

Audio Amplifier Project



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Designers often separate a problem into a number of smaller activities. This helps focus their thoughts and make the development of the design easier to control. By breaking the problem down into smaller sections it also helps ensure that no important features are left out.

Selection Of Problem - A number of design problems that use the Audio amplifier circuit are outlined on the Investigations page. Read the information provided and select one of the problems to develop a solution for.



Task 1

Select a problem from those described on the Investigations page.

Design Brief - The design brief is a short description that clearly states the aim of the design project and in a few words states the kind of product that is needed. For example, "Design a case" is not very helpful to a designer. "Design a case to hold a small amplifier circuit" gives the designer a clearer focus without applying restrictions.

Task 2

Write a design brief for your Amplifier project.

Investigation - When a designer has isolated a problem, the next task is to find out as much background information as possible to help them develop an effective solution.

A comprehensive investigation will collect relevant information from a variety of sources that are likely to affect your product.

Task 3

Investigate the selected problem using the tasks to start your work.

Specification - Once you have a clear understanding of the problem, you can work out the specification for your Amplifier. A specification is a list of things that the final design must do. A good specification will list the important features in order of importance.

Specifications are an important part of designing because they provide a check list against which you can review your ideas as you are working. They also give you something against which to evaluate your ideas and your finished product.

For example, 'needs to hold a battery' does not give the designer enough information. 'The case needs to hold a PP3 battery and have easy access so that the battery can be changed' is a clear statement without restricting the designer.

Task 4

Write a specification for your Amplifier.

- 1 Make a list of all the features you need to include in the design.
- 2 Place them in the correct order of importance.



Design
Tasks

Design Brief

Investigation

Specification

Initial Ideas

Development

Making

Evaluation

Investigations

Personal Stereo/Radio Amplifier

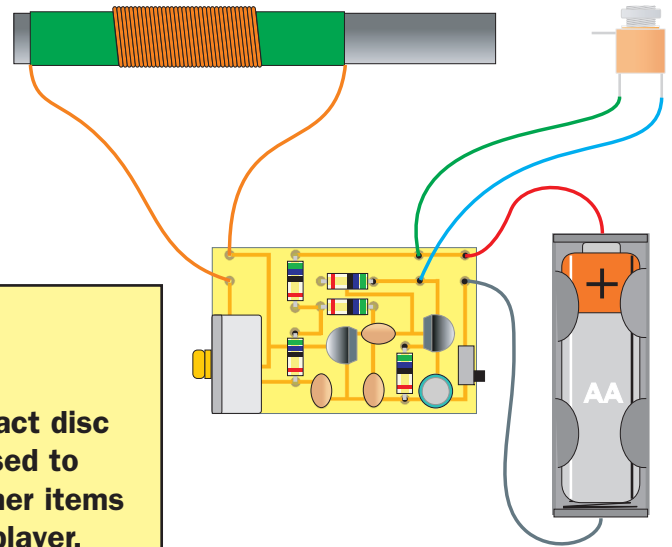


Sony introduced the first portable cassette player in the late 1970s. Its founder Akio Morita regularly travelled by plane and he wanted to listen to music. He asked his engineers to adapt a small journalist tape recorder to play back through headphones. He liked the design and the “Walkman” was born.

The personal stereo or CD player is a popular item to carry around, for you to take music wherever you want. The disadvantage of the personal stereo is that it is difficult to share your music with your friends.

The radio circuit to the right is a simple AM radio that can be purchased as a kit from Rapid Electronics (product code 70-0110). It was designed so that the user would listen to the output through a pair of headphones.

There is a clear need for a product that will enable the output from these devices to be played so that others can share the music.



Task 5

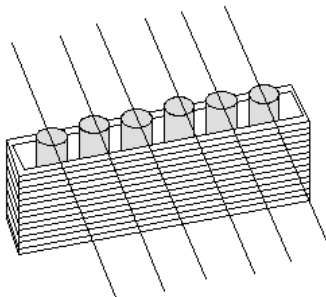
- 1 Research the history of the Compact Disc.
- 2 Research how people transport their compact disc players. What methods of protection are used to prevent damage whilst in transit? What other items need to be transported along with the CD player.

Guitar Amplifier

Electric guitars have solid bodies. If you pluck a string on an electric guitar that is not plugged in, the sound is barely audible, there is nothing to amplify the string’s vibrations.

To produce sound, an electric guitar senses the vibrations of the strings electronically and sends that electronic signal to an amplifier and speaker. The sensing occurs in a magnetic pickup mounted under the strings on the guitar’s body. A typical magnetic pickup looks like the diagram below.

The coils and magnets turn motion into electrical energy. In the case of an electric guitar, the vibrating steel strings produce a corresponding vibration in the magnet’s magnetic field and therefore a vibrating current in the coil.



When practicing the guitar it is important to hear the sounds generated. For this the guitar needs to be plugged into some form of amplification device. Traditional amplifiers tend not to be portable and those that are, still require some form of power supply.

There is a clear need for a small personal guitar amplifier that can be easily transported with the guitar, that allows the guitar to be practised.



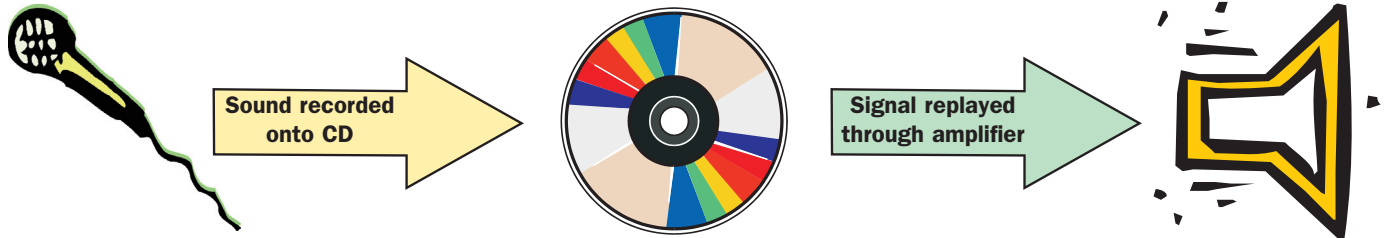
Task 6

- 1 Research the design development of the electric guitar.
- 2 Examine how electric guitars are transported and what additional items need to be carried at the same time.

Amplifiers

When people refer to amplifiers, they are usually referring to musical equipment. But this is only a small section of the range of amplifiers used in electronics. Amplification is an important process in many electronic circuits. We often use sensors that generate very small signals, which need amplification so we can read them.

In an audio system a microphone converts the sound wave into electrical signals. These signals are then recorded onto compact disc. When the compact disc is then placed into a player the recorded signals are reinterpreted through an amplifier back into sound that we can hear.

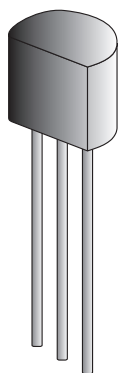


The major sections in this system are essentially translators. They take a signal in one form and put it into another. In the end, the sound signal is translated back into its original form, a physical sound wave.



In order to record the minute pressure changes in a sound wave, a microphone diaphragm has to be extremely sensitive. This means it is very thin, and moves only a short distance. As a result, the microphone produces a fairly small electric current.

This small electric current is suitable for most modules in the system - It is strong enough for recording, and it is easily transmitted through wires. But the final stage in the system - pushing the speaker cone back and forth - is more difficult. To do this you need to boost the audio signal. This is the job of the amplifier. It simply produces a more powerful version of the audio signal.

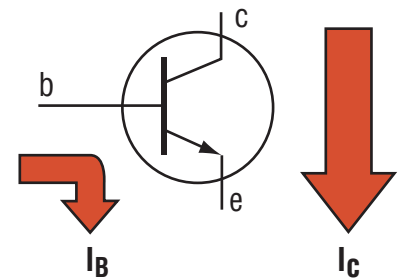


Transistor Amplifiers

The transistor is at the heart of most audio amplification circuits. It's invention in 1948 made it possible to manufacture the first portable battery powered radios.

A transistor can be either a conductor or an insulator. When there is no voltage applied to the base of the transistor it is acting like an insulator and as a result does not allow electricity to flow. This is like a switch that has not been pressed.

If a small voltage is applied to the base of the transistor, it becomes a conductor, allowing electricity to flow.



Where a very small current can turn on a large current, the input signal is said to be amplified to become a larger output current.

Transistor Power

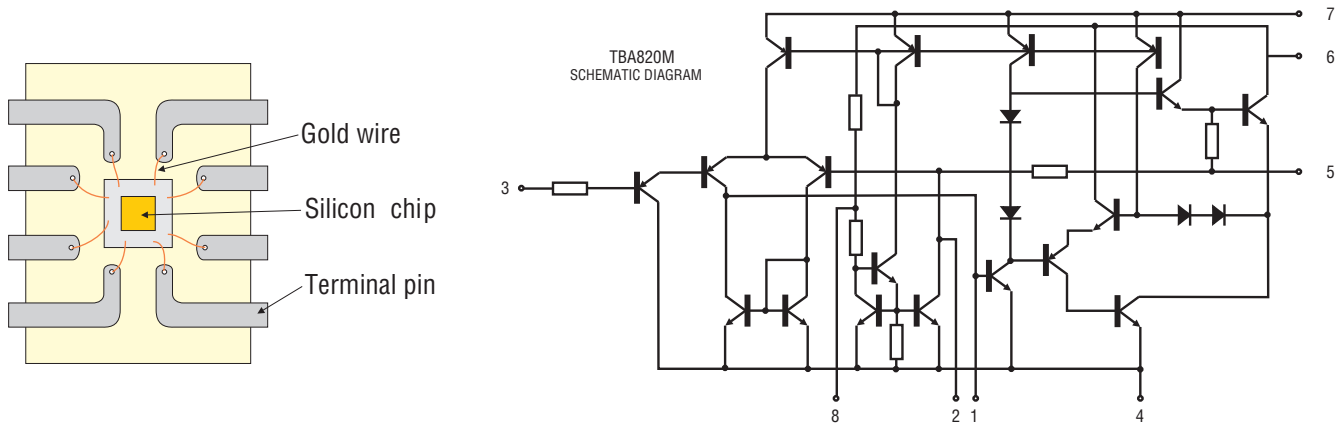
The power of the transistor is the maximum amount of current that can pass from the collector to the emitter. This can vary from 100 mA in the BC548B to 15 A in the 2N3055.

TYPE	IC max	Gain	Order code
BC108	200mA	200	81-0014
BC548	100mA	240	81-0066
ZTX300	500mA	50	81-0198
BFY51	1A	40	81-0122
BC639	1A	40	81-0080
2N3055	15A	20	81-0266

Transistor Gain

The ratio of I_{CE} to I_{BE} is called the gain of the transistor and is different in each type of transistor. Generally the smaller the transistor I_{CE} the higher the gain.

For audio output devices, many transistors need to be combined into a circuit that produces high quality sound. Rather than build these complex circuits from individual transistors, the circuit is placed on an IC (Integrated Circuit).

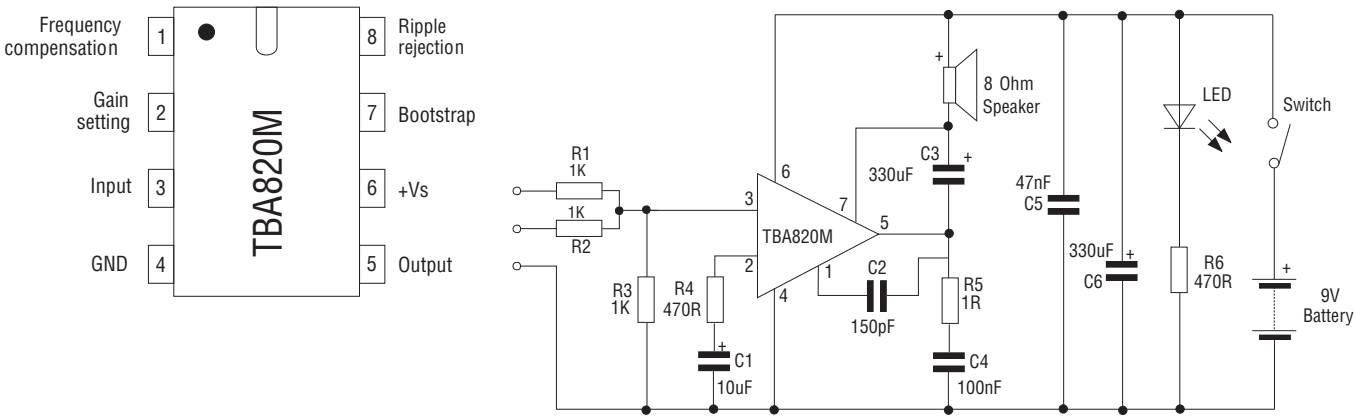


Engineers can now place all the components of a circuit onto a single piece of silicon. This makes the circuit more reliable and easier to construct. The diagram above left shows the typical inside of an IC. The terminal pins or legs are connected to the silicon chip with a series of very fine gold wires.

The circuit diagram to the above right shows the circuit that is used inside the TBA 820M audio amplifier IC that is used in this project. The circuit is made up from 18 transistors, 6 resistors and 4 diodes.

A large range of audio power amplifier ICs are now available. Some of these are single (mono) amplifiers whilst others are for stereo signals (dual). The chart below shows the most popular power amplifiers ICs.

Audio amplifier	Amplifier type	Max output Power	Supply voltage	Input impedance	Voltage gain	Bandwidth	Quiescent current
LM 386	Mono	325mW	4-15V	50kΩ	26dB	300kHz	4mA
TDA 822M	Dual	1W	1.8-15V	100kΩ	40dB	120kHz	6mA
TBA 820M	Mono	2W	3-16V	5MΩ	34dB	20Hz-20kHz	4mA
LM 380	Mono	3W	8-22V	150KΩ	34dB	100kHz	7mA
LM 384	Mono	5W	12-26V	150Ω	34dB	450kHz	8.5mA



The diagrams above shows the circuit and pin layout for the amplifier circuit used in this project. All amplifier ICs are represented in circuit diagrams by a triangle. The numbers placed around the edge indicate the pins the components need to be connected to.

Task 7

- 1 Combining two transistors into a “Darlington pair” is often used to improve a transistor circuit. Draw a simple circuit diagram and explain how a Darlington pair works.**
- 2 Look at the IC chart above and select an IC for stereo signal amplification. Find out more detail about the IC you have selected.**

Loudspeakers

A loudspeaker is an important output device in many electronic circuits. It allows us to convert electrical signals into sound waves. To understand how a speaker works, we first need to understand how sound travels.



How We Hear



We all hear sound through our ears. Inside the ear is a thin piece of skin, which vibrates when sound enters. This is called your eardrum. The brain interprets the vibrations as sound.

A sound is created when an object vibrates. Air particles around the object carry the pulse of the vibration through the air as a travelling disturbance. A vibrating object sends a wave of pressure fluctuating through the air. When the fluctuation wave reaches your ear, it vibrates the eardrum back and forth. Our brain then interprets this motion as sound.

A microphone works like our ears. It has a diaphragm that is vibrated by sound waves. The signal then gets encoded. When the signal is then played back through your stereo, the amplifier sends it to a speaker, which re-interprets it into physical vibrations.



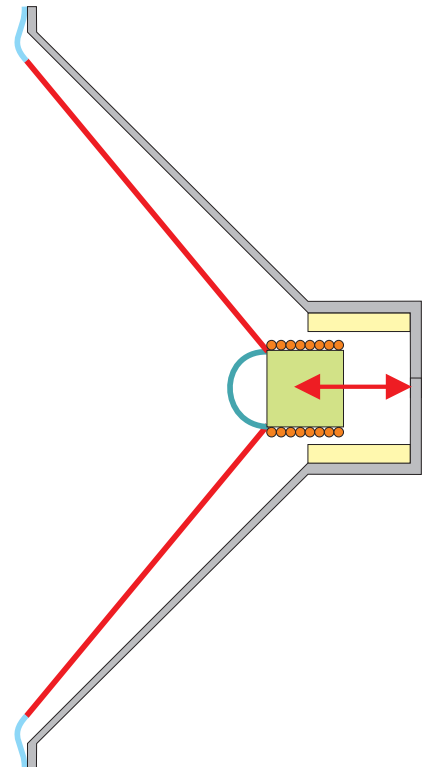
The speaker is therefore the final section of the translation circuit. It takes the electrical signal and translates it back into physical vibrations to create sound waves. The speaker should produce the same vibrations that the microphone originally recorded and encoded.

Traditional speakers do this with one or more drivers. A driver produces sound waves by rapidly vibrating a flexible cone or diaphragm.

The cone is usually made of paper and attached to the suspension. This is a rim of flexible material and it allows the cone to move. The suspension is attached to the basket, a metal frame in which the speaker sits.

The narrow end of the cone is connected to the voice coil. The coil is attached to the basket by the spider, a ring of flexible material. The spider holds the coil in position, but allows it to move freely back and forth.

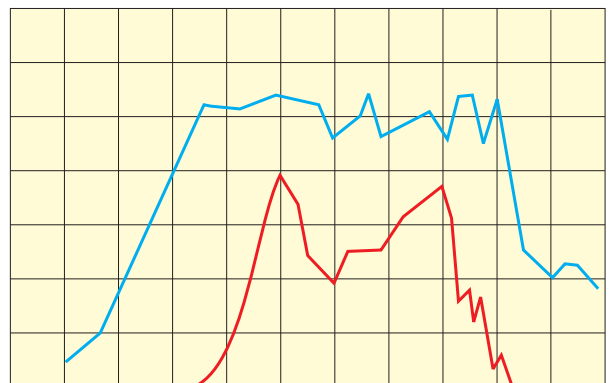
The voice coil is a basic electromagnet. Running an electrical current through the wire creates a magnetic field around the coil. The audio signal from the amplifier causes the current in the coil to change moving the coil back and forth rapidly. When the coil moves, it pushes and pulls on the speaker cone. This vibrates the air in front of the speaker, creating sound waves.



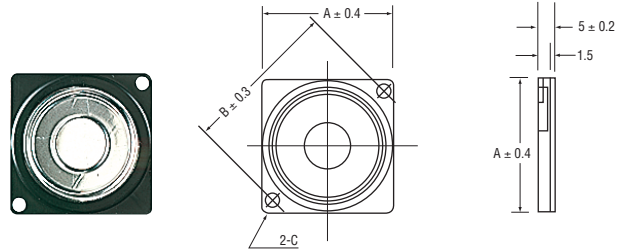
How We Hear

All loudspeakers resonate at certain frequencies. This means that they will reproduce certain frequencies better than others - which can lead to noticeable sound distortion.

The graph to the right compares the typical frequency response of two loudspeakers. The difference between a small loudspeaker and a more expensive type can clearly be seen. In recent years the design of speakers has started to change with the introduction of new materials.



A relatively new design now available is the ultra thin speaker. The speaker is made using a ferrite magnet and a stainless steel diaphragm rather than a paper cone and a flat coil. It is ideal for speech or alarm applications where space in an enclosure is limited.



Speaker Housing

For a speaker to work effectively it is important that it is housed correctly. If you simply placed a speaker on the table, the table would vibrate so much it would drown out a lot of the speakers' sound.

The speaker housing can effect how the sound is produced. The vibrating diaphragm emits sound waves in front of the cone. But since the diaphragm is moving back and forth, it is also producing sound waves behind the cone. Especially at low frequencies, these waves will cancel each other out and nothing is heard. There are a variety of methods for dealing with these backward waves.

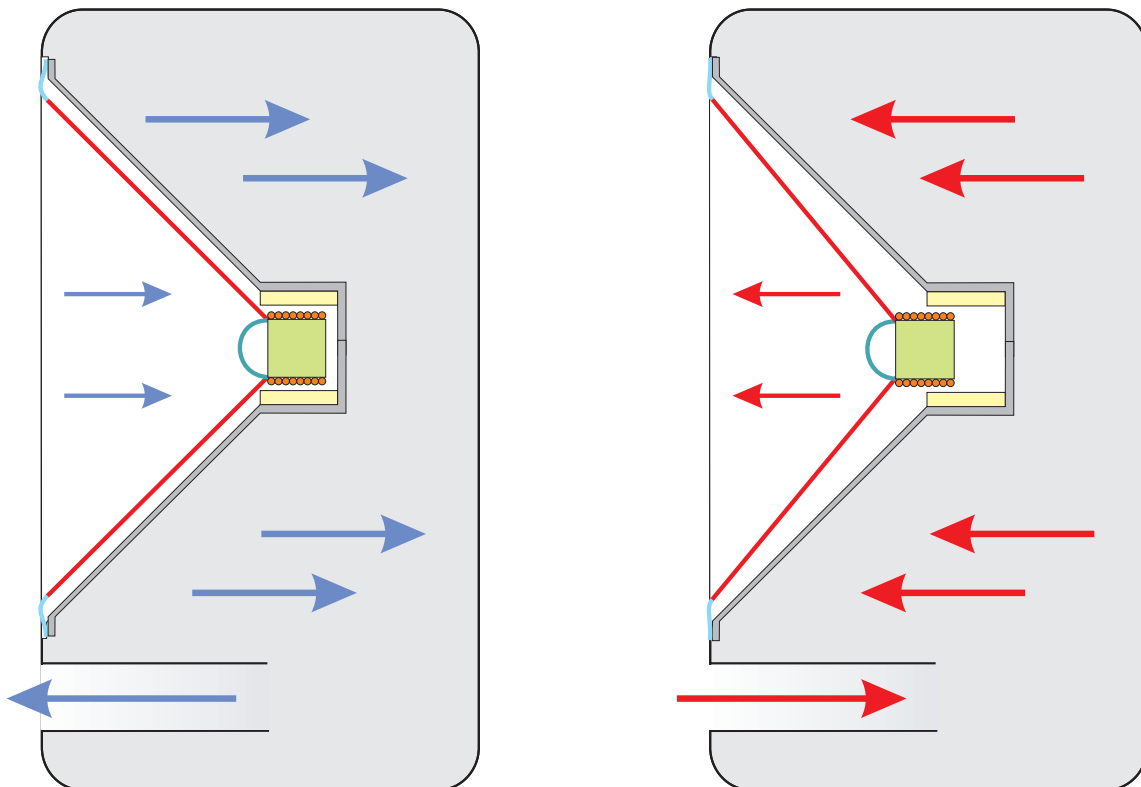
The easiest method to cancel these backward sound waves is to mount the speaker on a plate or baffle. You can see the effect of a baffle by cupping your hands behind the loudspeaker to form a simple baffle. The sound quality should improve and it gets much louder.

In most music systems the baffle plate is folded around completely to create a box enclosure. These boxes are normally sealed. The disadvantage is that the air trapped inside tends to dampen the effect of the loudspeaker at lower frequencies. These speaker designs are less efficient since the amplifier has to boost the signal to overcome the force of air pressure.

The Bass Reflex System is often used in stereo speakers. It redirects the inward sound wave outward, using it to supplement the forward sound wave. The most common way to do this is to build a small port into the speaker. In these bass reflex speakers, the backward motion of the diaphragm pushes sound waves out of the port, boosting the overall sound level.

A bass reflex speaker produces two sound waves by moving one speaker. When the speaker compresses air forward it draws air in through the port, so allowing the speaker to move to its maximum position without dampening.

The second sound wave is emitted from the port at the base of the speaker enclosure when the cone is drawn in again.



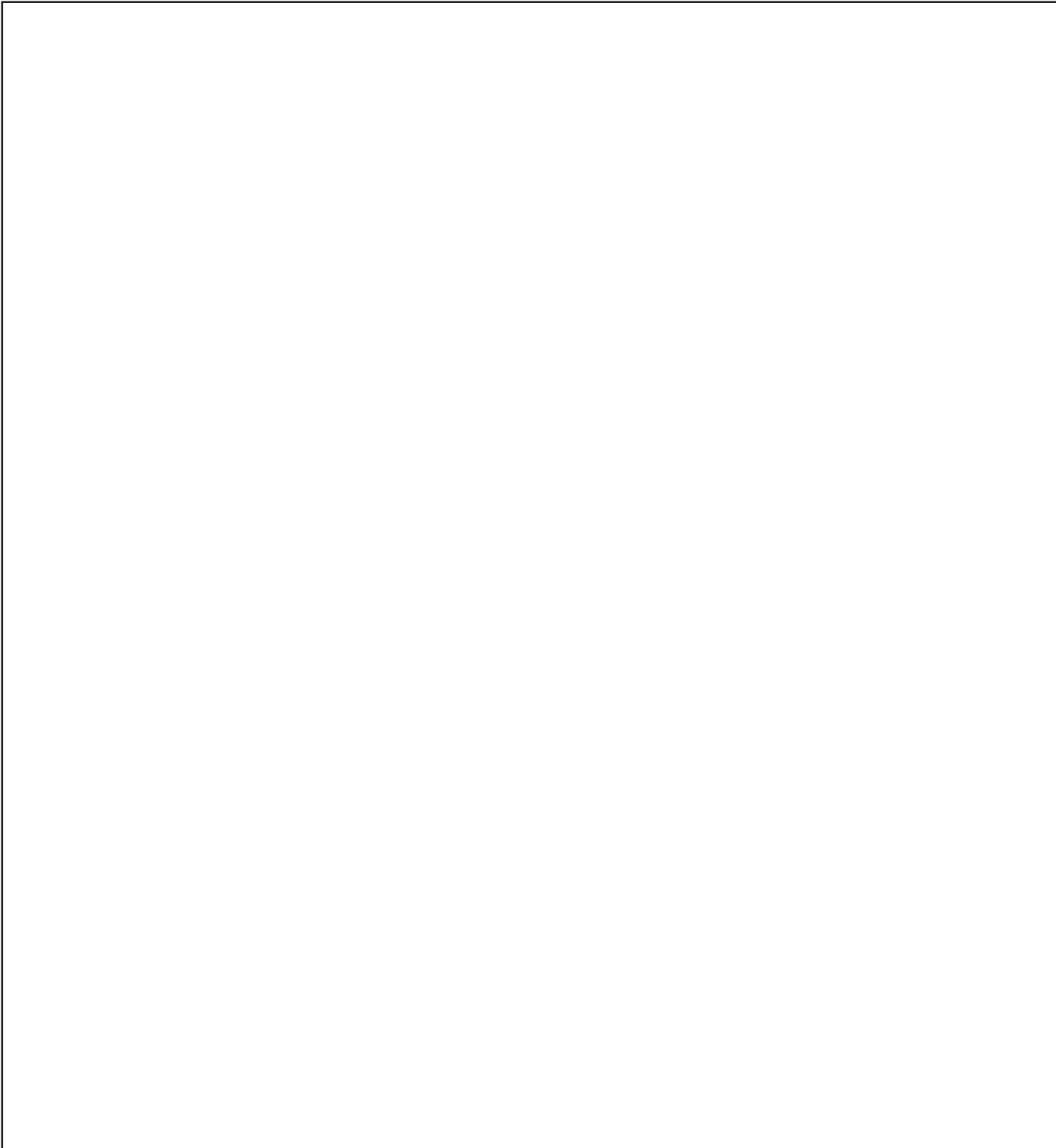
Initial Ideas

Once you have written a specification, the next stage is to draw some initial ideas. Designers try to come up with as many ideas as possible. Even if you think the idea might be a little silly, you should include it because it may be useful later.

Your specification will act as a guide for your ideas. Try to think of the main features you need to include whilst you are drawing.

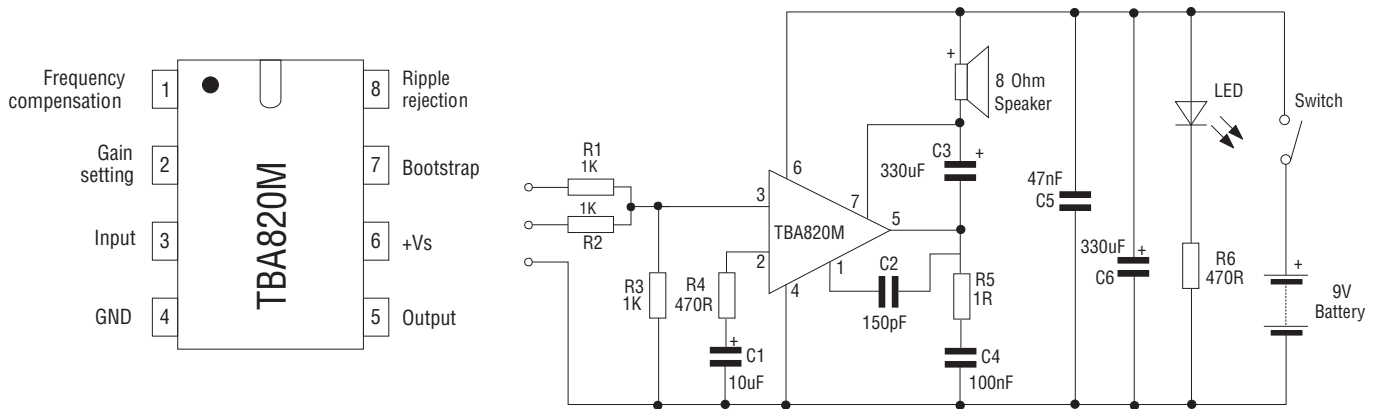
Task 8
Draw a range of ideas for the casing design of your Audio Amplifier project.

Do not make your designs too complicated.



Circuit Construction

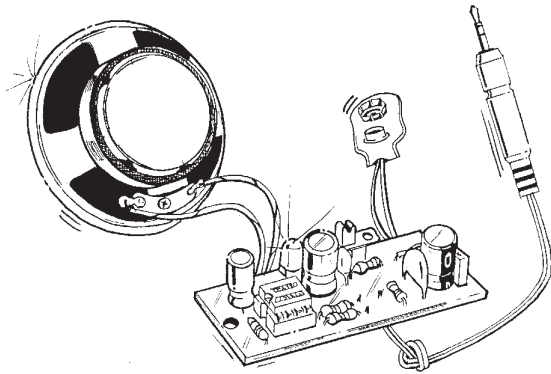
The TBA 820M audio amplifier is a low power amplifier that is capable of generating 1.2 Watts output. The TBA 820M is an 8 pin IC, that can operate from supply voltages as low as 3V and does not consume much current when there is no signal applied. The IC also has the advantage that there is little distortion when the signal is amplified.



Construction of circuit

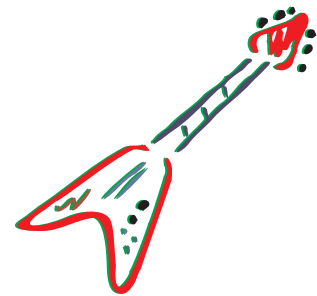
You will need to gather together the following equipment before you start construction of your circuit.

- Soldering equipment set
- Printed circuit board
- Components: IC TBA 820M, three 1K resistors (brown, black, red), two 470R resistors (yellow, violet, brown) and one 1R (brown, gold). Two 330uF electrolytic capacitors. One 47nF electrolytic capacitor. One 10uf electrolytic capacitor. One 150 pF ceramic capacitor. One 100nF polyester capacitor. One 8 Ohm speaker. One slide switch. One PP3 battery snap. One 3.5mm stereo jack socket.



Procedure for construction

- 1 Solder the resistors in place.
- 2 Solder the smaller capacitors in place.
- 3 Solder the electrolytic capacitors into position.
- 4 Solder the LED in position. Do not forget to leave sufficient room for the LED to protrude from the case you have designed.
- 5 Solder the IC socket and jack socket into place. This may be a tight fit.
- 6 Solder the remaining external components in place taking care that if cables need to be fed through a hole in the case you have made sure that you remember to do this.
- 7 Place the TBA820M in the IC socket.
- 8 Attach the battery and test the circuit.

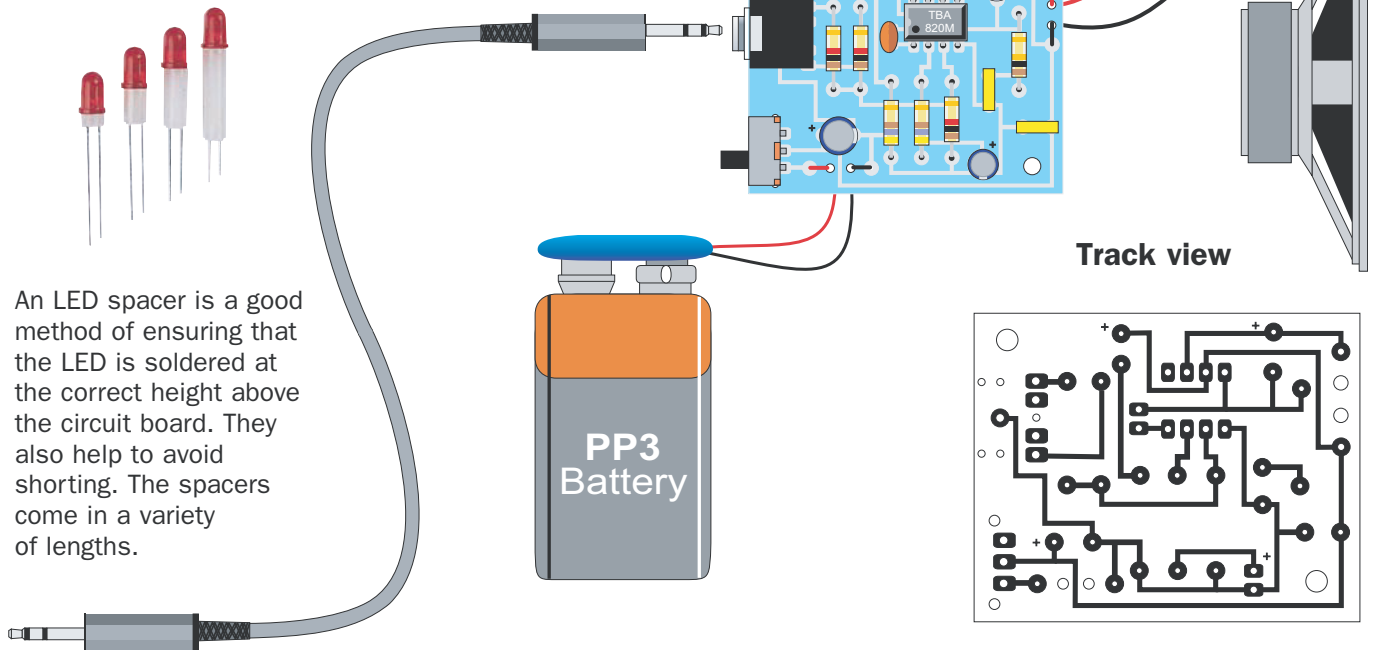


LED spacers

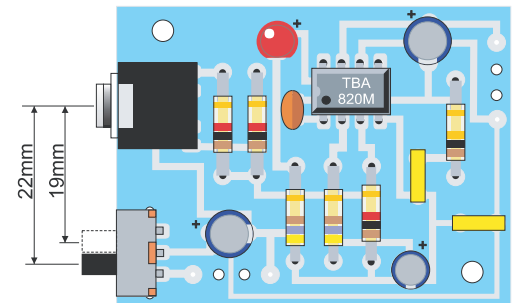
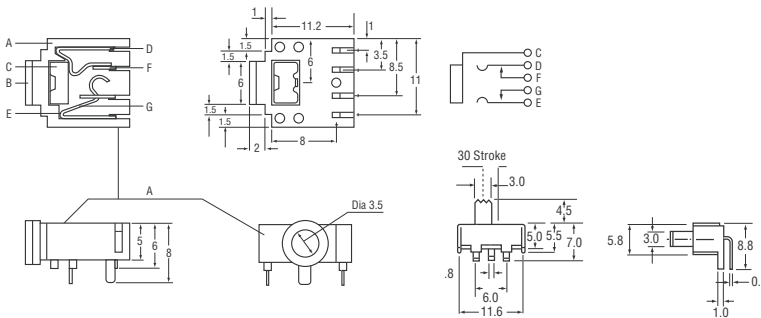
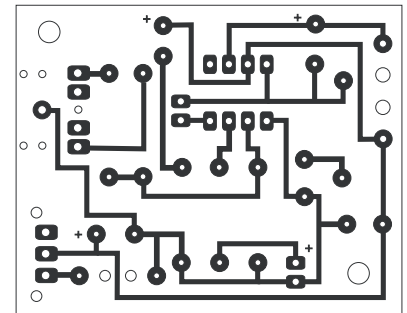


An LED spacer is a good method of ensuring that the LED is soldered at the correct height above the circuit board. They also help to avoid shorting. The spacers come in a variety of lengths.

Real View



Track view

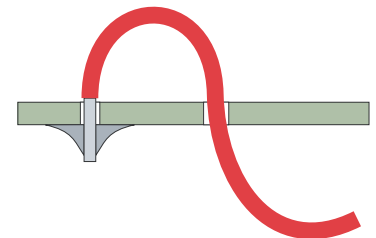


Casing Information



It is important to avoid damaging your circuit, by securing it into the case properly. You must also be able to change components and batteries.

Feeding a cable through the circuit board and then soldering it in place will help to prevent it being pulled from the board.



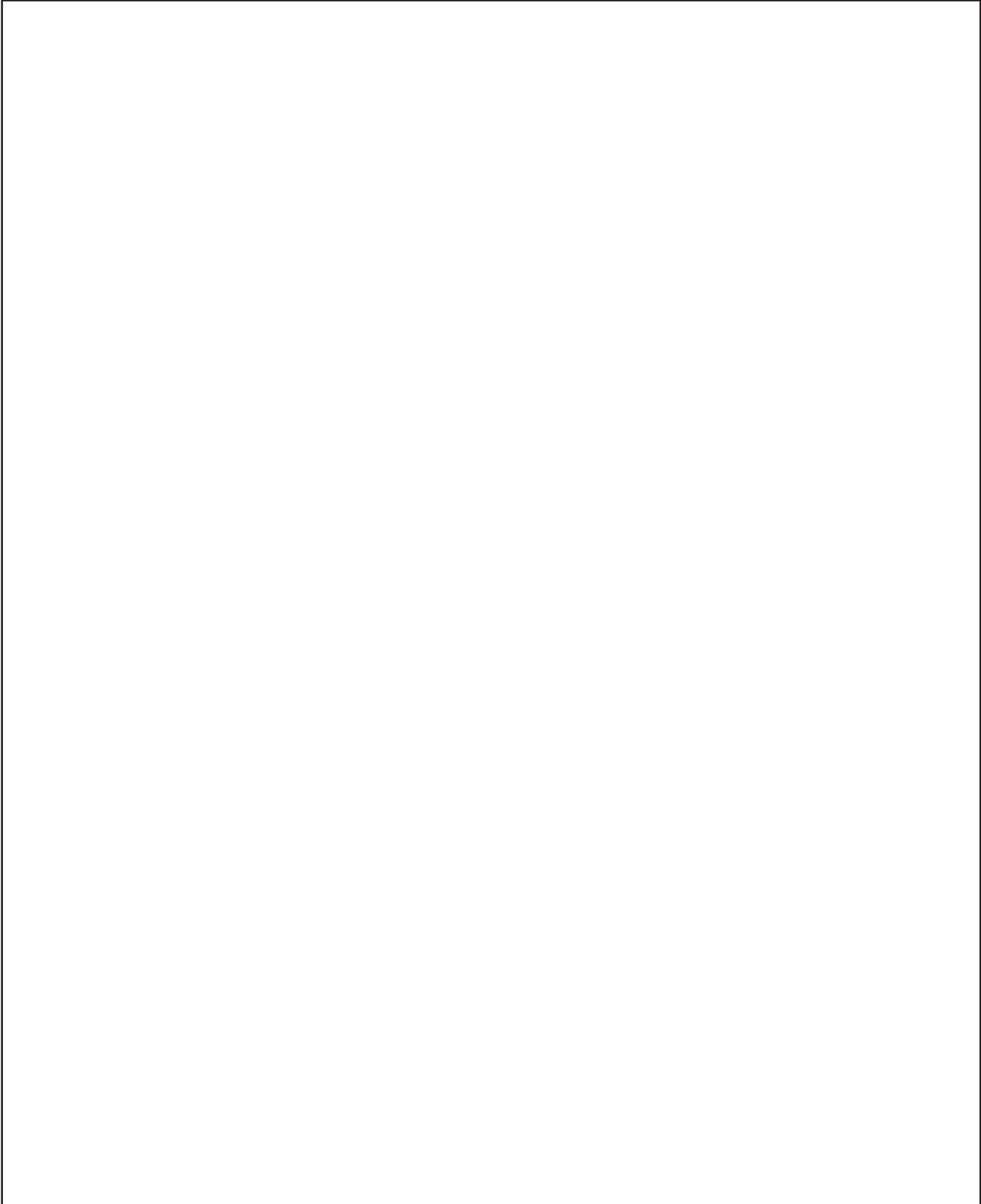
Task 9

- 1 Measure all the separate components that are going to make up your Audio Amplifier e.g. speaker, circuit board, battery, etc. Work out the optimum space needed to contain the circuit.
- 2 Use a series of sketches to show how the sections of your Audio Amplifier are to be held in your case design.
- 3 Draw a series of initial ideas for a vacuum formed case to hold the Audio Amplifier circuit. Think carefully about the following:
 - a. How the circuit is to be held in the case.
 - b. How much space is required to house the circuit.
 - c. How to gain access to change the battery.
- 4 Present your ideas as a series of sketches, highlighting those you feel are the most interesting with colour.

Development

Task 10

In the box below draw and colour your final design for your Audio Amplifier case. Take care not to make the design too complicated since this will prove difficult to cut out. Use the 'Circuit Construction' activity sheet for guidance on positioning the circuit.

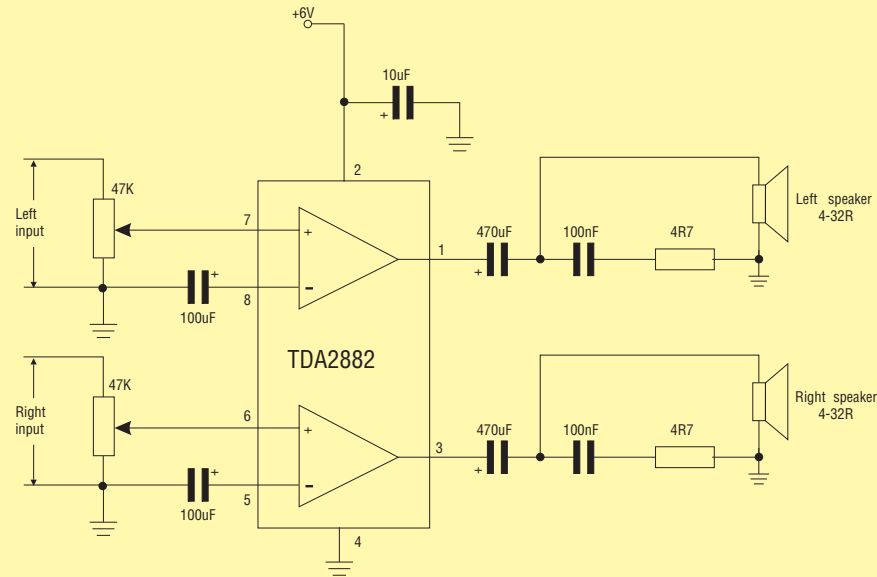


Product Development

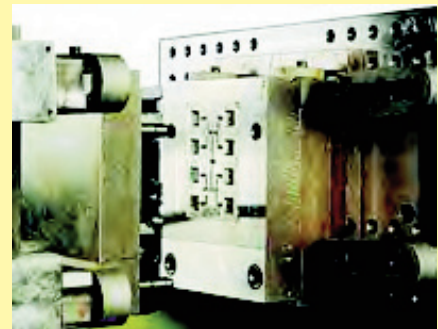
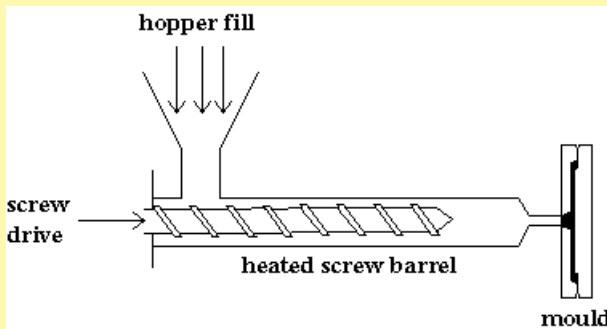
After testing and evaluating a new design, designers are frequently asked to make changes or improvements to their design. This is a process they may go through a number of times, testing and improving the product before it is finally manufactured.

Task 11

- 1 A manufacturer is interested in your designs. However, market research suggests that for use with a CD player, the output needs to be stereo instead of the mono in the current circuit. The following circuit has been suggested using the TDA2882 audio amplifier IC. Build a prototype and evaluate the design.**



- 2 Injection moulding is a popular method for manufacturing cases for electronic circuits. The process is capable of producing very accurate designs. However, the cost of the tooling means that it is normally only used for high volume production.**



- a. Draw a simple diagram to explain the injection moulding process.
- b. Examine five injection-moulded plastic products in your kitchen and draw them, paying particular attention to the following details, which should be sketched:
 - i. The gate, or point where the material was injected
 - ii. Any split lines
 - iii. Ejector pin marks
 - iv. Sink marks
 - v. Any moulded-in screw fittings
 - vi. A cross-section of the material

Evaluation

Evaluation is an important part of the design process. It is used by designers to check they have produced an effective design with all the features they identified in the specification. When you are evaluating a product you are trying to find out both its good and poor features.

Your own opinions are important, but you must also get some other people's opinions as well. They may notice qualities you are not aware of.

Task 12

Evaluate your Amplifier project by establishing if it meets your specification. Look at your specification and write down in the boxes below two features to establish the quality of your Amplifier.

1.

2.

Task 13

Sketch how your final Audio Amplifier design could be improved.

Progress Diary

Each week, write a short paragraph about the work you have done. As well as commenting on good aspects of the lesson, try to comment on work that has not gone so well, or that you did not fully understand.

When designing, it is also important to think ahead. Write down in the second section what work you anticipate doing next week on your project.

Week 1	Today _____
	Next Lesson

Week 2	Today _____
	Next Lesson

Week 3	Today _____
	Next Lesson

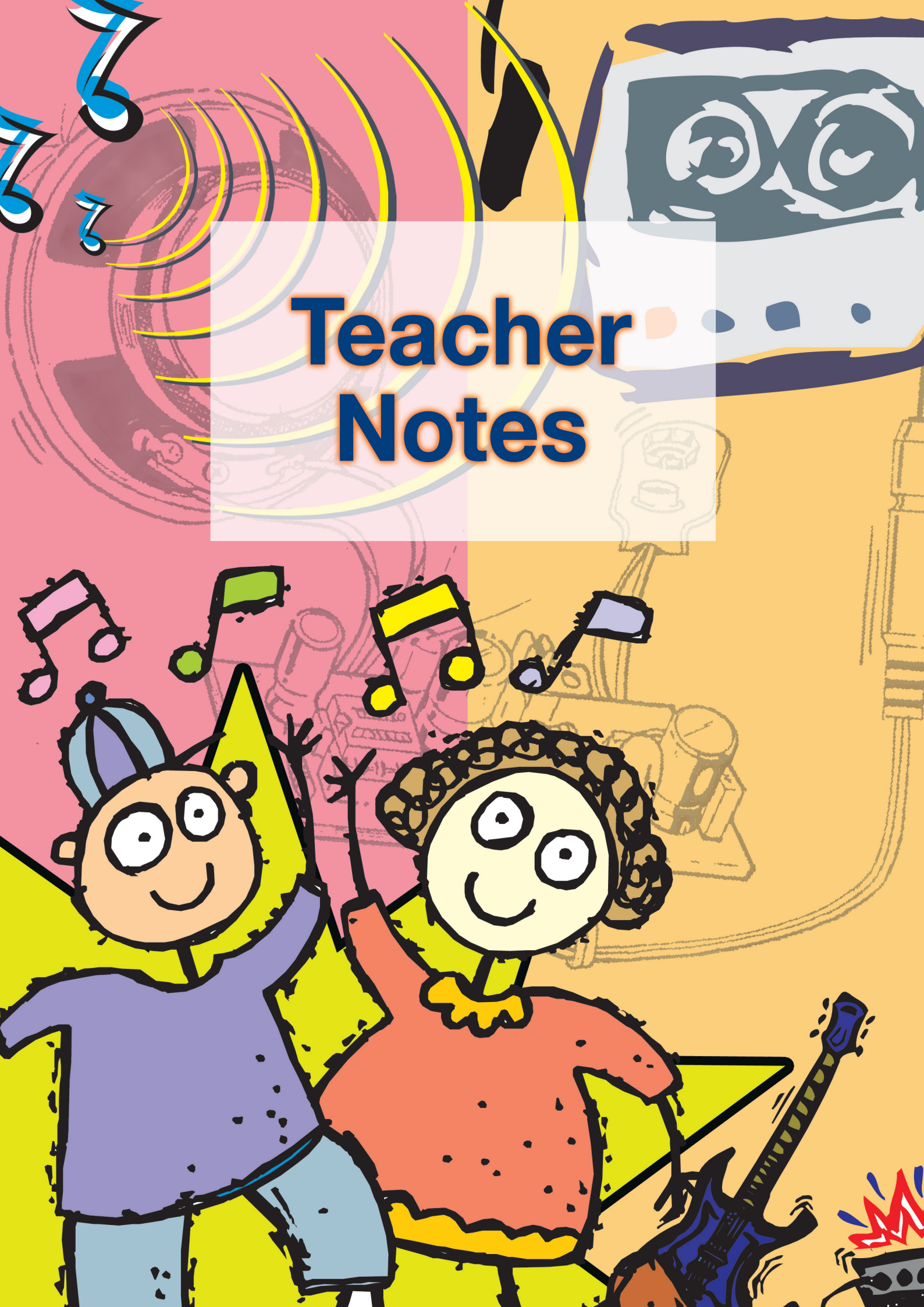
Week 4	Today _____
	Next Lesson

Week 5	Today _____
	Next Lesson

Week 6	Today _____
	Final comment:

Teacher comments:

Teacher Notes



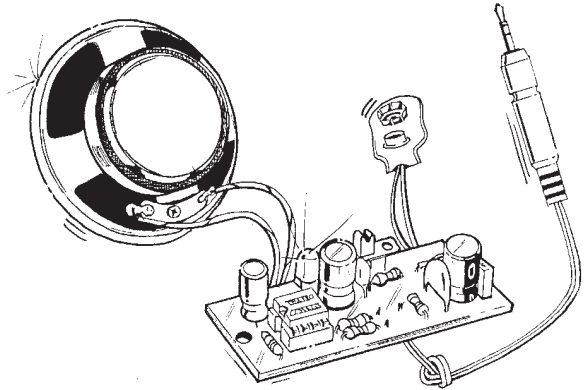
Teacher notes

Introduction

Rapid Electronics have developed the Audio Amplifier project in response to teacher requests for new and innovative material to stimulate student interest in electronics, whilst providing well-supported teaching resources.

The Audio amplifier project is an interesting introduction to the subject of amplification. The work is suitable for KS3/4 students. Emphasis has been placed on providing a means to a quality design outcome.

A key feature of the teaching material is that in addition to providing a student resource, it also contains detailed teacher support notes for guidance. The teaching pack has been designed to be photocopied. A number of the activity sheets can be used in isolation from the project. Included in the material are a series of structured homework assignments to support the work in class.



A series of lesson plans has been included based on teacher experience. However, the detailed project organisation will depend upon timetable, facilities and student needs. The practical work should be possible in a typical secondary based workshop.

Aims and objectives

The project is to design and make an audio amplifier for use with either a personal stereo or an electric guitar practice device. The project will enable students to experience the design and manufacture of an amplification circuit.

CONCEPTS:

- Electronic tuning circuits.
- Design and manufacture.
- Evaluation.

OBJECTIVES:

Pupils should understand:

- The need to investigate the background to a problem.
- How to select appropriate components to build simple electronic circuits.
- The importance of planned manufacture.
- How to improve a product by evaluation.

SCIENCE OPPORTUNITIES:

- Understanding of circuit theory.
- Concepts of sound, signal amplification and speaker design.

MATHS OPPORTUNITIES:

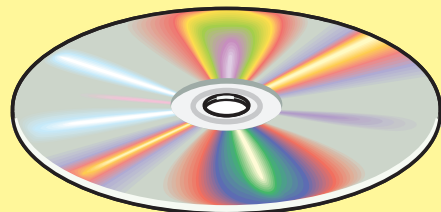
- Accurate measurement and marking out.

IT OPPORTUNITIES:

- CAD for designing case developments.
- Graphic packages to help generate design ideas.

ART OPPORTUNITIES:

- Drawing and presentational techniques to help represent ideas for casing designs.



Lesson Plans

Week 1 - Introduction and Investigations

Aim:

- Introduction situation.
- Investigate situations and identify one of the three suitable areas for focus work.
- Write Design Brief.

Student:

- Investigate chosen situation.
- Write design brief.

Teacher:

- Help identify suitable situation selection through background discussions.
- Assist in the writing of the design brief.
- Advice on organisation of information gained from the Investigations sheet.

Demonstrations:

- A range of personal CDs, tape machines and guitars.
- Investigation of signal strength, methods of connection.
- Completed amplifier circuit.

Resources:

- Examples of personal stereos (if available).
- Example of a completed Amplifier project.
- "Amplification project introduction" sheet.
- "Investigation and tasks" information and activity sheet.
- Access to Library/books/Internet for research information.

Homework:

- Research chosen design situations for Amplifier.
- Selected questions from "Investigations" sheet.
- Diary record.

Week 2 - Amplification Theory and Speaker Design

Aim:

- Understanding of signal amplification.
- Look at the design of speakers

Student:

- Simple amplification and speaker experiments.
- Questions based on activity sheets.

Teacher:

- Introduction to amplification theory.
- Introduction to speaker design.
- Assistance with work on activity sheets.

Demonstrations:

- Simple amplification theory experiments.
- Speaker design.
- Construction techniques and materials used.

Resources:

- "Amplifiers" activity sheet.
- "Speakers" activity sheet.
- Selection of input devices and speaker designs.

Homework:

- Selected questions from activity sheets.
- Diary record.



Lesson Plans

Week 3 - Containment Design

Aim:

- Establish specification.
- Generate initial ideas for case design.
- Develop graphical communication and presentation skills.

Student:

- Write specification.
- Establish range of initial ideas for securing circuit components into case.

Teacher:

- Discuss specification.
- Guide students through generation and development of ideas.
- Advice on presentation techniques and layout of work.

Demonstrations:

- Variety of presentation techniques suitable for communicating ideas.
- Methods of manufacturing case.

Resources:

- "Initial ideas" activity sheet.
- Component parts of Amplifier for measurement.
- Drawing materials.

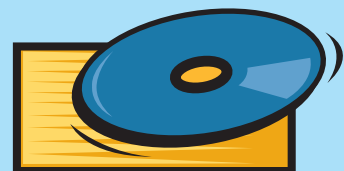
Homework:

- Completion of unfinished design work.
- Diary record.

Week 4 - Circuit Assembly

Aim:

- Review of safe working practices in the workshop.
- Design and production of PCBs.
- Students to start manufacturing Amplifier circuit.



Student:

- Manufacture Amplifier project.

Teacher:

- Go through safety in the workshop with students based on equipment to be used.
- Review the design and manufacture of PCBs.
- Provide assistance to students to start manufacturing Amplifier.

Demonstrations:

- Review soldering.
- Manufacturing a PCB.

Resources:

Class set for five students, order code 70-0180, which includes:

One IC TBA 820M, three 1K resistors (brown, black, red), two 470R resistors (yellow, violet, brown) and one 1R (brown, gold). Two 330uF electrolytic capacitors. One 47nF electrolytic capacitor. One 10uF electrolytic capacitor. One 150 pF ceramic capacitor. One 100nF polyester capacitor. One 8 Ohm speaker. One slide switch. One PP3 battery snap. One 3.5mm stereo jack plug

Class set of five printed circuit boards (pre-drilled), order code 70-0190

- Soldering tools.
- Workshop tools.

Homework:

- Circuit fixture exercises.
- Diary record.

Lesson Plans

Week 5 - Casing Manufacture/Assembly (This section will need additional time if students are to manufacture their own case designs).

Aim:

- Complete construction of Amplifier.
- Assemble Amplifier.

Student:

- Complete any unfinished circuit construction.
- Install circuit in case.

Teacher:

- Provide support to help students finish the soldering of their PCB.
- Assist students in the fitting of their circuits into the case.
- Examine alternative methods of case construction

Demonstrations:

- How to assemble circuit into case.
- Case construction techniques.

Resources:

- Examples to use in demonstrations for assembly of circuit into case.
- Cases for students.
- Vacuum forming machine, suitable mould and sheet material.
- Workshop tools for cutting, shaping and finishing.

Homework:

- Diary record.

Week 6 - Evaluation

Aim:

- Completion of Amplification assembly.
- Evaluation of Amplifier project and student progress.

Students:

- Completion of project assembly.
- Evaluation against specification.
- If sufficient time - Extension exercises based on stereo circuit and injection moulding.

Teacher:

- Help with final project assembly.
- Discussion on important features to include in project evaluations.
- Guidance on extension activity.

Demonstrations:

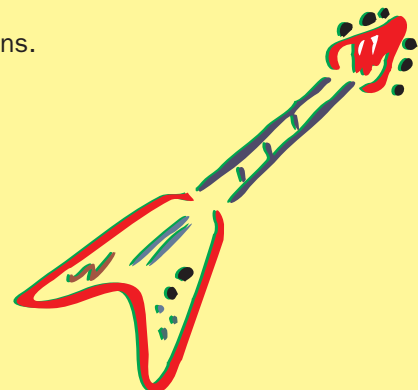
- Project evaluation exercise.

Resources:

- "Evaluation" activity sheets.
- "Product Development" activity sheets.

Homework:

- Diary record and final project evaluation.
- Extension activity.



National Curriculum 2000

Design & Technology

Programme of Study Key Stage 3

During key stage 3 pupils use a wide range of materials to design and make products. They work out their ideas with some precision, taking into account how products will be used, who will use them, how much they cost and their appearance. They develop their understanding of designing and making by investigating products and finding out about the work of professional designers and manufacturing industry. They use computers, including computer-aided design and manufacture (CAD/CAM) and control software, as an integral part of designing and making. They draw on knowledge and understanding from other areas of the curriculum.

Knowledge, skills and understanding

Developing, planning and communicating ideas

1. Pupils should be taught to:

- a) Identify relevant sources of information, using a range of resources including ICT.
- b) Respond to design briefs and produce their own design specifications for products.
- c) Develop criteria for their designs to guide their thinking and to form a basis for evaluation.
- d) Generate design proposals that match the criteria.
- e) Consider aesthetics and other issues that influence their planning .
- f) Suggest outline plans for designing and making, and change them if necessary.
- g) Prioritise actions and reconcile decisions as a project develops, taking into account the use of time and costs when selecting materials, components, tools, equipment and production methods.
- h) Use graphic techniques and ICT, including computer-aided design (CAD), to explore, develop, model and communicate design proposals.

Working with tools, equipment, materials and components to produce quality products

2. Pupils should be taught:

- a) To select and use tools, equipment and processes, including computer-aided design and manufacture (CAD/CAM), to shape and form materials safely and accurately and finish them appropriately.
- b) To take account of the working characteristics and properties of materials and components when deciding how and when to use them.
- c) To join and combine materials and ready-made components accurately to achieve functional results.
- d) To make single products and products in quantity, using a range of techniques, including CAD/CAM to ensure consistency and accuracy.
- e) About the working characteristics and applications of a range of modern materials, including smart materials.

Evaluating processes and products

3. Pupils should be taught to:

- a) Evaluate their design ideas as these develop, and modify their proposals to ensure that their product meets the design specification.
- b) Test how well their products work, then evaluate them.
- c) Identify and use criteria to judge the quality of other people's products, including the extent to which they meet a clear need, their fitness for purpose, whether resources have been used appropriately, and their impact beyond the purpose for which they were designed.

Knowledge and understanding of materials and components

4. Pupils should be taught:

- a) To consider physical and chemical properties and working characteristics of a range of common and modern materials.
- b) That materials and components can be classified according to their properties and working characteristics.
- c) That materials and components can be combined, processed and finished to create more useful properties and particular aesthetic effects.
- d) How multiple copies can be made of the same product.

Knowledge and understanding of systems and control

5. Pupils should be taught:

- a) To recognise inputs, processes and outputs in their own and existing products.
- b) That complex systems can be broken down into sub-systems to make it easier to analyse them, and that each sub-system also has inputs, processes and outputs.
- c) The importance of feedback in control systems.
- d) About mechanical, electrical, electronic and pneumatic control systems, including the use of switches in electrical systems, sensors in electronic switching circuits, and how mechanical systems can be joined together to create different kinds of movement.
- e) How different types of systems and sub-systems can be interconnected to achieve a particular function.
- f) How to use electronics, microprocessors and computers to control systems, including the use of feedback.
- g) How to use ICT to design sub-systems and systems.

Knowledge and understanding of structures

6. Pupils should be taught:

- a) To recognise and use structures and how to support and reinforce them.
- b) Simple tests and appropriate calculations to work out the effect of loads.
- c) That forces of compression, tension, torsion and shear produce different effects.

Breadth of study

7. During the key stage, pupils should be taught the Knowledge, skills and understanding through:

- a) Product analysis.
- b) Focused practical tasks that develop a range of techniques, skills, processes and knowledge.
- c) Design and make assignments in different contexts. The assignments should include control systems, and work using a range of contrasting materials, including resistant materials, compliant materials and/or food.

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If your school would like to be a member of our schools development network to help to evaluate new teaching material, please contact the Education Section at Rapid Electronics.

