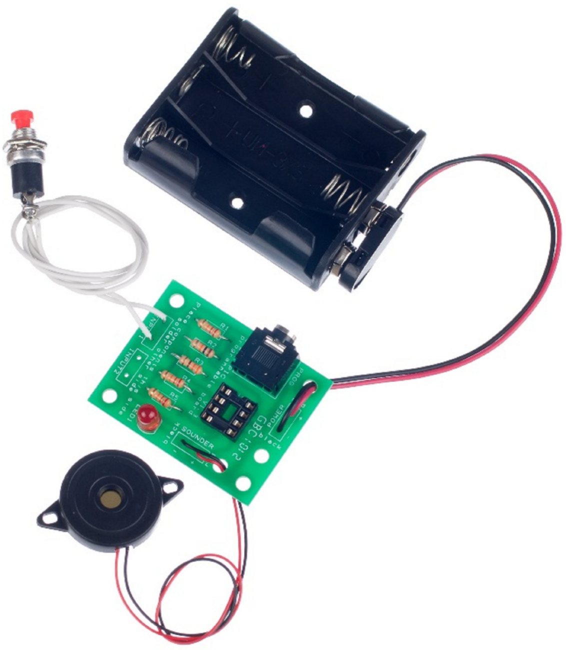
TEACHING RESOURCES

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

CREATE YOUR OWN UNQUIE TIMER WITH THIS

PROGRAMMABLE TIMER KIT



Version 2.0

Index of Sheets

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 timing products that are currently on sale. These may include clocks, watches, stop watches etc. List the common features that make these suitable for their intended use.
Hour 2	Develop a specification for the project using the ‘Developing a Specification’ sheet. Resource: Sample timing 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	Split the students into groups and get them to perform a group design review using the ‘Design Review’ sheet. Start the ‘Resistors’ sheet. Homework: Complete any of the remaining resistor tasks.
Hour 5	Using the ‘How to solder’ sheet demonstrate and get students to practice soldering.
Hour 6	Build the electronic kit using the ‘Build Instructions’.
Hour 7	Complete the build of the electronic kit. Check the completed PCB and fault find if required using ‘Checking Your Timer PCB’ and fault finding flow charts. Homework: Read ‘How the Timer Works’ sheet.
Hour 8	Programming task 1 – The basic timer.
Hour 9	Programming task 2 – The timer with time up warning bleeps.
Hour 10	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 11	Build the enclosure. Homework: Collect some examples of instruction manuals.
Hour 12	Build the enclosure. Homework: Read ‘Instructions’ sheet and start developing instructions for the student’s timer design.
Hour 13	Build the enclosure. Homework: Complete instructions for the student’s timer design.
Hour 14	Using the ‘Evaluation and Improvement’ sheet, get the students to evaluate their final product and state where improvements can be made.

Additional Work
Programming tasks,
- Task 3 - User configurable delay
- Task 4 - Musical

Package design for those who complete ahead of others.

Electronics only

Hour 1	Introduction to the kit demonstrating a built unit. Using the 'How to solder' sheet practice soldering.
Hour 2	Build the kit using the 'Build Instructions'.
Hour 3	Check the completed PCB and fault find if required using the 'Checking Your timer PCB' and fault finding flow charts.
Hour 4	Programming task 1 – The basic timer.

Answers

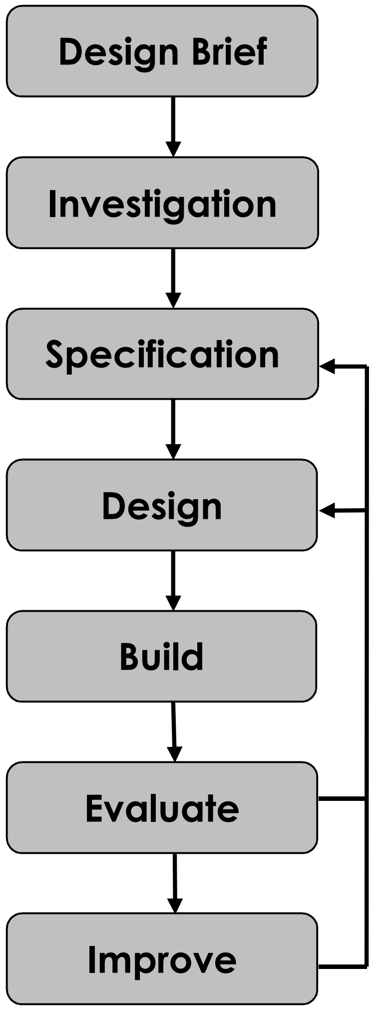
Resistor questions

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*

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

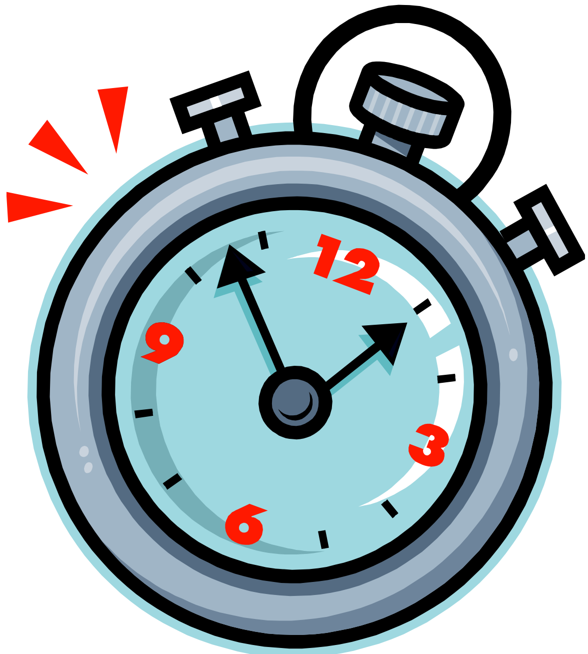
Do you feel the product could be improved in any way? These improvements can be added to the design.

The Design Brief

A clock manufacturer has designed a simple timer. The timer will be very cheap to produce and can be used for applications that do not require split second accuracy.

The manufacturer can think of a great many applications that the timer could be used for, such as for timing peoples turns on a board game.

The manufacturer would like you to research and select a particular use for the timer. They would then like you to produce a design that is suitable for that use. The design must meet all the requirements of the selected target market.

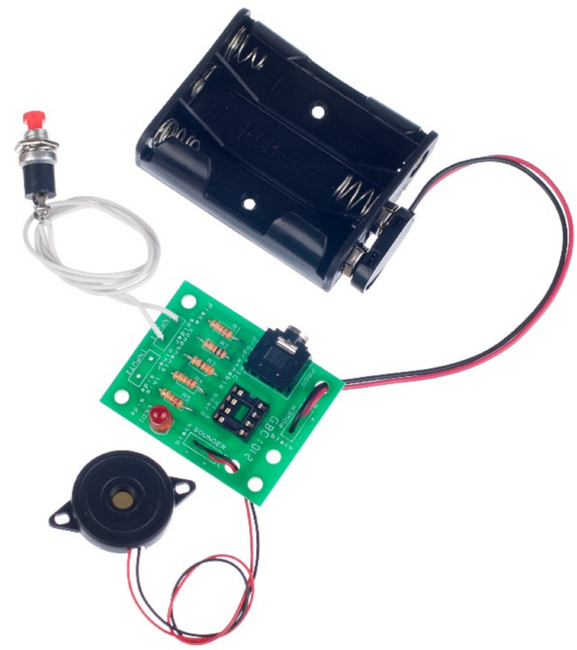


Description of the Timer

Once the timer is started it waits for a period of time and then produces a tone using a sounder. As the timer is programmable the duration of the timer and how long it sounds for can be adjusted. A push button switch is used to start the timer.

Complete Circuit

A fully built circuit is shown below.



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 some holes.	Example: So that the sound can be heard.

Design

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

Name…………………………………………… Class……………………………

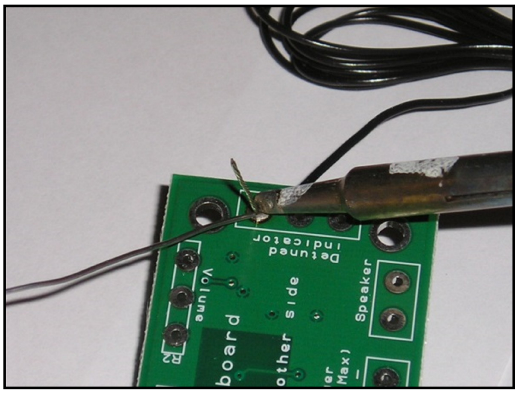
Design Review (group task)

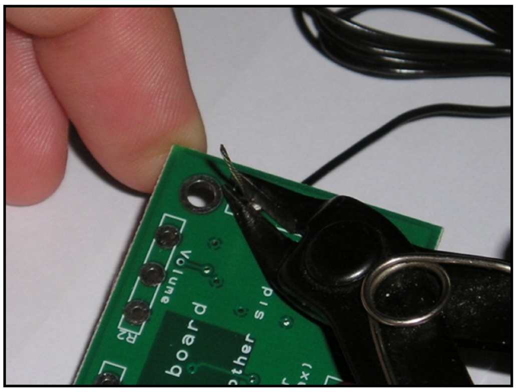
Split into groups of three or four. Take it in turns to review each person's design against the requirements of their specification. Also look to see if you can spot any additional aspects of each design that may cause problems with the final product. This will allow you to ensure that you have a good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

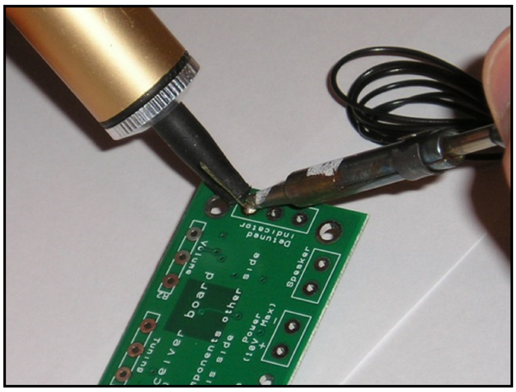
Comment	Reason for comment	Accept or Reject

Soldering in Ten Steps

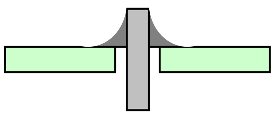
1. Start with the smallest components working up to the taller components, soldering any interconnecting wires last.
2. Place the component into the board, making sure that it goes in the right way around and the part sits flush against the board.
3. Bend the leads slightly to secure the part.
4. Make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



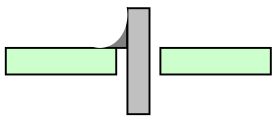




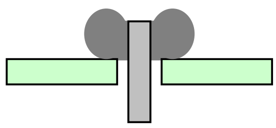
Solder joints



Good solder joint



Too little solder

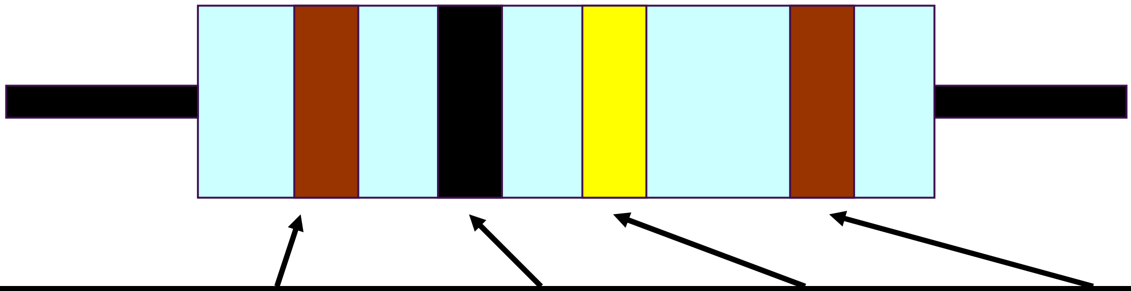


Too much solder

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

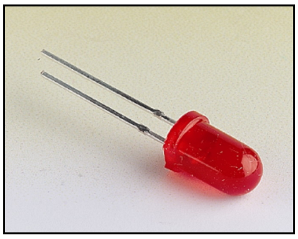
There are a number of different ranges of values for resistors. Two of the most popular are the E12 and E24. They take into account the manufacturing tolerance and are chosen such that there is a minimum overlap between the upper possible value of the first value in the series and the lowest possible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

LEDs & Current Limit Resistors

Before we look at LEDs, we first need to start with diodes. Diodes are used to control the direction of flow of electricity. In one direction they allow the current to flow through the diode, in the other direction the current is blocked.



An LED is a special diode. LED stands for Light Emitting Diode. LEDs are like normal diodes, in that they only allow current to flow in one direction, however when the current is flowing the LED lights.

The symbol for an LED is the same as the diode but with the addition of two arrows to show that there is light coming from the diode. As the LED only allows current to flow in one direction, it's important that we can work out which way the electricity will flow. This is indicated by a flat edge on the LED.

For an LED to light properly, the amount of current that flows through it needs to be controlled. To do this we use a current limit resistor. If we didn’t use a current limit resistor the LED would be very bright for a short amount of time, before being permanently destroyed.

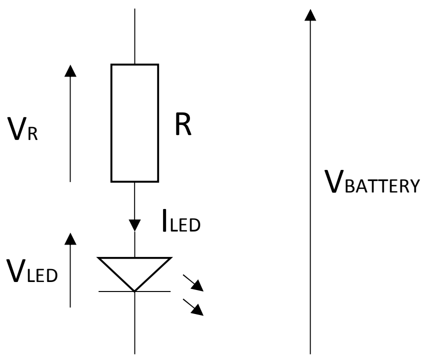
To work out the best resistor value we need to use Ohms Law. This connects the voltage across a device and the current flowing through it to its resistance.

Ohms Law tells us that the flow of current (I) in a circuit is given by the voltage (V) across the circuit divided by the resistance (R) of the circuit.

$$I = \frac{V}{R}$$

Like diodes, LEDs drop some voltage across them. For a high brightness white LED this is 3.5 volts.

Suppose this LED is run off a 5V supply there must be a total of 5 volts dropped across the LED (V_{LED}) and the resistor (V_R). As the LED manufacturer’s datasheet tells us that there is 3.5 volts dropped across the LED, there must be 1.5 volts dropped across the resistor. ($V_{LED} + V_R = 3.5 + 1.5 = 5V$).



LEDs normally need about 10mA to operate at a good brightness. Since we know that the voltage across the current limit resistor is 1.5 volts and we know that the current flowing through it is 0.01 Amps, the resistor can be calculated.

Using Ohms Law in a slightly rearranged format:

$$R = \frac{V}{I} = \frac{1.5}{0.01} = 150\Omega$$

Hence in this circuit we would need a 150Ω current limit resistor.

LEDs Continued

Packages

LEDs are available in many shapes and sizes. The 5mm round LED is the most common. The colour of the plastic lens is often the same as the actual colour of light emitted – but not always with high brightness LEDs.

Advantages of using LEDs over bulbs

Some of the advantages of using an LED over a traditional bulb are:

Power efficiency	LEDs use less power to produce the same amount of light, which means that they are more efficient. This makes them ideal for battery power applications.
Long life	LEDs have a very long life when compared to normal light bulbs. They also fail by gradually dimming over time instead of a sharp burn out.
Low temperature	Due to the higher efficiency of LEDs, they can run much cooler than a bulb.
Hard to break	LEDs are much more resistant to mechanical shock, making them more difficult to break than a bulb.
Small	LEDs can be made very small. This allows them to be used in many applications, which would not be possible with a bulb.
Fast turn on	LEDs can light up faster than normal light bulbs, making them ideal for use in car break lights.

Disadvantages of using LEDs

Some of the disadvantages of using an LED over a traditional bulb are:

Cost	LEDs currently cost more for the same light output than traditional bulbs. However, this needs to be balanced against the lower running cost of LEDs due to their greater efficiency.
Drive circuit	To work in the desired manner, an LED must be supplied with the correct current. This could take the form of a series resistor or a regulated power supply.
Directional	LEDs normally produce a light that is focused in one direction, which is not ideal for some applications.

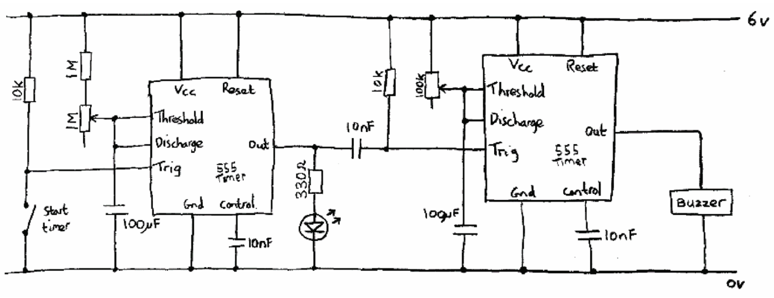
Typical LED applications

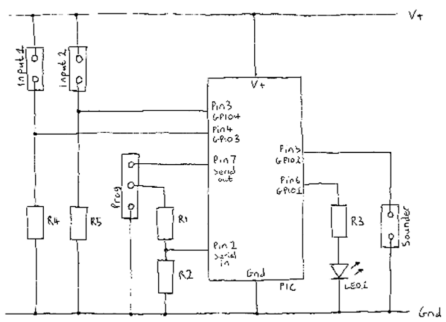
Some applications that use LEDs are:

- Bicycle lights
- Car lights (break and headlights)
- Traffic lights
- Indicator lights on consumer electronics
- Torches
- Backlights on flat screen TVs and displays
- Road signs
- Information displays
- Household lights
- Clocks

Why use a PIC micro-controller?

This timer could be built using two 555 timers instead of the micro-controller. The 555 timer circuit needs lots of extra components to work and as a result it is bigger. This can be clearly seen if you look at the two circuit diagrams below. The one on the left is the 555 timer based circuit (19 parts) and the one on the right is the micro-controller based circuit (11 parts).





There are a number of other advantages of using a micro-controller; some of these are outlined below.

Advantages of using PIC micro-controllers:

- Complex functionality can be produced a very low cost.
- Circuit size (as described above).
- It is very easy to make minor alterations to the function of the product.
    - These include changing the length of the delays and the duration of sounds.
    - The ability to change the tone of the buzzer and even play musical tunes if so desired.
- Flexibility. The circuit could easily be used for a completely different function by simply re-writing the software.

Easy to develop and debug. Most software packages allow you to simulate the software while it is being developed making it much more likely to work when used. It is also possible to break the functionality down into small steps which is easier to get right then jumping straight to the final design

Instruction Manual

Your programmable timer is going to be supplied with some instructions. Identify four points that must be included in the instructions and give a reason why.

Point to include:

Reason:

Point to include:

Reason:

Point to include:

Reason:

Point to include:

Reason:

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

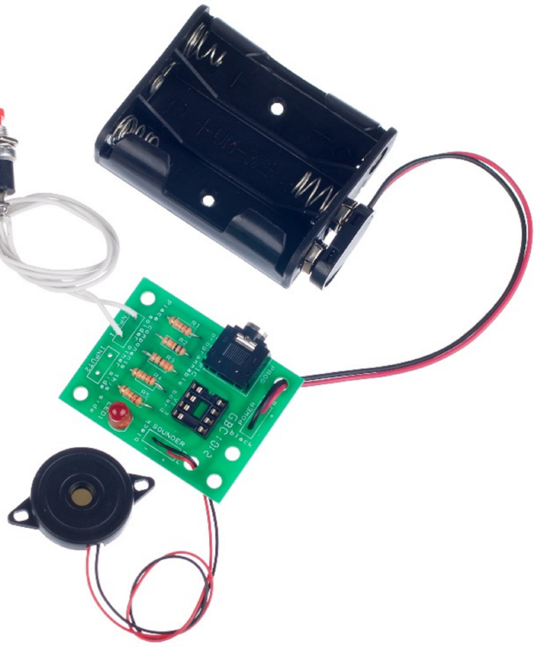
Develop a packaging design for your product that meets these requirements. Use additional pages if required.

ESSENTIAL INFORMATION

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

CREATE YOUR OWN UNQUIE TIMER WITH THIS

PROGRAMMABLE TIMER KIT



Version 2.0

Programmable Timer Essentials

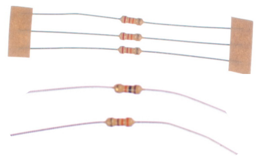
www.kitronik.co.uk/2121

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 the resistors

Start with the five resistors:
The text on the PCB shows where R1, R2 etc go.
Ensure that you put the resistors in the right place.



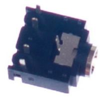
PCB Ref	Value	Colour Bands
R1, R4 & R5	22kΩ	Red, red, orange
R2	10kΩ	Brown, black, orange
R3	330Ω	Orange, orange, brown

2 Place the IC holder

Solder the Integrated Circuit (IC) holder in to IC1. When putting this 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.

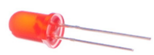
3 Place the programming connector

Solder the programming connector into the board where it is labeled ‘PROG’.



4 Place the LED

Solder the Light Emitting Diode (LED) in to LED1. The timer won’t work if it doesn’t go in the right way around. If you look carefully one side of the LED has a flat edge, which must line up with the flat edge on the lines on the PCB.



5 Place the battery clip lead

The battery clip should be soldered into the ‘POWER’ terminal. First start by feeding the wire through the strain relief hole (feed from the solder side). The red wire must go to the ‘+’ terminal (also marked ‘red’) and the black wire must go to the ‘–’ terminal (also marked ‘black’).

6 Place the buzzer

The buzzer should be soldered into the ‘SOUNDER’ terminal. First start by feeding the wire through the strain relief hole (feed from the solder side). The red wire must go to the ‘+’ terminal (also marked ‘red’) and the black wire must go to the ‘–’ terminal (also marked ‘black’).

Build Instructions continued

7 Place the switch

Cut and strip two pieces of wire to the required length for connecting to the timer start switch. Solder one end of each wire to each of the terminals on the switch and the other end to the terminals labeled ‘INPUT1’. It does not matter which wire goes to which terminal.

8 Place the IC

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

Checking Your Programmable Timer PCB

Check the following before you insert the batteries:

Check the bottom of the board to ensure that:

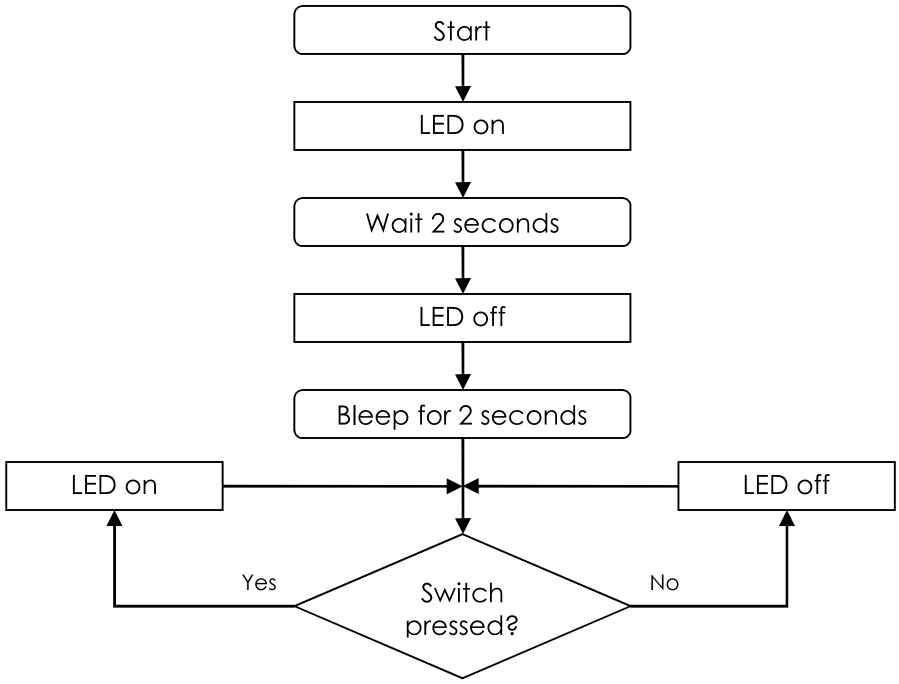
- All holes (except the 4 large 3 mm holes & INPUT2) are filled with the lead of a component.
- All these leads are soldered.
- Pins next to each other are not soldered together.

Check the top of the board to ensure that:

- The notch on the IC and the IC holder are in the same orientation as the markings on the printed circuit board.
- R2 has Brown, Black, and Orange colored bands.
- R3 has Orange, Orange, and Brown colored bands.
- The red wire on the battery connector goes to the + terminal on the power terminals and the black wire goes to the – terminal.
- The LED is in the right way around (the flat edge on the LED matches the markings on the board).

Testing the PCB

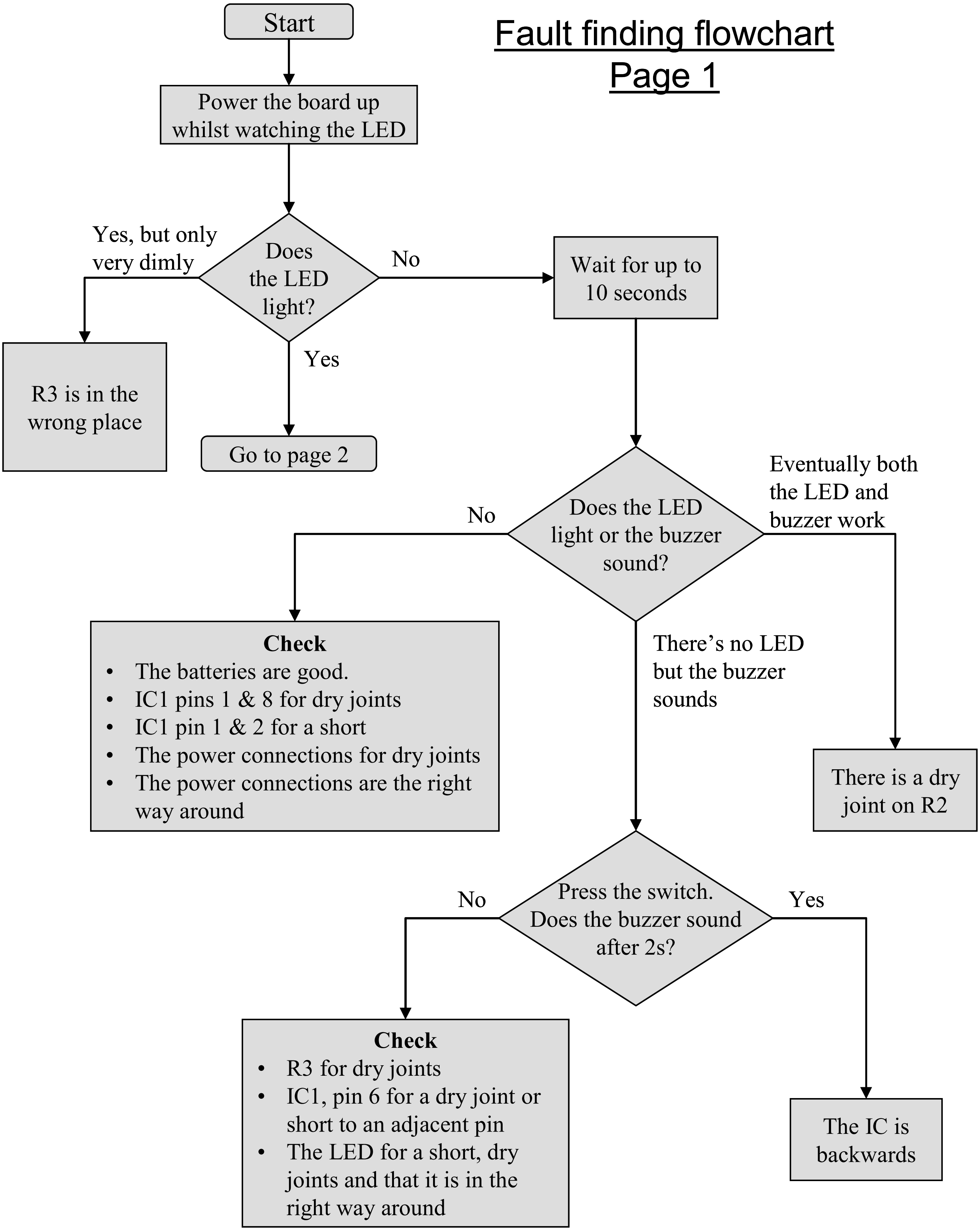
The circuit has been designed to allow easy testing of the PCB. To test the PCB you will first have to insert a chip programmed with some software to allow it to be tested. The purpose of the test program is to test that the LED can turn on and off, the buzzer can sound and that the switch is functioning (used to turn the LED on and off). The test software works as shown below.



If you have problems with any of the above use the fault finding flow charts to find the cause of the fault. Please note that these fault finding diagrams have been based around using the test software outlined above. If you are using an alternative test program they will not be suitable.

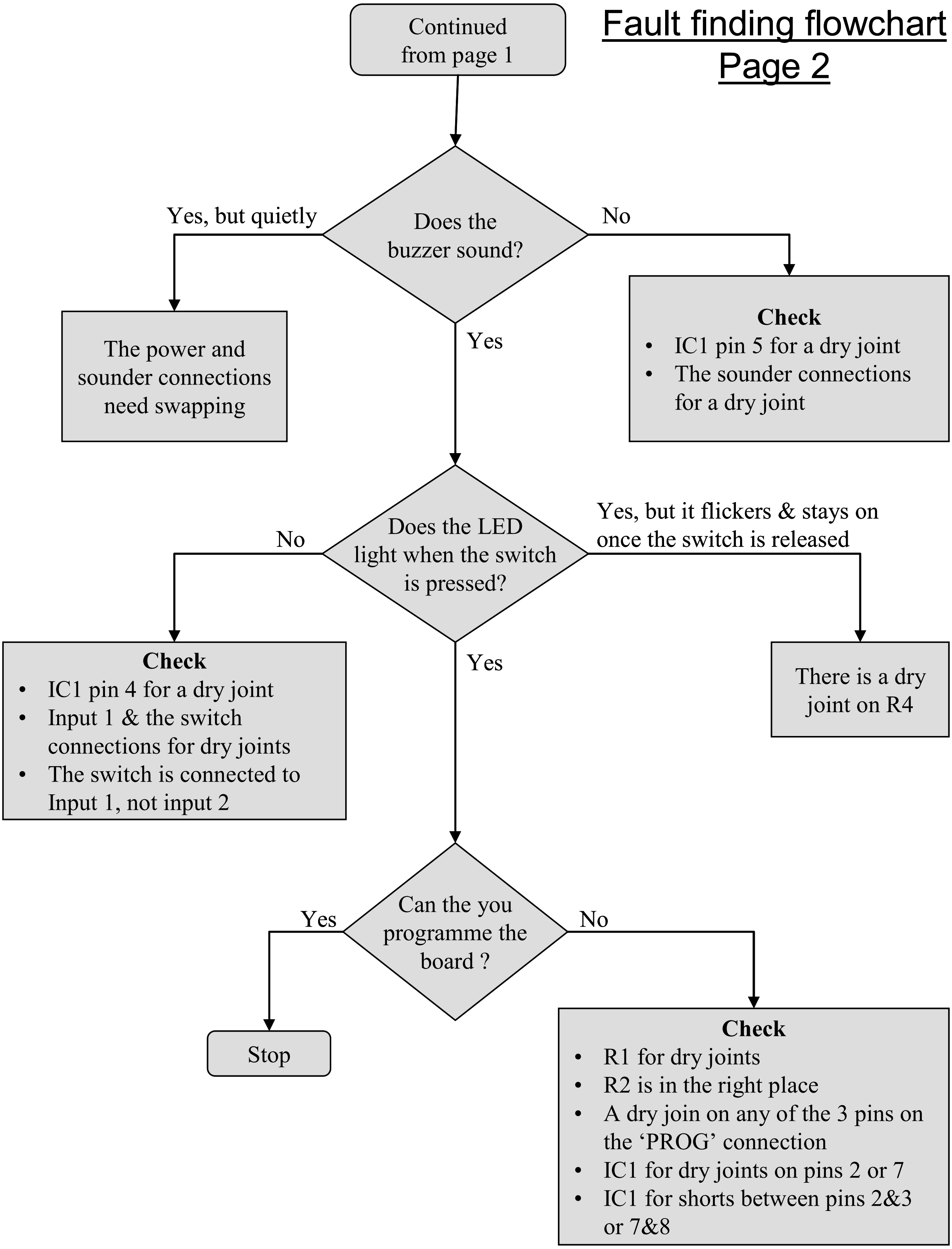
Fault Finding

Fault finding flowchart Page 1



Fault Finding continued

Fault finding flowchart
Page 2

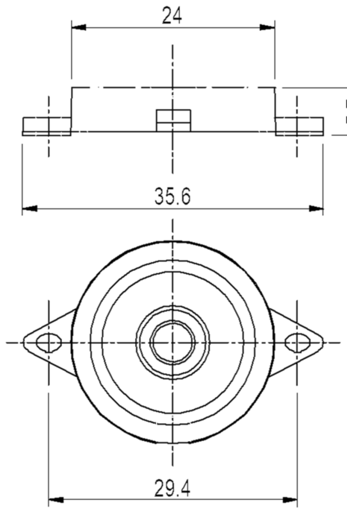


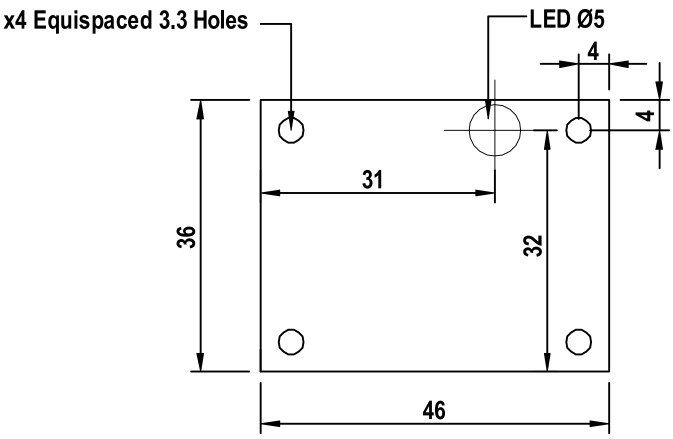
Designing the Enclosure

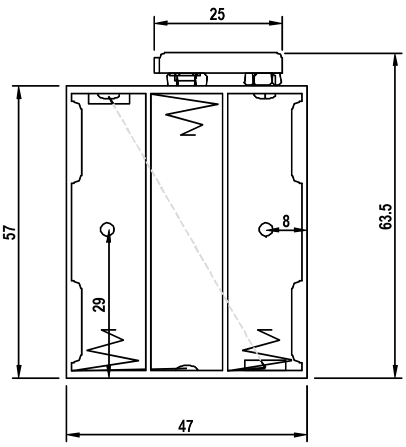
When you design the enclosure, you will need to consider:

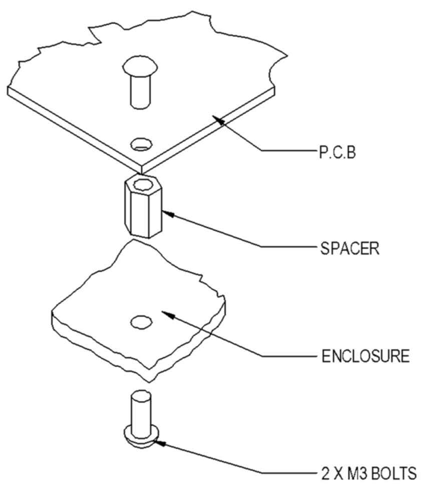
- The size of the PCB (below left).
- Where the LED is located on the PCB.
- Where the start switch will be mounted (bottom right).
- Where the sounder will be mounted (right).
- Access to the batteries to allow them to be changed (below right).

Technical drawings of these items are illustrated on this page, which should help you design your enclosure.
All dimensions are in mm.





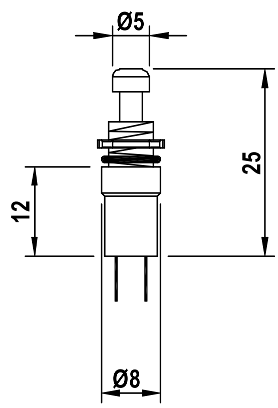




Mounting the PCB to the enclosure

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.



Possible student programming tasks

Test program

The test program referenced in the 'Testing the PCB' section can be downloaded from the resource section of the Kitronik website at the web address listed at the bottom of this page. We would suggest that you program up a chip with this test software. This can then be placed in an IC holder (to protect its legs) and used by students to test their PCBs once they have completed building them.

Task overview

We would suggest that you split the programming of the timer board into up to four separate tasks.
These are:

Task 1 - Basic timer
When the button is pressed the LED will light for 10 seconds, then the buzzer will sound for one second.

Task 2 - Early warning bleeps
A few seconds before the one second out of time buzzer sounds, it will give a short bleeps to warn the time is almost up.

Task 3 - User configurable delay
A special mode will be added to set how long the delay is so the timer can be reprogrammed during normal use without a PC.

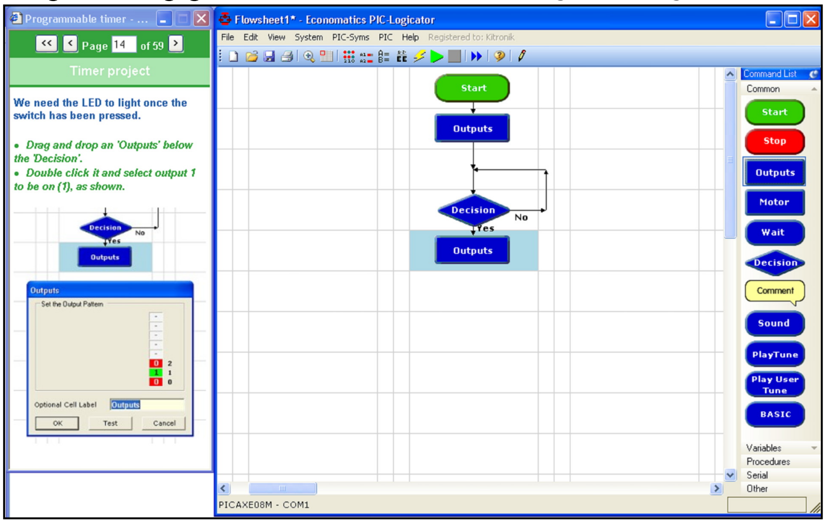
Task 4 - Musical
The final task will be to replace the time out tone with a tune.

Student guides available on-line

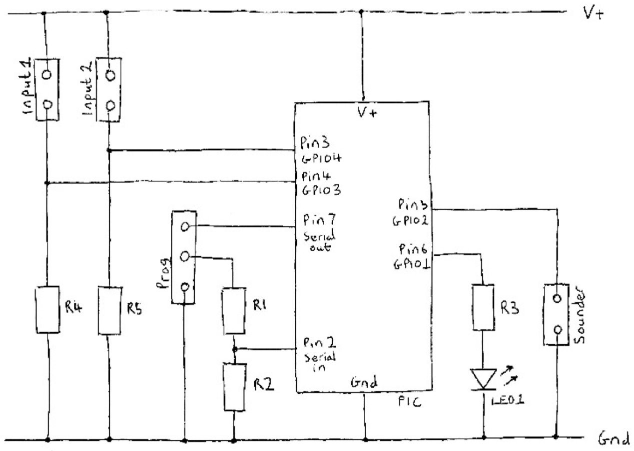
To guide students through the programming tasks listed above an electronic guide can be run or downloaded from our website. This guide runs in any web browser, so you don't need to install any software, however the files can be copy onto the PC if you don't have internet access. It is intended that the guide takes up ¼ of the screen, leaving space for the flowchart software. The screen shot below is of the PIC logicator guide, but guides for other software packages are available. To find out if there is a guide for your software and to give it a try go to:

www.kitronik.co.uk/timer_tasks.htm

Programming guide Programming software



How the programmable timer works



The timer is based around an eight pin PIC microcontroller device. A PIC is in effect a small computer that behaves in a way determined by the software it's programmed with. This software is generated by the user / student. It is this code that will determine the eventual function of the project. To aid the design of this software the following describes the function of the hardware (circuit) that this software controls. From the programmable timer circuit above you can see that the PIC has two usable inputs and two usable outputs.

Input/Output	Pin	Connected to
Input 1	Pin 4, GPIO3	Switch
Input 2	Pin 3, GPIO4	User defined
Output	Pin 6, GPIO1	LED1
Output	Pin 5, GPIO2	Sounder

The other connections to the PIC are to provide it with power (V+ and Gnd) and also allow it to be programmed with the user defined software (Pins 2 and 7).

Input 1 is connected to the switch which is of the push to make variety. When this switch is not pressed resistor R4 pulls the voltage on the input to the PIC to a low voltage. When the switch is press (closed) the voltage on the PIC pin is pulled up to a high voltage. You will be able to read this change of state in your software.

Input 2 has been left as a spare input should you wish to add another input device. The pull down resistor R5, which is the same as that used on Input 1 is already included.

The purpose of resistor R3 is to limit (restrict) the flow of current into the LED. This controls the brightness of the LED and prevents it from becoming damaged, which would happen if no resistor was used.

The sounder (buzzer) that has been used in the circuit does not have any drive circuitry. This means that it needs driving with square wave (alternating high low voltage signal) to make it produce a tone. The frequency of the tone will be the same as that of the square wave that is used to drive it.

One other point worth noting is the processor clock. For any micro-controller to work it requires a clock source. The micro-controller uses this clock so that it knows when to execute the next line of software. Often these clocks are generated externally but in the chip used in this circuit the clock is built into the chip itself. This is why it does not appear on the circuit diagram.

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/2121

This kit is designed and manufactured in the UK by Kitronik

Telephone: +44 (0) 845 8380781

Sales email: sales@kitronik.co.uk

Tech support email: support@kitronik.co.uk

Web: www.kitronik.co.uk

www.kitronik.co.uk/twitter

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