FACTFILE:

GCE TECHNOLOGY & DESIGN

1.13 ELECTRONIC COMPONENTS

Electronic Components

Learning Outcomes:

Students should be able to:
- demonstrate knowledge and understanding of the following components:
  - resistors (colour code, E12 series, tolerance and power ratings);
  - capacitors – electrolytic and non-polarised; and
  - diodes (circuit protection with inductive loads)

Course Content

Resistance

Resistance is the property of a component which restricts the flow of electric current. Electrical energy is converted to heat energy as the voltage across the component drives the current through it.

Resistance is measured in ohms and the symbol for ohm is the Greek letter omega - Ω.
Since currents in electronic circuits tend to be milliamps rather than Amps, resistances are usually of the order of kilohms or megohms rather than ohms.

1 kΩ = 1000 Ω   1 MΩ = 1000000 Ω.

Resistors

Resistors are components which restrict or resist the flow of electric current.

Fixed resistors
If you are planning to make any product using standard materials and components, it is important to be aware of the value or sizes available. For instance if you are looking for a sheet of MDF 4 mm thick, you may be disappointed to find that it is available in 3mm or 6mm thicknesses and that you have to buy a sheet 2440 mm x 1220 mm. It is better to be aware of this before starting your design. Similarly electronic components such as resistors are available in only certain values, called the preferred values or nearest preferred values. For the purposes of this specification it is only necessary to be familiar with the E12 series. In the E12 series, there are 12 values of resistor available between 10 Ω and 100 Ω:

E12 Series

10	12	15	18	22	27	33	39	47	56	68	82
Do not learn these values!											

Similarly there are 12 values available between 1 Ω and 10 Ω, obtained by dividing each of these values by 10, and 12 values available between 100 Ω and 1000 Ω, obtained by multiplying each of these values by 10 and so on. (There are other series available from E6 to E192 where the values are selected using the same principle, but it is not necessary to be familiar with them for this specification.) It is not necessary to learn these values – they will be supplied in an examination question.

Worked Example

A pupil calculates that he requires the following resistors for his project: 230 Ω, 2.0 kΩ and 880 kΩ. Find the nearest preferred values.

Answers

By consulting the E12 series, the following values are obtained: 220Ω, either 1.8 kΩ or 2.2 kΩ and 820 kΩ

Tolerance of Resistors

When you buy a sheet of 3 mm mdf, the thickness may vary within a certain range. Similarly, the actual value of a resistor is not necessarily the value encoded on it, which is known as its nominal value. Like many objects, it is manufactured within a certain tolerance, perhaps 5% or 10%. A resistor encoded with the value 1000Ω and having a tolerance of 10% may have a value between 900Ω and 1100Ω. If it had a tolerance of 5%, its value would lie between 950Ω and 1050Ω.

Resistor Colour Code

In the E12 series, the value of each resistor is listed to 2 significant figures. As a result, the value of a resistor may be stated as a two digit number multiplied by a power of 10. For instance 470 Ω = 47 x 10^1Ω, 220 kΩ = 22 x 10^4 Ω 1 MΩ = 10 x 10^5Ω.

At one time the value of a resistor was written by hand on the body of the resistor. Modern resistors are much smaller and it is much more efficient for the values to be coded using coloured bands. Three coloured bands are used in order to code the nominal value of the resistor. The first and second bands represent digits. The third band, called the multiplier, is the number of zeros after the first 2 digits. The tolerance of a resistor is encoded on it using a coloured 4th band. A tolerance of 10% is indicated by a silver band and a tolerance of 5% is indicated by a gold band.

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	
Red	2	100	
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	
Blue	6	1,000,000	
Violet	7	10,000,000	
Grey	8		
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%

Do not learn these codes! **It is not necessary to learn these codes – they will be supplied in an examination question.**

For the examples given the colour codes would appear as follows, assuming a tolerance of 5%:

Nominal Value		First Band	Second Band	Multiplier	Tolerance	Resistor
470 Ω	47 x 10^1 Ω	Yellow	Violet	Brown	Gold	
220 kΩ	22 x 10^4 Ω,	Red	Red	Yellow	Gold	
1 MΩ	10 x 10^5 Ω.	Brown	Black	Green	Gold	

Worked Examples

1 A calculation shows you that you require a resistor with a value in the region of 230 Ω.

(a) What is the E12 nearest preferred value to 230Ω?
(b) If the resistor has a tolerance of 5%, what is the range of values that the nearest preferred value resistor could have?
(c) What is the complete colour code for this nearest preferred value resistor?

Answer:

(a) The E12 series gives the value 220 Ω
(b) 220 Ω +/- 11 gives the range 209 Ω to 231 Ω
(c) 220 Ω = 22 x 1 (5% tolerance) which is coded as Red Red Brown Gold

2 A resistor has a colour code - orange white yellow gold.
  (a) What is the value represented by this colour code?
  (b) What is the tolerance of this resistor?
  (c) Between what two values must the actual value of the resistor lie?

Answer:
(a) 39 x 10^4 Ω = 390 kΩ
(b) Gold represents 5%
(c) 390 kΩ +/- 19.5 kΩ = 370.5 kΩ to 409.5 kΩ

Power Ratings of Resistors

Electrical energy is converted to heat when current flows through a resistor. Usually the effect is not important, but if the resistance is low (or the voltage across the resistor high) a large current may pass making the resistor become warm to the touch. The resistor must be able to withstand the heating effect and so resistors with appropriate power ratings must be chosen.

For the majority of resistors used in circuits, a power rating of 0.25 W would be suitable. However it is wise to perform a simple calculation to check if a resistor with a higher power rating would be required. It is possible to obtain resistors with power ratings from 0.1 W to 100 W. This will be covered in Fact File 1.14.

Capacitors
Capacitors store electric charge. Capacitance is a measure of a capacitor's ability to store charge. A large capacitance means that more charge can be stored. Capacitance is measured in farads, symbol F. However 1F is very large, so prefixes are used to show the smaller values.

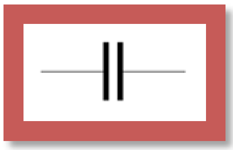
A IF capacitor would be enormous and impractical in terms of its physical size. We still have to use the farad as a unit as it is an SI quantity but in reality the smaller values are used.

Three prefixes (multipliers) are used, µ (micro), n (nano) and p (pico):

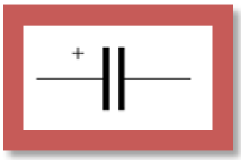
- µ means 10^{-6} (millionth), so 1000000µF = 1F
- n means 10^{-9} (thousand-millionth), so 1000nF = 1µF
- p means 10^{-12} (million-millionth), so 1000pF = 1nF

There are many types of capacitor but they can be split into two groups; polarised and non-polarised. Each group has its own circuit symbol.

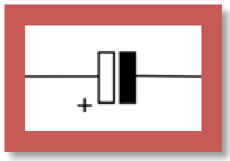
Circuit symbols



Non –polarised capacitor



Or



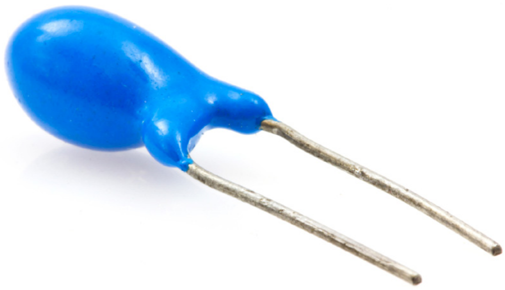
Electrolytic or polarised capacitor

Non-polarised capacitors
(small values, up to about 1µF)
Small value capacitors are unpolarised which means that they may be connected either way round. They are used to provide smoothing of the supply from a battery for instance. Another use is in providing short delays in timing circuits. They generally have high voltage ratings – perhaps 250 V or so.

Electrolytic (polarised) capacitors (values from about 1µF)
Polarised capacitors must be connected the correct way round. Their leads will be marked + or -. The voltage rating can be quite low (6 V for example) and it should always be checked when selecting a polarised capacitor. If the project parts list does not specify a voltage, choose a capacitor with a rating which is greater than the project's power supply voltage. A sensible minimum would be 25 V for most battery circuits. They are physically much smaller and also cheaper than non-polarised

capacitors of the same value which is why they are used. They are used to smooth the DC output of a mains power supply by acting as a reservoir of charge. They are also used to provide long delays in timing circuits. One disadvantage of electrolytic capacitors is that they have a relatively large leakage which means that they lose their charge even when not connected in a discharging circuit. They also have a relatively large tolerance, in some cases +80% / - 20%. This means that they may not be used for accurate timing applications.

Aluminium electrolytic capacitor

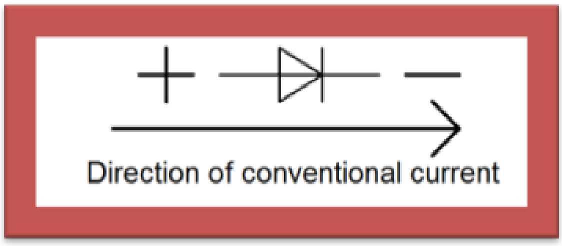


Tantalum capacitor

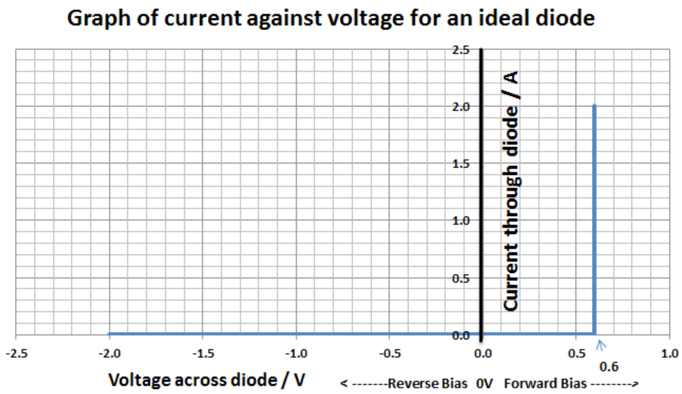
A special type of polarised capacitor, the tantalum capacitor has a number of advantages over traditional aluminium electrolytic capacitors. They are physically much smaller, have low leakage and close tolerance. As a result, they are usually more expensive and tend only to be used for specialist applications.

Diodes

The diode is the simplest semiconductor device, and has two terminals (connections). The diode functions as an electrical one way valve.
Its symbol and the direction in which conventional current flows (from +ve to -ve) is shown in the diagram. When connected like this it is said to be forward biased. When connected in the opposite direction, no current flows and it is said to be reverse biased.

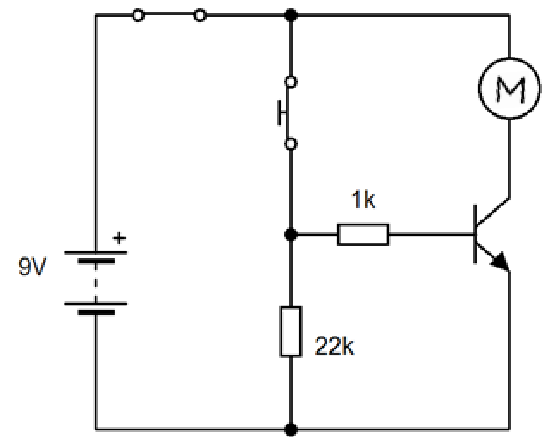


Characteristic Graph
The current through an electrical component usually depends on the potential difference (voltage) across it. The relationship between the current and voltage can be seen using the "characteristic graph" of current against voltage.

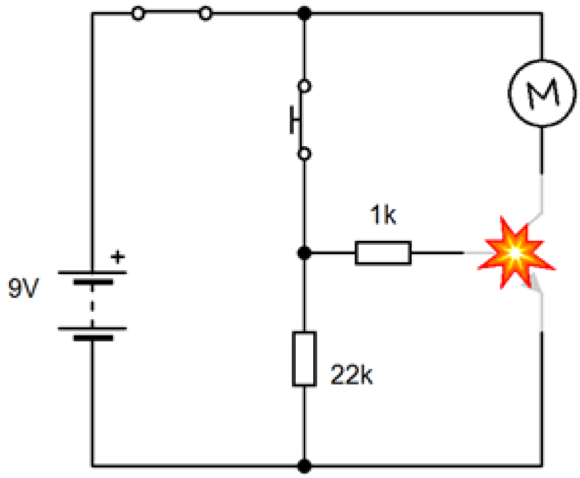


For simplicity, we can usually regard the diode as behaving as shown in the "Ideal Characteristic" - i.e. the current is zero when reverse biased or when the forward bias voltage is small. When the forward biased voltage reaches 0.6 V, current suddenly flows.

Inductive loads and back e.m.f.
When a current is flowing in an inductive load such as a motor, solenoid or relay coil, magnetic energy is stored in the coil of the load.

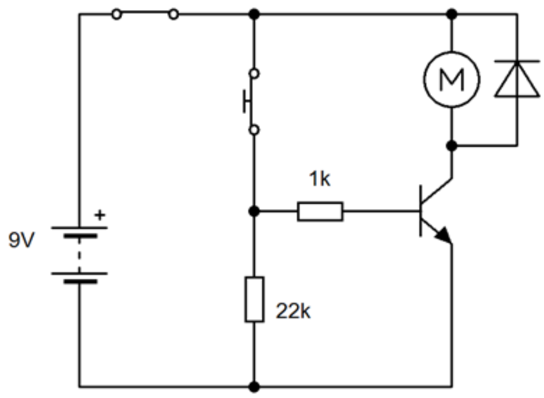


When the current is stopped suddenly, the magnetic energy generates a voltage in the opposite direction to the original applied voltage, called a back emf. It is possible for this to be quite a large voltage, of the order of hundreds of volts. This may easily damage any “active” components such as transistors or integrated circuits.



When the motor stops suddenly, a large back emf is generated in the opposite direction of the original voltage.

Diodes and back e.m.f.
If a diode is placed in parallel with the inductive load as shown, under normal circumstances it does not conduct since it is reverse biased. However when the back emf is generated in the opposite direction to the original voltage, the diode conducts immediately and the voltage is prevented from doing any damage.



Revision Questions

1. A resistor (shown in a circuit) is taken from the E12 series. State what is meant by the term E12 series.

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2. The resistor R (shown in a circuit) has a specified tolerance. Explain what is meant by tolerance when referring to resistors.

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3. Fixed resistors have a tolerance. Explain with an example, what is meant by the term tolerance when referring to fixed resistors.

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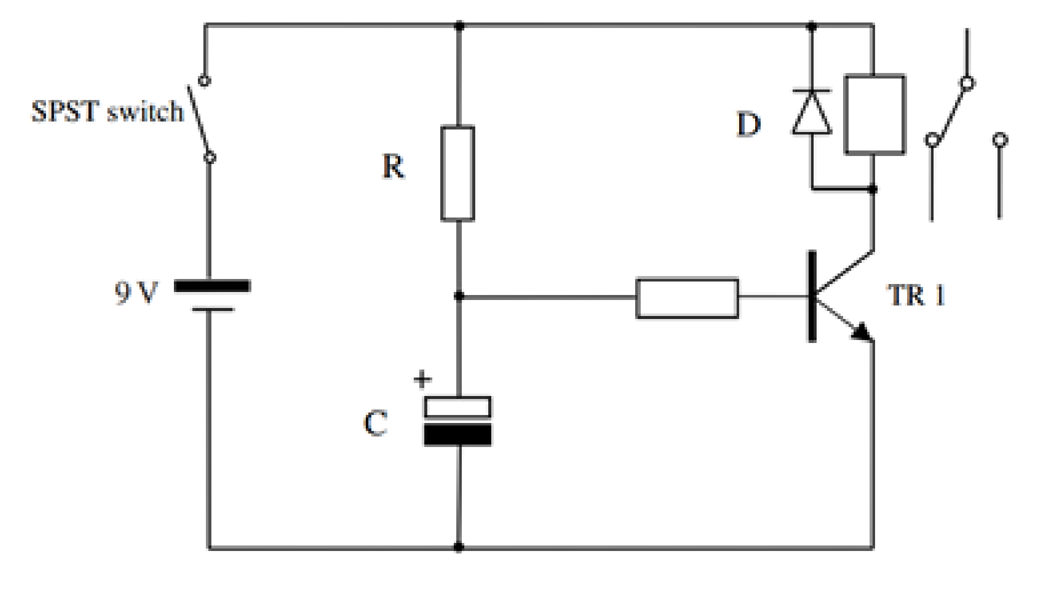
Revision Questions

4 The figure below shows an electronic timing circuit.



(i) State the function of the diode D in the circuit shown.

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(ii) State one main feature an electrolytic capacitor that makes it suitable for a timing circuit.

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