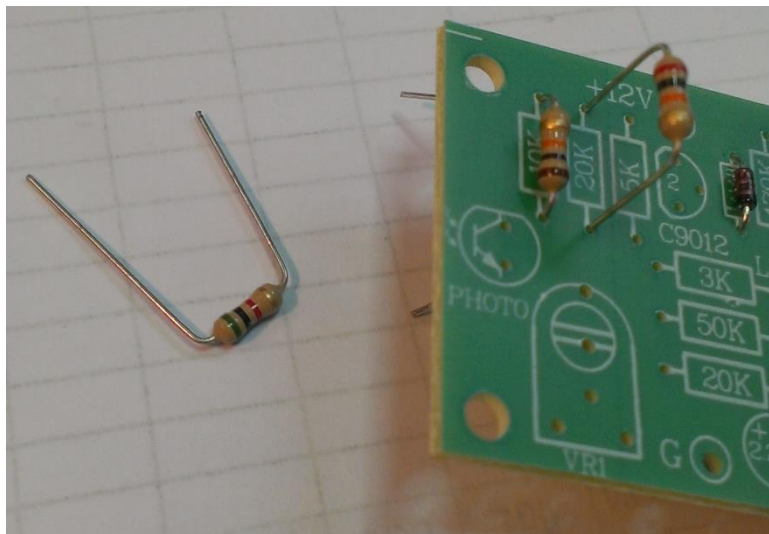


Fig 3.3 Installing Resistors (Oops... notice that the 20K resistor is about to be inserted back-to-front!)

Step 3. Installing the transistors.

Take care at this stage. The two transistors look alike from their outsides, but they are VERY different inside. If you install them in the wrong positions, you may easily destroy their insides!

Take time to find their part numbers on their case. Refer to figure 3.4 to 3.6 for suggestions on how to do this.

Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

Carefully bend the middle leg of the transistor slightly backward and the two outer legs out and carefully manipulate them as you place them through the holes and onto the PCB as shown in *Fig3.6*. Pull the legs through until the transistor is sitting about 10mm off the PCB. Once in the correct position solder it into place and trim the excess wire.

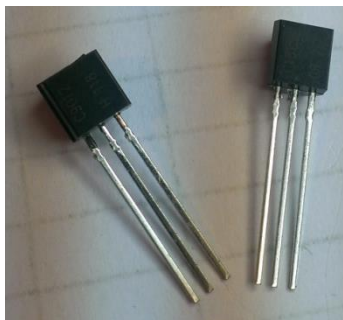
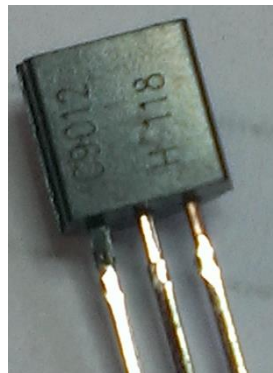


Fig 3.4 Take care as the two transistors look alike but are actually very different inside!



*Fig 3.5 Identifying the Transistor Part Number.
(This one is Part Number “C9012” and is used as TR2).*

Teacher Resource Guide

for FK401 (Light Activated Switch)

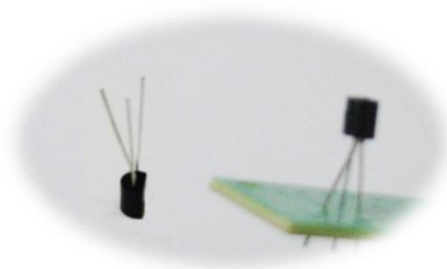


Fig 3.6 Bending the legs and Installing the Transistor

Comments for teachers:

Some students may need help to find and read the part numbers on the transistors. If help is required, we recommend:

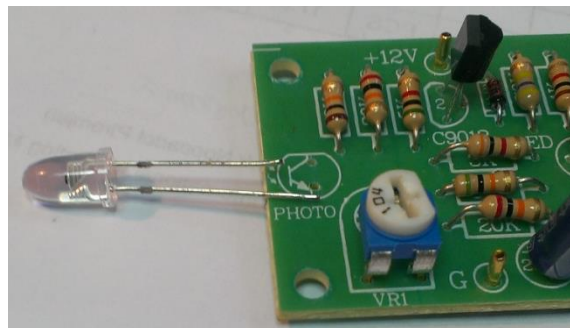
- *Use a bright light source*
- *Use a magnifying glass if possible.*
- *Encourage students to “move” the transistors around until they are reflecting the light and the Part Numbers are visible.*
- *Usually the Transistors will have two lines of marking on them.*
 - *The first line is usually the Part Number, while*
 - *The second line is usually a “Batch Code” or other factory related information which is normally only used by very large manufacturing operations.*

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

Step 4. Installing the Photo Transistor and the LED.

Carefully identify and then orient the Photo Transistor as shown in Fig 3.7.



*Fig 3.7 Orienting the Photo Transistor correctly.
(The longer leg goes to the bottom of the white overlay on the PCB).*

Once it is installed correctly, leave the legs longer than the other components, and solder it in place. (Refer Fig 1 for suggested installation).

Repeat for the Red LED. Take care with the polarity of any LED. They must be installed facing the correct way. Ensure the longer leg of each LED is placed at the back of the triangle in the diode symbol which is shown on the PCB (see Fig 3.8). Once in the position solder it into place and trim the excess wire.

Comments for teachers:

In the event that the leads on the Photo Transistor have been cut BEFORE being inserted, there is a “back up” method of identifying the “Negative” leg.

- *The Photo Transistor casing is NOT symmetrical.*
- *There is a “Flat” edge to the “-” leg (which is the shorter leg in Fig 3.7)*
- *Careful study of Fig 4 below will show the flat side and its orientation!*

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

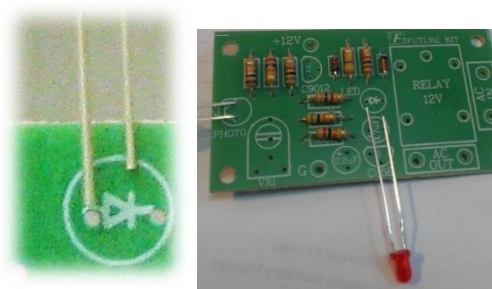


Fig 3.8 Installing the Red LED

Step 5. Installing the Capacitors

Refer to *Fig 3.2* determine the value of each capacitor and place them in their correct positions as indicated on the printed circuit board (PCB).

Caution : These capacitors **MUST** be installed with the correct orientation.

The longer leg on a new capacitor is the positive (“+”). The PCB white overlay will also indicate which is the correct polarity for installing them.

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

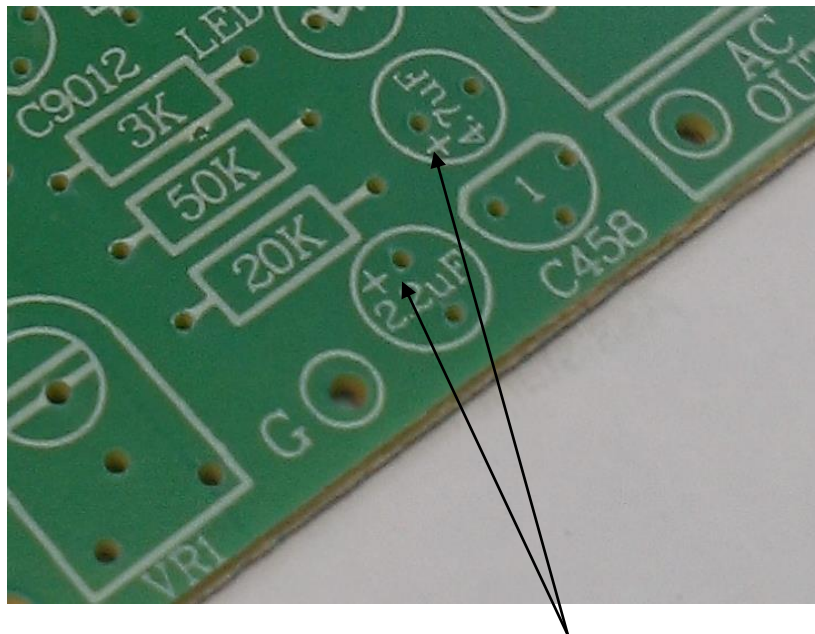


Fig 3.9 showing the capacitor polarity markings (+ indicate the positive leg)

Step 6. Installing the connection Posts

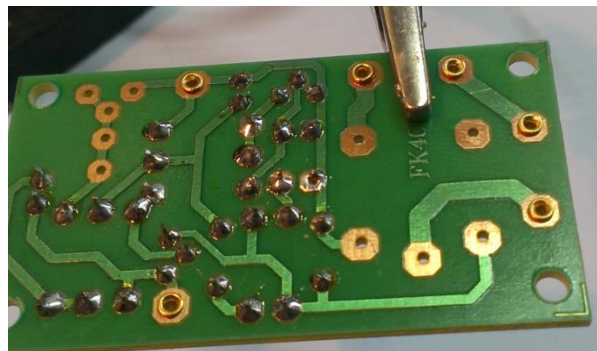


Fig 3.10 The connection Posts have been inserted from behind and are about to be soldered into place.

Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

Step 7. Installing the Trimmer Potentiometer (VR1)

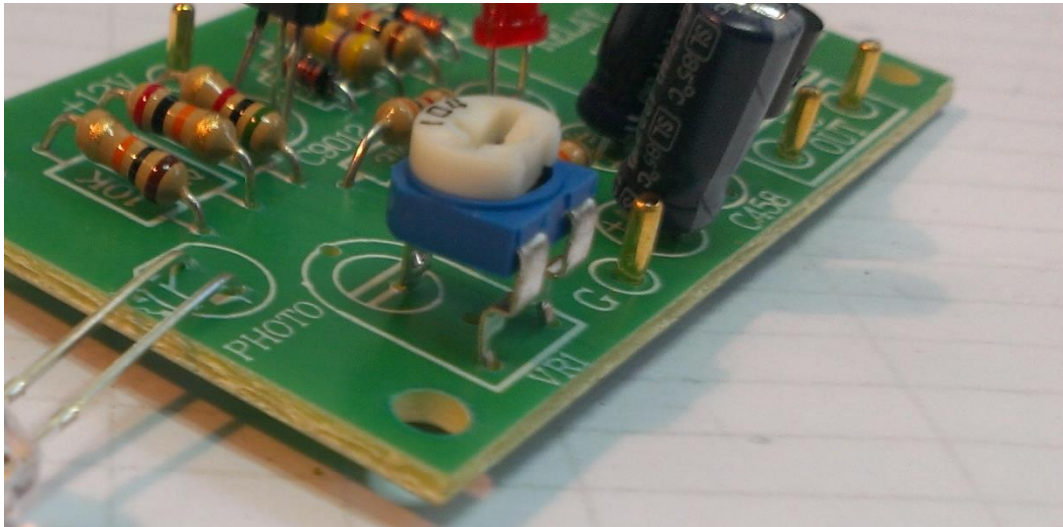


Fig 3.11 Installing the Trimmer Potentiometer.

Note that there are a wide variety of different Trimmer Potentiometer (“Trimpot”) styles. Your kit may not have the exact same style as shown in this photo.

The PCB has a variety of holes in it which will permit the most common style to be used.

Step 8. Installing the Relay:

Insert the relay and solder into place.

It will only fit in one orientation.



Teacher Resource Guide

for FK401 (*Light Activated Switch*)

Testing:

- 1) Double check your work . Ensure all components are installed and oriented correctly.
- 2) Check for solder bridges (solder blobs across multiple tracks and leads).
- 3) Check for any “cold-solder” joints. (All joints should look bright and shiny... not smoky or crazed. If any joints are not “shiny”, re-melt them with your soldering iron and allow them to cool without any movement.)
- 4) Connect the power supply.
- 5) The LED and Relay may all come on when first connected.
- 6) Cover the Photo Transistor and make it as dark as possible. Does the Relay turn OFF ? (If “yes”... well done!)
- 7) You can adjust the sensitivity of the system to light levels by adjusting the VR1 trimpot.

Trouble shooting:

Most problems with this kit arise from the following causes:

- Component inserted incorrectly. (Check LED's, Transistors and Capacitors for correct orientation)
- Solder bridge is creating a “Short Circuit” path.
- Poor solder joint is not making connection (This is a “Cold Solder” joint). Please read our tips in “Towards Better Soldering” on how to recognize a good solder joint versus a poor joint.

Teacher Resource Guide

for **FK401 (Light Activated Switch)**

Connecting wires and power supply:

‘Tin’ each Connection post with solder. (For more information on “tinning”, please refer to our separate document “Towards Better Soldering”). The power supply connection can be soldered into place by ‘tinning’ the leads and ensuring the black wire is attached to the ‘ground’ (G) or negative (-) pole and the red wire to the positive (+). Finally the four remaining connection posts can be tinned and connected to the load as required. (See *Fig 4* for attaching the wires).

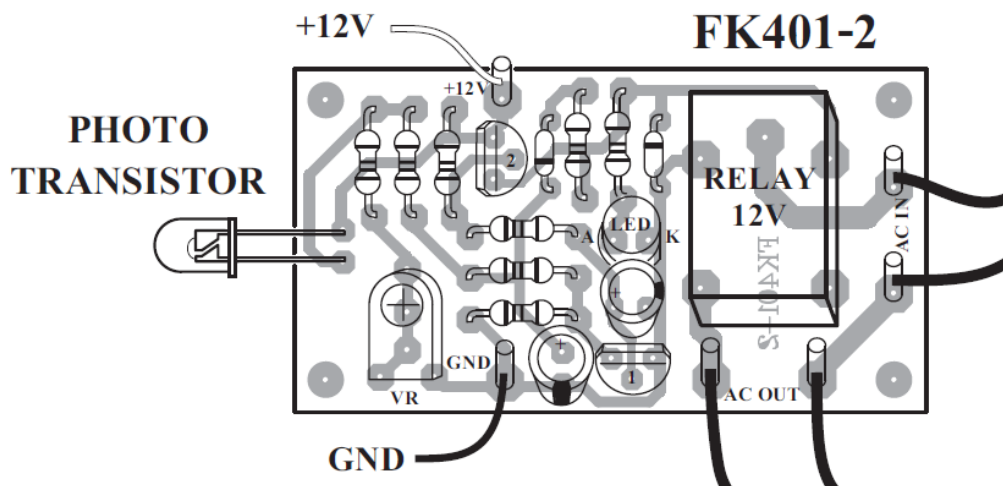


Fig 4 Attaching the wires

CAUTION: DO NOT CONNECT TO 240 V AC!

Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

Extension Activities (Suggestions):

- 1) Consider encapsulating the Photo Transistor so that the light can only enter it via the lens cap.
 - a. Refer to Figure 5 for a possible suggestion.
 - b. Teachers may choose to use a thick drinking straw or perhaps insulation tape as a light shield .

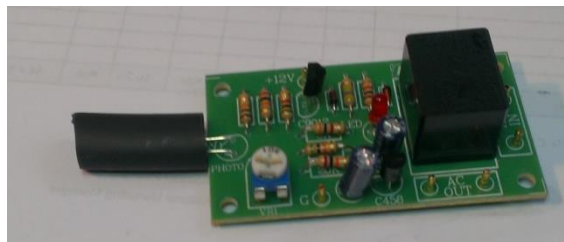


Fig 5 A light shield installed over the Photo Transistor. (In this case we have used a piece of “Heat shrink” insulation tube).

- 2) Where could this module find applications?

Discuss

Possible answers: Where ever someone wants to trigger an action when light comes on.

- a. Dawn detection for automated agricultural applications.
- b. Safety light (e.g. in common fridges or cupboards, etc.)
- c. A hidden “Alarm sensor”
- d. Other



Teacher Resource Guide

for FK401 (*Light Activated Switch*)

3) Could this be adjusted to detect a fading light situation?

3 parts to the answer

- a. Yes... but this is beyond most class room applications.
- b. There is a slightly different kit (FK403) which does this already.
- c. Some advanced students may recognize that one of the pins on the Relay is not used.(See underneath the PCB).
 - i. This is the “Normally Closed” pin of the relay.
 - ii. It is possible to use this pin instead of the left “AC Out” pin .
 - iii. This configuration would then change the relay to switch OFF the load at increasing light, and then switch the load ON again as the light faded.
 - iv. This modification is ONLY recommended for advanced users to trial.

It will require a good standard workmanship with soldering to avoid possible faults and damage to the electronics.

WARNING !

The kit comes with an included data sheet which suggests the relay can be used for 240 V AC.

This is NOT suitable for Australian School students!

Only a qualified Electrician should deal with 240 V AC.

We STRONGLY urge all teachers to explain that the relay is designed to handle only 12 V DC or 24 V DC loads!

Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

APPENDIX 1

Identifying the correct orientation for the Photo Transistor.

There are three alternative ways of identifying the correct orientation for the Photo Transistor in this kit.

- 1) Prior to assembly, use the “longer leg”.
- 2) After assembly, use the “Flat side” of the Photo Transistor
- 3) After assembly, use the “chip carrier” inside the Photo Transistor.

Refer to the photos and detailed explanations which follow:

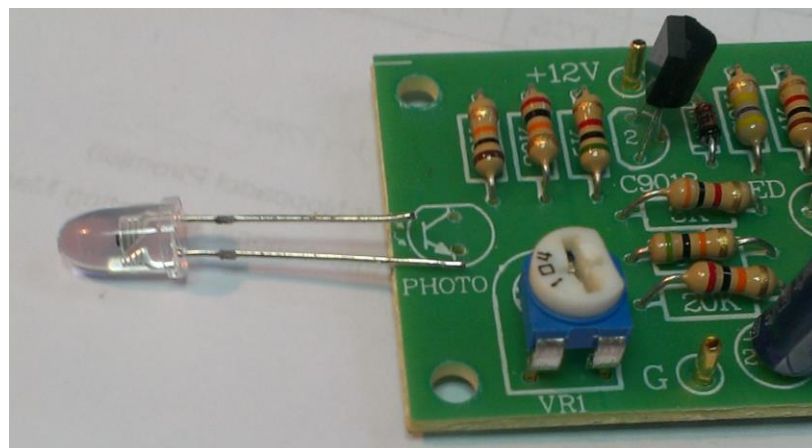


Photo 1: Showing the “longer leg” oriented to the correct mounting hole, prior to assembly.

Teacher Resource Guide

for **FK401** (*Light Activated Switch*)

APPENDIX 1

Identifying the correct orientation for the Photo Transistor.

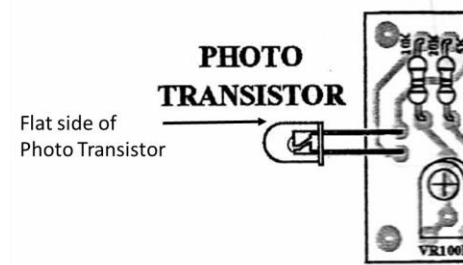
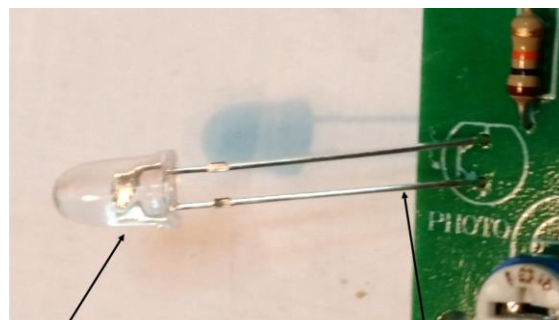


Photo 2: Showing the “flat side ”of the Photo Transistor orientation. Often used to identify the correct orientation after assembly or during re-work.



Note the correct orientation of the Chip Carriers (inside the Photo Transistor).
Smaller of the carrier pads is attached to the Cathode!

Photo 3: Showing the “Chip Carrier ” inside the Photo Transistor. Often used to identify the correct orientation after assembly or during re-work.