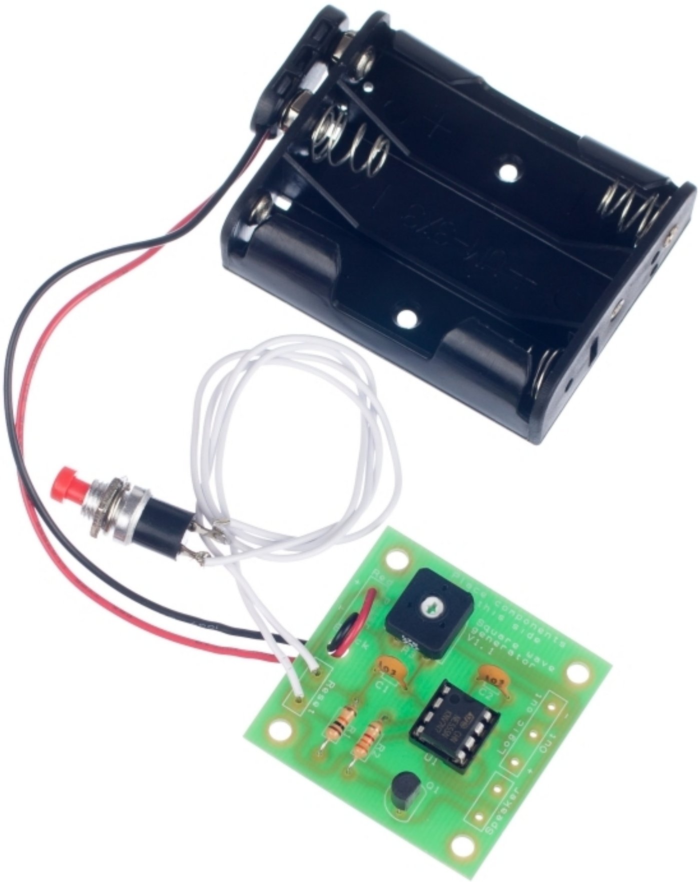
TEACHING RESOURCES

SCHEMES OF WORK
DEVELOPING A SPECIFICATION
COMPONENT FACTSHEETS
HOW TO SOLDER GUIDE

INVESTIGATE THE 555 TIMER CHIP WITH THIS

555 TIMER ASTABLE KIT



Version 2.0

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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. 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. Homework: Collect examples of doorbells or similar products. 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. Resource: Sample of products. Homework: Using the internet or other search method, find out what is meant by 'design for manufacture'. List five reasons why design for manufacture should be considered on any design project.
Hour 3	Read 'Designing the Enclosure' sheet. Develop a product design using the 'Design' sheet. Homework: 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.
Hour 5	Split the students into groups and get them to perform a group design review using the 'Design Review' sheet.
Hour 6	Using the 'Soldering in Ten Steps' sheet, demonstrate and get students to practice soldering. Start the 'Resistor Value' and 'Capacitor Basics' worksheets. Homework: Complete any of the remaining resistor / capacitor 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 PCB' section and the fault finding flow chart. Homework: Read 'How the Square Wave Generator Works' 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 PCB’ and fault finding flow chart.

Answers

Resistor questions

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*

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

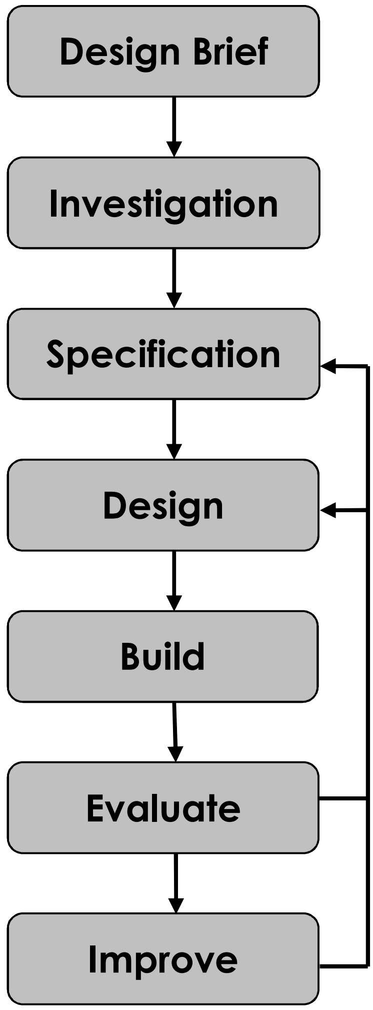
Printing on capacitor	Two digit start	Number of zero’s	Value in pF
222	22	00	2200pF (2.2nF)
103	10	000	10000pF (10nF)
333	33	000	33000pF (33nF)
473	47	000	47000pF (47nF)

RC Time Constants

Resistor Value	Capacitor Value	RC Time Constant
2,000,000 (2MΩ)	**0.000,1 (100µF)**	200 Seconds
100,000 (100KΩ)	**0.000,1 (100µF)**	10 Seconds
100,000 (100KΩ)	**0.000,047 (47µF)**	4.7 Seconds

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.

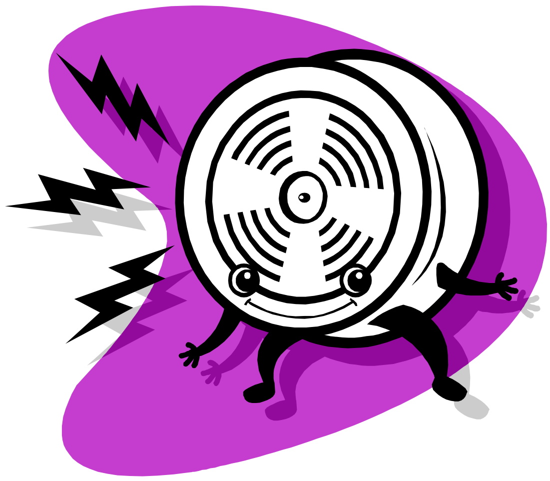
Evaluate

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



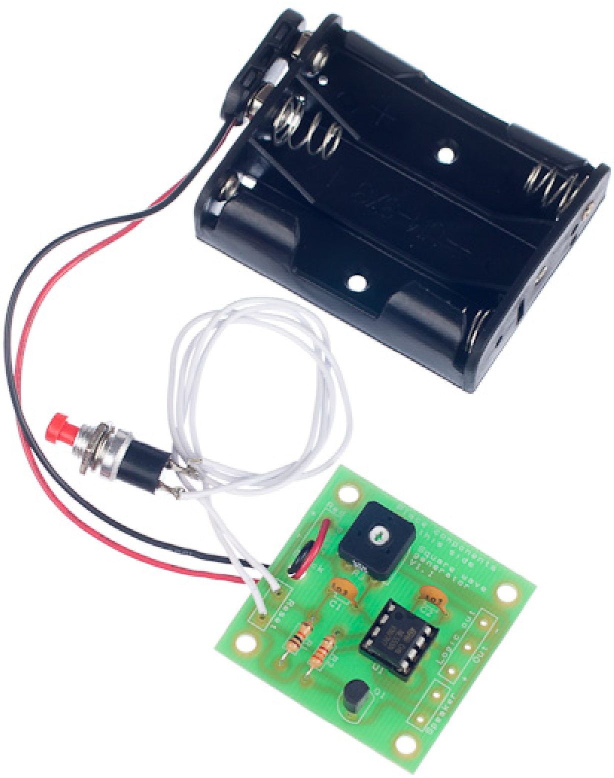
A doorbell manufacturer has developed a simple circuit for producing a doorbell sound. The circuit outputs a signal that can drive a speaker so that it makes a tone. The frequency (pitch) of the tone can be varied by a variable resistor on the PCB. The circuit has been developed to the point where they have a working Printed Circuit Board (PCB).

The manufacturer would like ideas for an enclosure for the PCB and speaker and also for the doorbell button. The manufacturer has asked you to do this for them. The design wants to be different from those already on the market.

It is important that you make sure that the final design meets all of the requirements that you identify for such a product.

* This requires the addition of a speaker to the kit.

Complete Circuit



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 enclosure should have holes in it.	Example: So that sound from the speaker can be heard.

Design

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

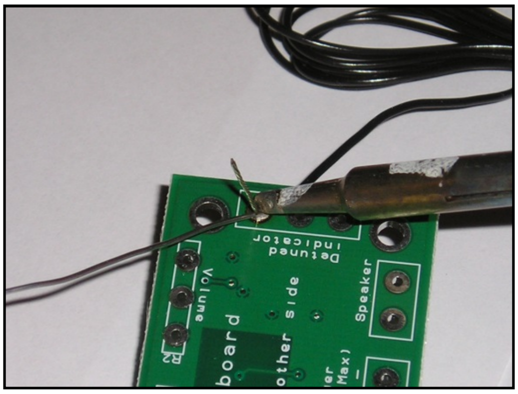
Name……………………………………………… Class…………………………….

Design Review (group task)

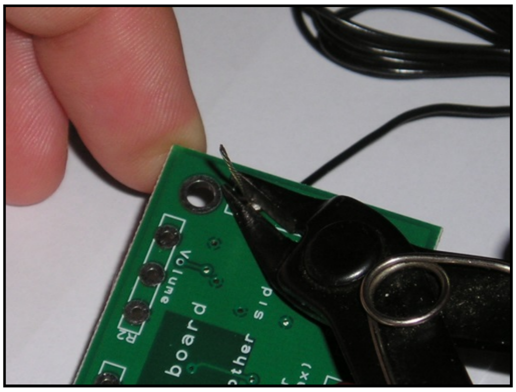
Split into groups of three or four. Take it in turns to review each person's design against the requirements of their specification. Also look to see if you can spot any additional aspects of each design that may cause problems with the final product. This will allow you to ensure that you have a good 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.

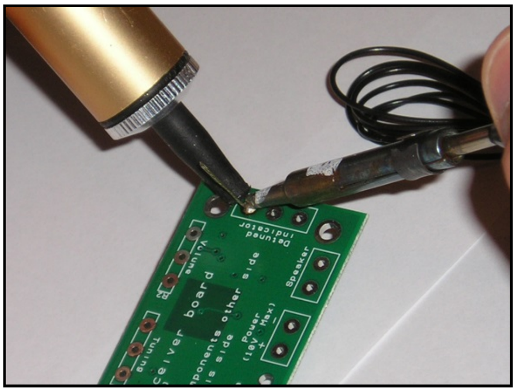
Comment	Reason for comment	Accept or Reject

Soldering in Ten Steps

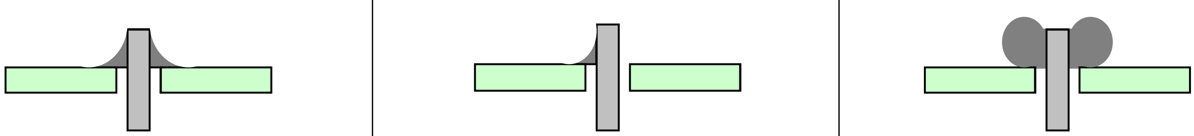


1. Start with the smallest components working up to the taller components, soldering any interconnecting wires last.
2. Place the component into the board, making sure that it goes in the right way around and the part sits flush against the board.
3. Bend the leads slightly to secure the part.
4. Make 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

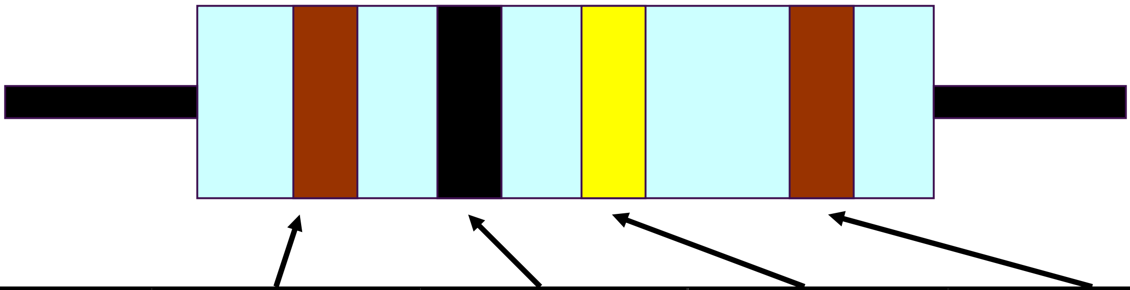


Good solder joint | Too little solder | Too much solder

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 Ω (ohms) and is often referred to as its 'resistance'.

Identifying resistor values



Band Colour	1st Band	2nd Band	Multiplier x	Tolerance
Silver			÷ 100	10%
Gold			÷ 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:
2 (Red) **7** (Violet) x **1,000** (Orange) = 27 x 1,000
= **27,000** with a 5% tolerance (gold)
= **27KΩ**

Too many zeros?

Kilo ohms and mega ohms can be used:

1,000Ω = 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 Ω			
3,900 Ω			
47,000 (47K) Ω			
1,000,000 (1M) Ω			

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

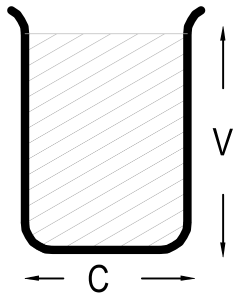
There are a number of different ranges of values for resistors. Two of the most popular are the E12 and E24. They take into account the manufacturing tolerance and are chosen such that there is a minimum overlap between the upper possible value of the first value in the series and the lowest possible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

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

E-24 resistance tolerance (± 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

Capacitor Basics

What is a capacitor?

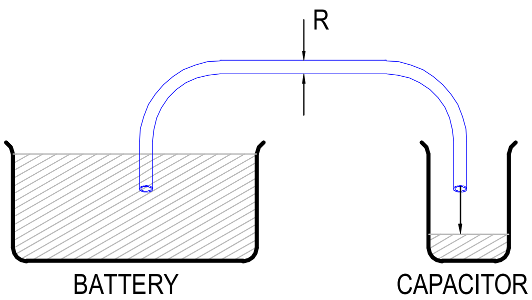


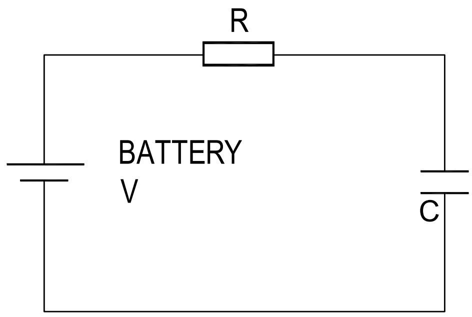
A capacitor is a component that can store electrical charge (electricity). In many ways, it is like a rechargeable battery.

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

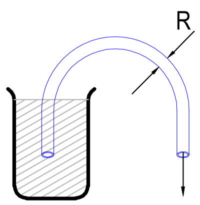




When a capacitor is connected to an item such as a battery, charge will flow from the battery into it. Therefore the capacitor will begin to fill up. The flow of water in the picture above left is the equivalent of how the electrical charge will flow in the circuit shown on the right.

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

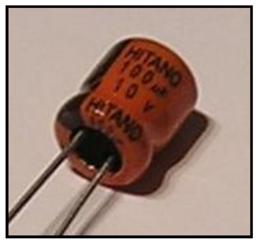


Once a capacitor has been filled with an amount of charge, it will retain this charge until it is connected to something into which this charge can flow.

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

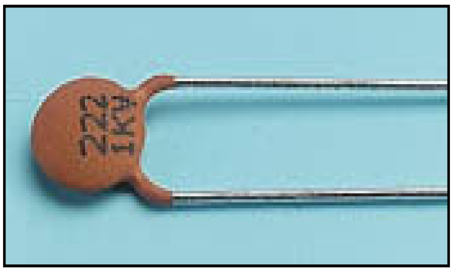
Values

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 (μF), nano Farads (nF) and pico Farads (pF). A μF is a millionth of a Farad, 1μF = 1000 nF and 1nF = 1000 pF.

1F	= 1,000mF
1F	= 1,000,000μF
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 μF)

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			

RC Time Constants

The amount of time taken to charge (fill) or discharge (empty) the capacitor to a given voltage depends upon how quickly charge is allowed to flow into the capacitor. If a capacitor is connected across a battery without a resistor, it will charge to the same voltage as the battery almost instantly as the flow of charge is not opposed. If however, a current limiting resistor is placed in series with the capacitor, the charge is opposed and the capacitor charges at a slower rate. When a resistor and capacitor are used together, an RC timing circuit is produced. The RC timing circuit can be used to produce delays; the amount of time taken to get to 70% of the final voltage is given by the resistance times the capacitance.

Example of calculating RC constants for a 1MΩ resistor and a 100µF capacitor:

T = R x C
T = 1,000,000 (1M) x 0.000,1 (100µF)
T = 100 Seconds

So an RC of 1 second could be produced with a 10K resistor and 100µF capacitor.

Resistor Value	Capacitor Value	RC Time Constant
2,000,000 (2MΩ)	**0.000,1 (100µF)**	
100,000 (100KΩ)	**0.000,1 (100µF)**	
100,000 (100KΩ)	**0.000,047 (47µF)**	

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

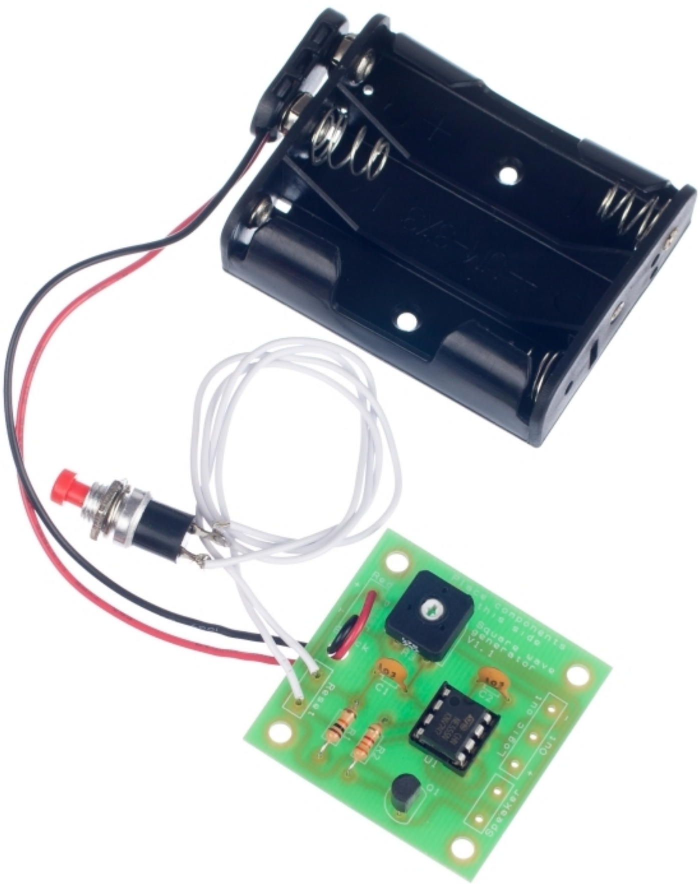
Develop a packaging design for your product that meets these requirements. Use additional pages if required.

ESSENTIAL INFORMATION

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

INVESTIGATE THE 555 TIMER CHIP WITH THIS

555 TIMER ASTABLE KIT



Version 2.0

555 Timer Astable Essentials

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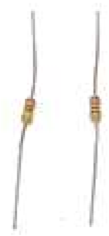
Build Instructions

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 two 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	10KΩ	Brown, black, orange
R2	3.3KΩ	Orange, orange, red

2 SOLDER THE CAPACITORS

Place the two 10nF capacitors into the board where it is labelled C1 and C2. It does not matter which way around the devices are fitted.

3 SOLDER THE TRANSISTOR

Place the BC547 transistor into the board where it is labelled Q1. Make sure that the device is the correct way around. The shape of the device should match the outline on the PCB.

4 SOLDER THE POTENTIOMETER

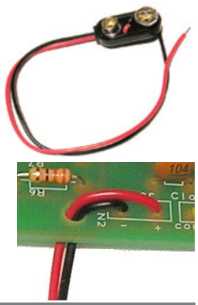
The 47KΩ variable potentiometers should be soldered into R3 on the PCB. The legs on the device should be matched with the holes on the PCB.

5 SOLDER THE IC HOLDER

Solder the Integrated Circuit (IC) holder into U1. When putting it into the board, be sure to get it the right way around. The notch on the IC holder should line up with the notch on the lines marked on the PCB.

6 ATTACH THE BATTERY CLIP

Now you must attach the battery clip. Start by feeding the leads through the strain relief hole between the power and reset connections. The wire should be fed in from the rear of the board (see right, below).
The leads should be connected to the 'Power' terminals. The red lead should be soldered to the '+' terminal (also marked with text 'red') and the black lead should be soldered to the '-' terminal (also marked with the text 'black').



7 CONNECT THE SPEAKER

To connect the speaker to you need to cut two pieces of wire to the desired length. Strip both ends and solder them into ‘Speaker’ and the other end to the tabs on the speaker. The wires can go either way around.

8 SOLDER THE SWITCH

Cut and strip two pieces of wire to the required length for connecting to the switch. Solder one end of each wire to each of the terminals on the switch and the other end to the terminals labelled ‘Reset’. It does not matter which wire goes to which terminal.

9 INSERT THE IC INTO HOLDER

The IC can now be put into the holder, ensuring that the notch on the chip lines up with the notch on the holder.

Using the Logic Output

The square wave generator board can be used to drive logic instead of a speaker. When the logic output is to be used the speaker doesn't need to be present and connections to the 'logic out' can be made as follows:

+ This is the positive power
- This is 0 Volts
Out This is the logic level output

Checking Your PCB

Check the following before you power up the unit:

Check the bottom of the board to ensure that:

- All holes (except the large mounting 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 notch on the 555 IC matches the outline on the PCB.
- The shape of the transistor matches the outline on the PCB.
- The resistor bands on R1 are brown, black and orange.
- All the connecting leads are connected to the right part and that the power connection is the right way around.

555 Timer Astable Essentials

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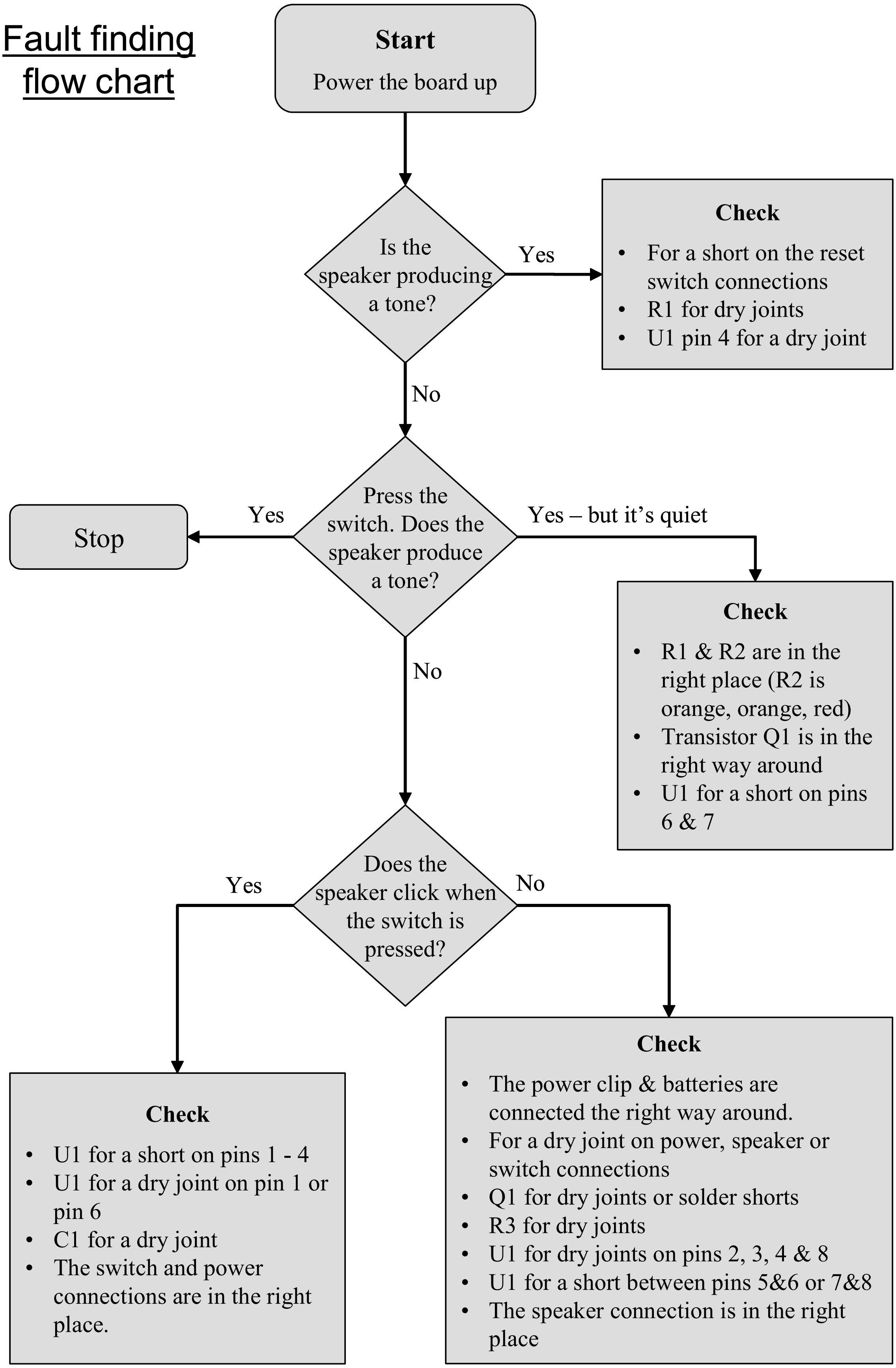
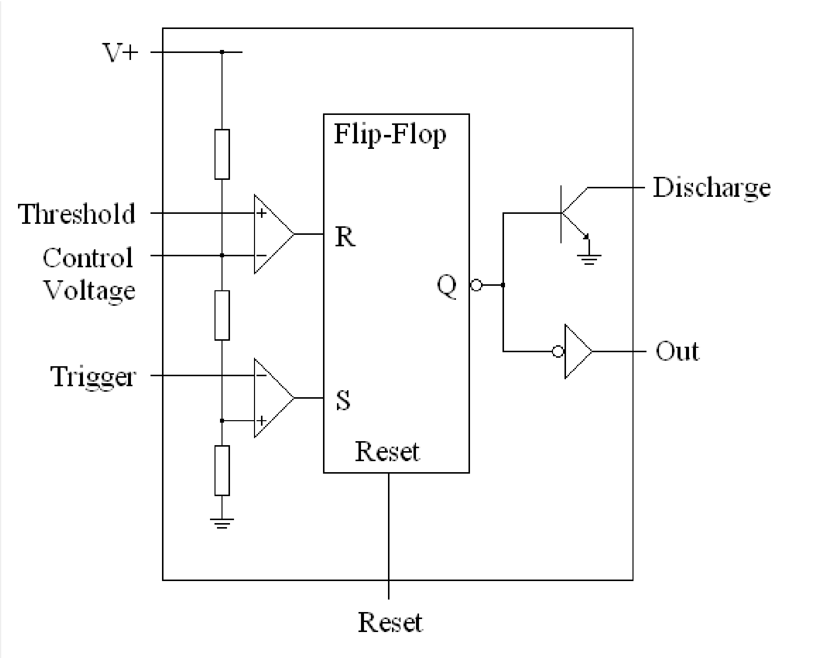
Fault finding flow chart



The 555 IC



Operating Overview

The 555 Timer is a simple integrated circuit. By taking the trigger signal from high to low, the flip-flop is set. This causes the output to go high and the discharge pin to be released from Gnd (0V). The releasing of the discharge pin from Gnd causes an external capacitor to begin charging.

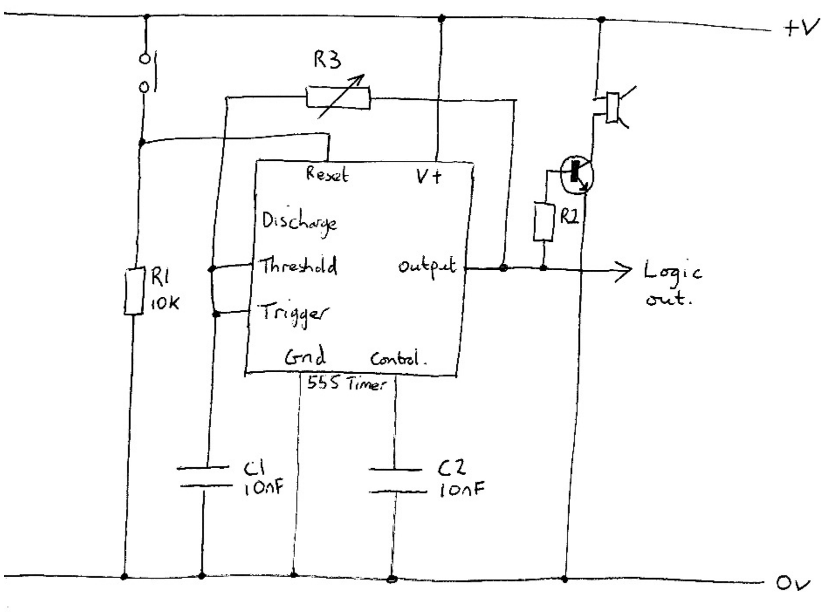
When the capacitor is charged, the voltage across it increases. This results in the voltage on the threshold pin increasing. When this is high enough it will result in the threshold pin, causing the flip-flop to reset.

This causes the output to go low and the discharge pin is also taken back to Gnd. This discharges the external capacitor, ready for the next time that the device is triggered.

Pin Descriptions

V+ = Supply voltage.
GND = Gnd (0V) connection for supply voltage.
Threshold = Active high input pin that is used to monitor the charging of the timing capacitor.
Control Voltage = Used to adjust the threshold voltage if required. This should be left disconnected if the function is not required. A 0.01uF capacitor to Gnd can be used in electrically noisy circuits.
Trigger = Active low trigger input that start the timer.
Discharge = Output pin that is used to discharge the timing capacitor.
Out = Timer output pin.
Reset = Active low reset pin. Normally connected to V+ if the reset function is not required.

How the Square Wave Generator Works



555 timer

The 555 Timer needs to be configured as an astable timer (it outputs a continuous alternating signal). In this configuration the 555 Timer re-triggers itself after each cycle, which results in the continuous alternating signal.

The frequency of the output frequency is determined by the time taken to charge the 10nF capacitor C1. This capacitor charges through the 47K variable resistor R3. When the output of the circuit (pin 3) goes high, C1 begins to charge until the voltage across it is high enough to activate the threshold input. This causes the output to go low and the capacitor now starts to discharge through R3. This continues until the voltage across C1 is low enough to activate the (active low) trigger input. The output now goes high and the process is repeated.

The minimum 555 output frequency is determined as follows:

$$f = \frac{1.44}{R3 \times C1} \qquad f = \frac{1.49}{47K \times 10nF}$$

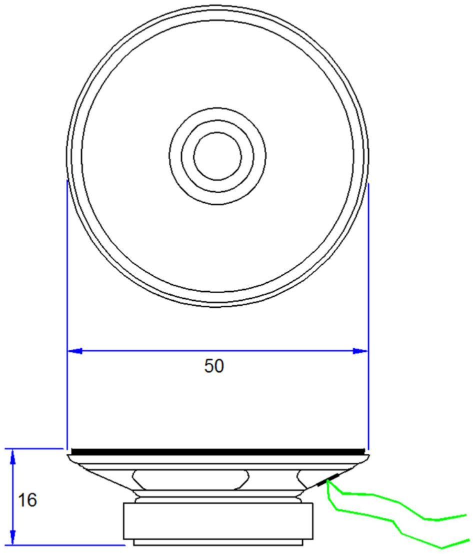
Hence f is approx. 3.2KHz.

The output signal is used to switch the transistor. The transistor is used as it allows larger loads (i.e. the speaker) to be driven than the 555 Timer output could drive on its own.

The reset line is active low, this means that to the hold the timer in reset so that the timer stops, the reset line is taken low and in normal operation it is taken high. This is implemented with the 10K pull down resistor R1 and the push to make switch between the reset pin and the supply line. When this buttons is pressed the circuit operates and the tone is generated. When it is released the circuit is held in reset and no tone is generated.

The capacitor C2 on the control voltage (CV) pin is present for improved noise immunity.

Designing the Enclosure

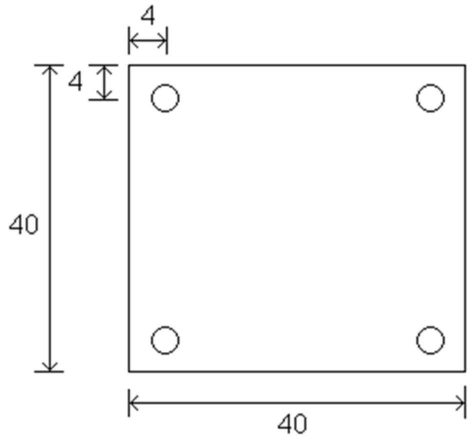


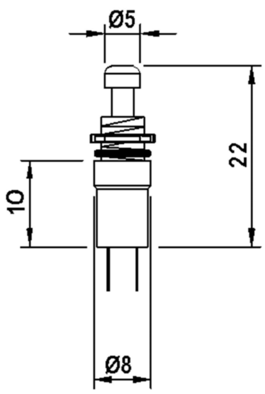
When you design the enclosure, you will need to consider:

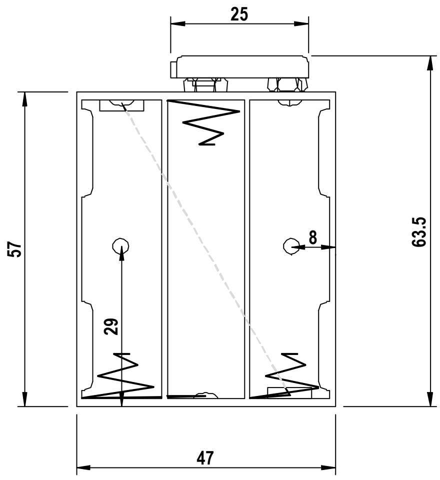
- The size of the PCB (below left).
- Where the batteries will be housed.
- Where the switch will be mounted.
- Where the speaker will be mounted (if you are using one).

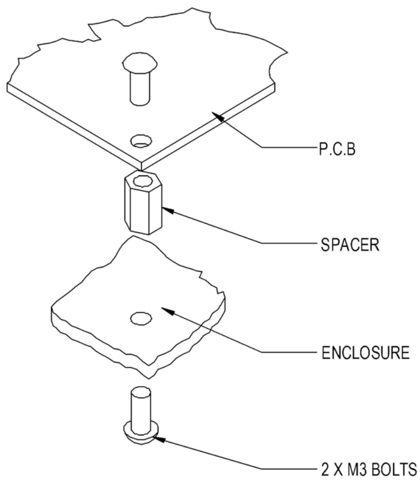
This technical drawing PCB and other components should help you to design your enclosure.

All dimensions are in mm. The PCB has four mounting holes 3.3mm in diameter.









Mounting the PCB to the enclosure

The drawing to the left shows how a hex spacer can be used with two bolts to fix the PCB to the enclosure.

Your PCB has four mounting holes designed to take M3 bolts.

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/2117

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