FACTFILE:
GCE TECHNOLOGY & DESIGN

1.38 INPUT COMPONENTS

Rewarding Learning

Input components

Learning outcomes

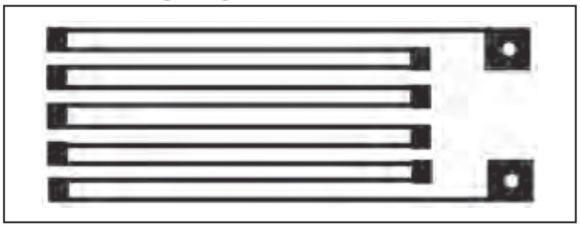
- demonstrate knowledge and understanding of the properties and applications for the following components:
  - strain gauge;
  - phototransistor;
  - optical switches – reflective and slotted – encoded discs to include binary coded decimal (BCD) and Gray code;
  - switches to include reed switch;
  - light dependent resistors (LDR), thermistor and variable resistor; and
  - Schmitt trigger.

Course content

The Strain Gauge

When a force is applied to an object, it causes the object to strain – stretch or shrink depending on how the force is applied. In the case of a so-called rigid object, the strain is usually very small. A special type of resistive transducer called a STRAIN GAUGE is used to measure it. Strain gauges are used to measure the strain in concrete and steel structural elements and in the wings of airplanes. A strain gauge consists of a thin foil, which is formed by rolling out an electrically resistive material (foil) and etching parts away leaving a thin flexible resistor in the form of a grid pattern.

Strain gauge resistance 120 Ω



Strain Gauge
Source: CCEA May 2014 A2 Q1

How It Works

The strain gauge is glued to the surface of the object undergoing strain. As the object bends, expands or contracts so does the strain gauge.
  - If metal is stretched, its resistance increases.
  - If metal is compressed, its resistance decreases.

The resistance change is so small that special electronic circuitry is needed to show the amount of strain on a meter.

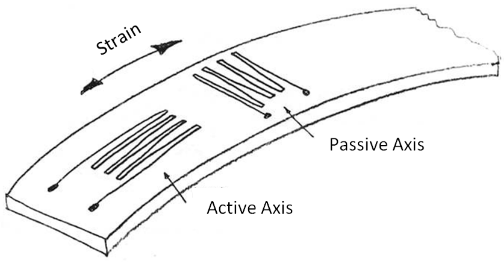
Effects on a Strain Gauge

Although strain gauges measure the amount of strain a material is put under by force acting upon it, in reality there are also other factors which will affect the strain measurement reading. The most common one is temperature.

As strain is applied, deformation takes place. There is often a change of temperature in the material undergoing the strain. This change will affect the resistance of the gauge. On way of eliminating this is to include a second strain gauge aligned at 90° to the first. This means that the strain will only affect the first gauge, but the temperature change will affect both gauges. The second gauge has been added as a control gauge; sometimes known as a dummy gauge. It is the difference between the two readings, which is actually the strain on the material.

The two strain gauges are placed on the material on two different axes. The strain gauge, which is measuring the strain under which the material is being subjected to, is placed on the ACTIVE AXIS, whilst the control gauge is on the PASSIVE AXIS.

The diagram below shows two strain gauges on a piece of material undergoing strain and the axes marked.



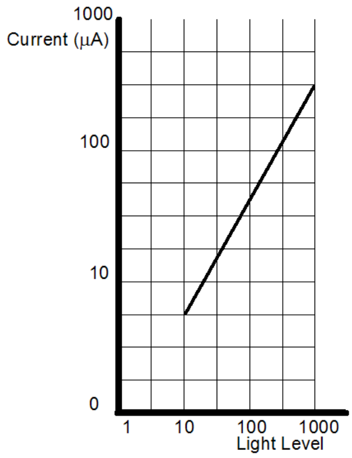
The Phototransistor

Phototransistors are special transistors that change the resistance between the collector and emitter depending on how much light is shining on them. Unlike normal transistors, they have no base connection. Light enters the transistor via a transparent plastic window in the case, or alternatively, the whole transistor case is made from solid transparent plastic.

They are used in similar applications to light-dependent resistors (LDRs), but offer some advantages:

- They allow less leakage current to flow when dark and so preserve battery life
- They are more sensitive.
- They have a much faster response time.

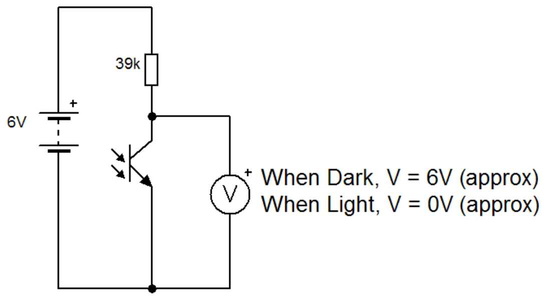
In the dark, the resistance between the collector and emitter is extremely high, typically only allowing a few nano Amps to flow (1nA = 10^{-9}A). In bright light, the resistance between the collector and emitter falls, allowing currents up to perhaps 500μA to flow (1μA = 10^{-6}A).

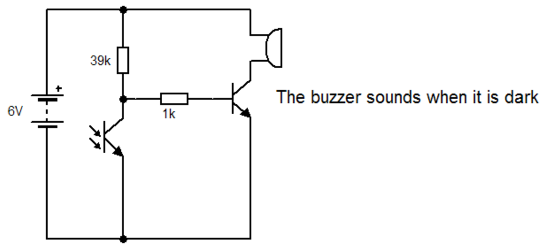


Relationship between current and light level for a phototransistor

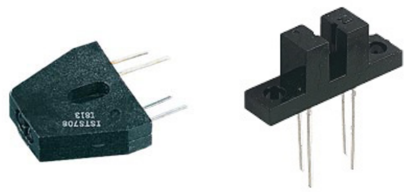
Phototransistors are used as input devices to electronic control circuits that have to respond to a change in light levels. The first circuit diagram below shows a phototransistor connected as part of a potential divider.

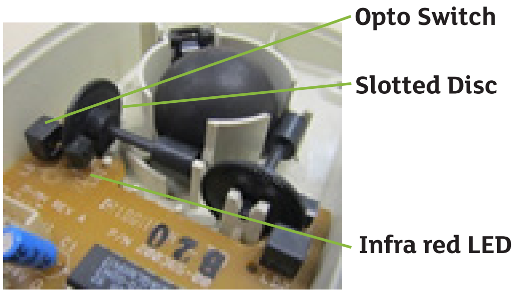
The second shows a typical application where the phototransistor is used to drive a transistor which switches an output device on and off.



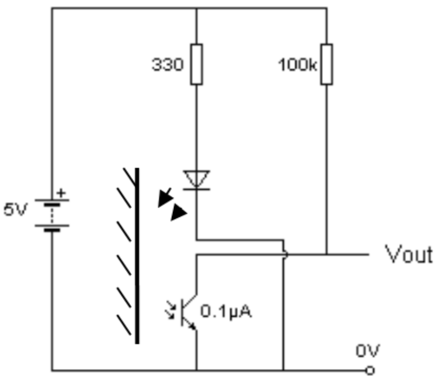


Optical switches – reflective and slotted

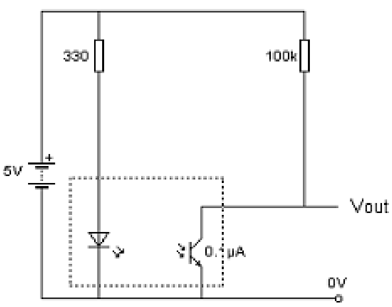




A reflective optical switch contains an infra red LED and a phototransistor in a single package. When a reflecting surface passes the device, the phototransistor detects the reflected light and a current flows between its base and collector.



Reflective opto-switch circuit



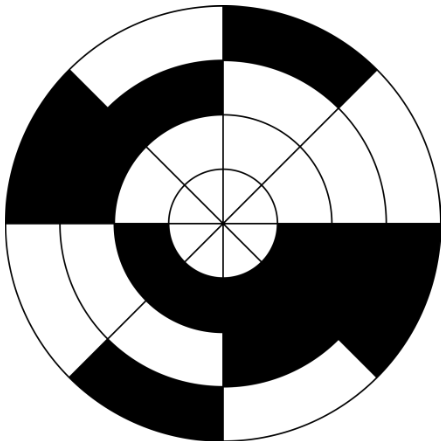
Slotted opto-switch circuit

A slotted optical switch contains an infra red LED and a phototransistor facing each other across a slot in a single package. Normally the phototransistor detects the light from the LED and current flows between its base and collector. When the beam is broken, the resistance of the phototransistor becomes very high and the current becomes very small. This is detected as a voltage change.

These devices have numerous applications including bicycle speedometers, wind speed meters, object counting and position detecting.

A set of 3 reflective optical switches may be used along with a binary encoded disc to count from 0 to 7. The white sector represents 000 and the binary numbers up to 111 are represented by the other 7 sectors with the least significant bit on the outside of the disc.

Binary Encoding			
Sector	**Switch 3**	**Switch 2**	**Switch 1**
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1



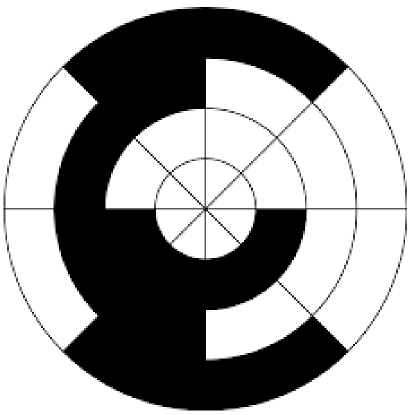
Binary encoded disc

For BCD counting, a total of 10 sectors, read by 4 switches are required to represent the decimal numbers 0 to 9.

BCD Encoding				
Sector	**Switch 4**	**Switch 3**	**Switch 2**	**Switch 1**
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

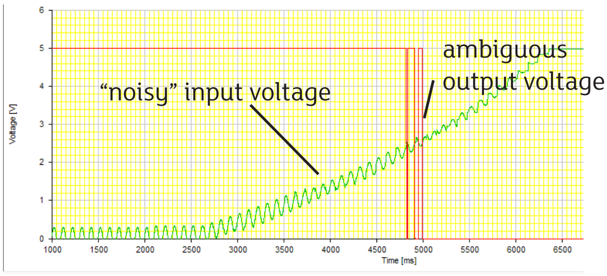
On closer examination we can see that the change from 1 to 2 (binary 010 to 010), involves a change in state for two optical switches at the same time. If these are out of sync by even a tiny amount, this could be detected as two separate changes. The situation is even worse when the sequence changes from 3 to 4 (binary 011 to 100). Here there are three changes at the same time. In order to avoid ambiguous counting, a disc encoded using the Gray code may be used. When counting using the Gray code, only one digit changes at a time so that there can be no ambiguity when using a Gray encoded disc.

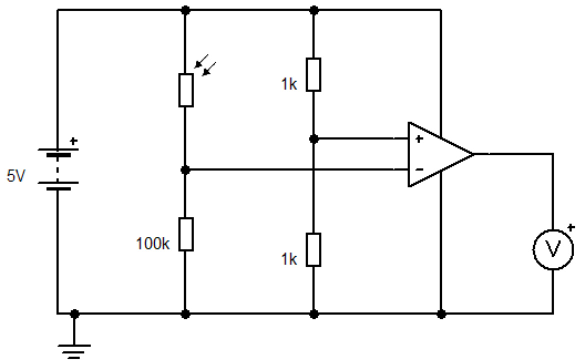
Decimal	Binary	Gray
0	000	000
1	001	001
2	010	011
3	011	010
4	100	110
5	101	111
6	110	101
7	111	100



Schmitt trigger

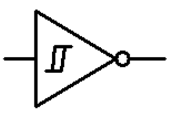
In Fact File 1.17 we saw that the purpose of a comparator is to compare 2 analogue voltages and give a digital output to indicate which input voltage is the greater. This is useful in converting a varying analogue voltage to a digital one. However, if the analogue voltage is changing slowly or is "noisy", there can be ambiguity at the changeover point, resulting in the output changing rapidly or oscillating.



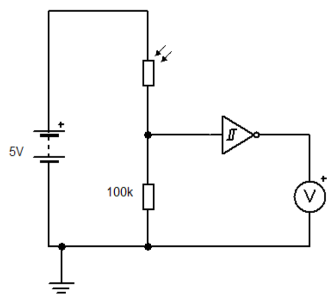


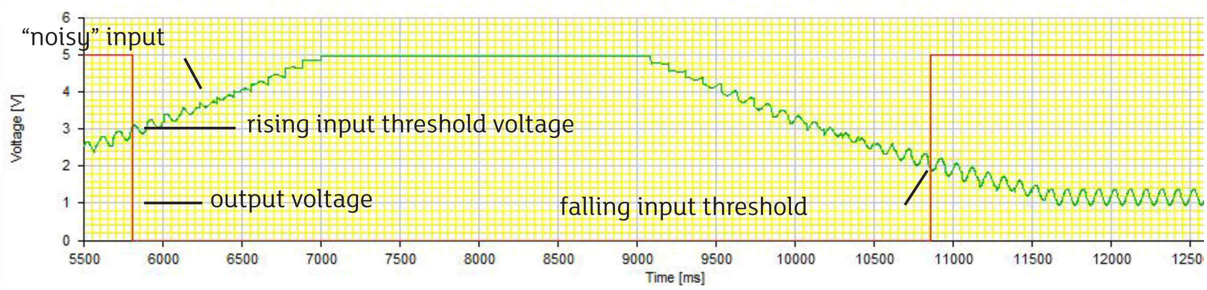
Comparator circuit

This problem may be solved using a special logic gate called a Schmitt trigger. The main feature of a Schmitt trigger is that it has a different rising input threshold voltage than falling input threshold voltage. Hence, once the output changes state, relatively small changes in the input voltage will have no effect.



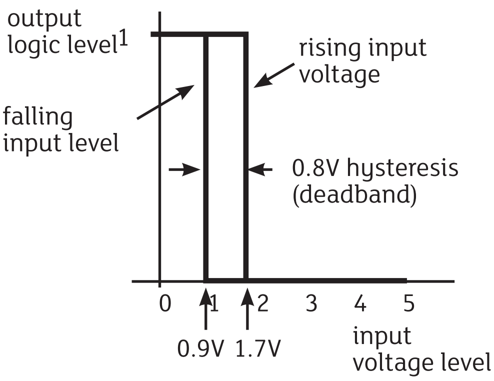
Symbol for Inverting Schmitt trigger





In this example the rising input threshold voltage is 3 V whilst the falling input threshold voltage is 2V. Once the input voltage reaches 3 V and the output changes over, the output cannot change again until the input falls below 2V. Note that the output is inverted since an Inverting Schmitt trigger has been used – this is the most commonly used Schmitt trigger. (Note also that the Schmitt trigger is a process device but has been included in this fact file for convenience,)

The property of a Schmitt trigger whereby the rising input threshold voltage is different from the falling input threshold voltage is called hysteresis. This is illustrated on the following graph of output voltage against input voltage for a device which exhibits hysteresis.



An important application of the Schmitt trigger is the regeneration of digital signals which have been affected by noise.

? Revision Questions

1 An electronic system has been devised to measure the deflection of steel beams under loading.

Fig. 1(a) shows how the beams are to be loaded using a hydraulic pump/actuator which is switched by an electrical control signal. The placement of strain gauges on the beam is shown along with the pattern of a typical strain gauge.

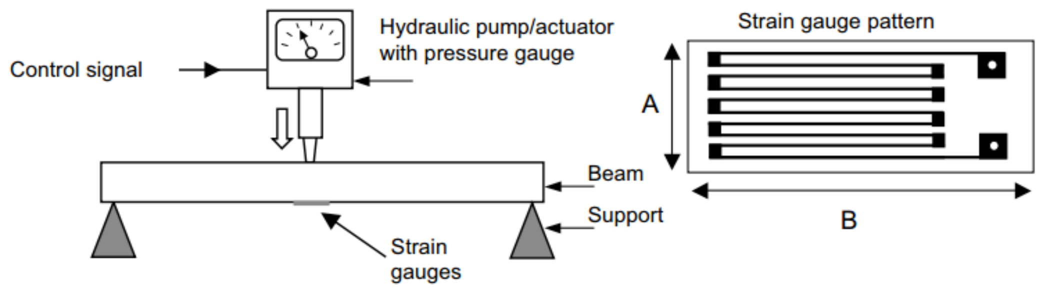


Fig. 1(a)

(a) (i) State the main physical property of a strain gauge that changes when the gauge is deformed.

....

....

(ii) With reference to the strain gauge pattern shown in Fig. 1(a), briefly explain the distinction between the active and passive axis on a strain gauge and state if axis A in Fig. 1(a) is the active or passive axis.

....

....

(iii) Two strain gauges are to be used to eliminate errors due to changes in temperature. With reference to the strain gauge in Fig. 1(a) describe with the aid of a sketch how to orientate the two gauges in order to eliminate errors due to temperature changes.

Revision Questions

2 Fig. 2(a) shows an incomplete circuit consisting of a 5 volt supply and two resistors, R1 and R2. The resistors are connected to an infra red LED and phototransistor respectively.

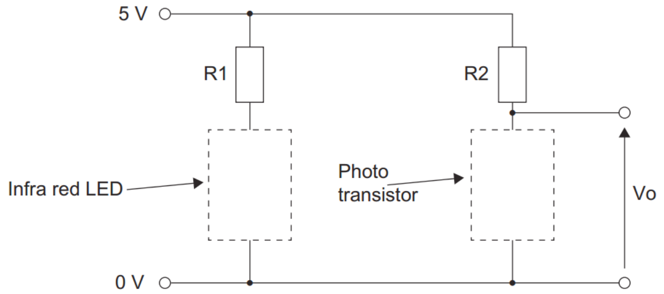


Fig. 2(a)

(a) (i) Draw the circuit symbols for an infra red LED and a phototransistor.

(ii) With the aid of a labelled graph, explain how the voltage Vo in Fig. 2(a) changes when a solid object passes between the infra red LED and the phototransistor.

Revision Questions

2 (iii) Show, with the aid of a diagram, how the circuit shown in Fig. 2(a) could be modified to incorporate an LED that will illuminate to indicate when the phototransistor is conducting.