ELECTRONICS NOTEBOOK

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by

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A TALKING ELECTRONICS PUBLICATION

INTRO-94

This book is a reprint of the 1984 edition and shows the material we produced 10 years ago is still current. The only thing we have done is increase the number of pages from 66 to 74 to include some extra articles.

As you can see, publishing is a long-term venture as it has taken 5 years to sell the 20,000 copies we had printed. We have been out of copies for nearly 5 years now, due to the high cost of printing but the demand has forced us to reprint.

My intention is to build a collection of books at your local electronics store to get the equivalent of a mini encyclopaedia in electronics, at very low cost.

Up to now we have produced 6 Electronics Notebooks. Number 6 has a complete index so you have a reference for all the issues.

Keep a look-out at your local electronics store as new books will be released as soon as we get the pages ready.

CONSTRUCTION

I have mentioned it before, but I will say it again: The only way to learn electronics is by construction.

It doesn't matter if you build only one project a month, the essential part is to keep up the practical side.

Obviously, the more projects you build, the more you will learn and the theory will be re-inforced at the same time. Talking Electronics has over 140 projects so there's no excuse for not finding something interesting.

Our thrust has always been to present the FUNDAMENTALS of electronics and that's why many of our projects are simple. They are designed to increase your knowledge of BUILDING BLOCKS.

Building blocks are the basis of electronics. When you need to design something in the future, you will find it consists of a number of these blocks. If you have studied them, as we have suggested for the past 10 years, you will be surprised how easy it is to put something together. On quite a number of occassions I have impressed myself by getting a complex design to work, simply by following the approach I have outlined in this series of notebooks. If it works for me, it will work for you. Trust me, I'm an electronics technician!

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Second printing 1994

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Introduction

THIS IS THE SECOND BOOK IN A SERIES OF NOTEBOOKS DESIGNED AROUND THE HANDWRITTEN PAGE.

PREVIOUS WORKS STYLED IN THIS FORMAT RECEIVED INCREDIBLE INTEREST AND THIS HAS SPURRED ME TO RELEASE A FURTHER COLLECTION.

WRITING A PAGE IS SIMILAR TO DRAWING A CARTOON — IT'S 90% INSPIRATION & 10% PERSPIRATION. EACH PAGE REPRESENTS UP TO A FULL DAY'S EFFORT, AS NOTHING IS BEGUN UNTIL THE WHOLE IDEA FOR THE PAGE IS REALIZED. FROM CONCEPT TO COMPLETION OCCUPIES A LOT OF TIME BECAUSE OF THE ATTEMPT TO CONDENSE A LOT OF INFORMATION INTO A SMALL SPACE.

THE FINAL RESULT IS EFFECTIVE BECAUSE EVEN I CAN UNDERSTAND IT.

TRANSISTOR CIRCUITS, ALTHOUGH BEING PHASED OUT, ARE AN IDEAL WAY OF INTRODUCING ELECTRONICS. THEY FORM SIMPLE BUILDING BLOCKS WHICH REQUIRE A FORM OF UNDERSTANDING THAT IS PECULIAR TO ELECTRONICS. WITH SUFFICIENT KNOWLEDGE, CIRCUITS CAN "COME ALIVE" & THE DESIGNER CAN "SEE" THEM OPERATING — LONG BEFORE THEY ARE CONSTRUCTED.

WHEN YOU SEE THIS TOO, THE REMAINDER OF ELECTRONICS FALLS INTO PLACE MUCH EASIER. DIGITAL CIRCUITS BECOME COMPREHENSIBLE, MICROPROCESSOR OPERATION BECOMES CLEAR AND YOU ADVANCE TO THE STAGE OF PRODUCING COMPUTER PROGRAMS.

AND BELIEVE ME, SOME READERS HAVE ALREADY RISEN TO THIS LEVEL. WE CAN SEE THEIR PROGRESS THROUGH THE KITS THEY BUY, THE QUESTIONS THEY ASK & THE PROGRAMS THEY SUBMIT.

I AM SURE YOU WILL FIND THE CONTENTS OF THIS BOOK A GUIDE TO THIS END.

REMEMBER THIS PHRASE:

"THE DIFFERENCE BETWEEN NOT KNOWING & FULLY UNDERSTANDING IS TWO WEEKS!".

COLIN MITCHELL.

JUNE 1984

TALKING ELECTRONICS

ELECTRONICS IS A WONDERFUL MEDIUM FOR DISCUSSION. BUT TO SOUND INFORMED, YOU MUST USE THE CORRECT JARGON. TAKE THE CASE OF CONSTRUCTION. WHILE YOU DO THE SOLDERING, YOUR FRIEND IS IN-CHARGE OF DEALING OUT THE PARTS. HERE IS HOW TO ASK FOR THEM.

"PASS 'US A 47K" - - - - - - - - - - -
"PASS 'US A 2K2" - - - - - - - - - - -

THIS REQUEST ASKS FOR A 47K ¼WATT RESISTOR & A 2K2 RESISTOR. YOU ONLY HAVE TO SAY "47K" — THE REST IS UNDERSTOOD.

"PASS 'US A 5 MILL LED"

THIS INFERS A RED LED — FOR OTHER COLOURS YOU ASK FOR GREEN, ORANGE OR YELLOW.

A TRANSISTOR IS JUST AS EASY.

"PASS 'US A 547".

THIS MEANS A SMALL-SIGNAL NPN TRANSISTOR. NEVER SAY BJT (FOR BI-POLAR JUNCTION TRANSISTOR) OR "TRANNY". WHEN EVER YOU SAY TRANSISTOR YOU MEAN THE COMMON NPN TYPE. IF YOU WANT A PNP — ASK FOR "A 557" OR "BC 557".
IF YOU WANT A FET OR UJT OR PUT ASK FOR "THE FET" OR "THE PUT". YOUR FRIEND WILL KNOW WHICH TYPE IS REQUIRED FOR THE PROJECT.

"PASS 'US A SIGNAL DIODE"

THIS MEANS A IN914 OR IN4148

PASS 'US A POWER DIODE.

THIS MEANS A IN4001, IN4002 OR IN4004.

"47n" - - - - "1n" - - - - - - - - "100n" - - - - - - -

THESE ARE ALL GREENCAPS.

FOR AN ELECTROLYTIC, SAY: "2 POINT 2 MICKEY" "47 MICKEY".

INTEGRATED CIRCUITS ARE REFERRED TO BY THEIR IMPORTANT NUMBERS. FOR A CMOS DEVICE SAY:

"PASS THE 4011" OR "PASS THE 4001".

YOUR FRIEND IS SUPPOSED TO BE ALERT ENOUGH TO KNOW THAT YOU WANT AN IC AND NOT A 4001 DIODE!

TWO OSCILLATORS TO AVOID! (YOU CAN'T GET THE COILS)

1. COLPITTS
2. HARTLEY.

DURING YOUR STUDIES YOU MAY ENCOUNTER THESE NAMES & WONDER IF YOU ARE MISSING OUT ON A GOOD CIRCUIT. YOU ARN'T!

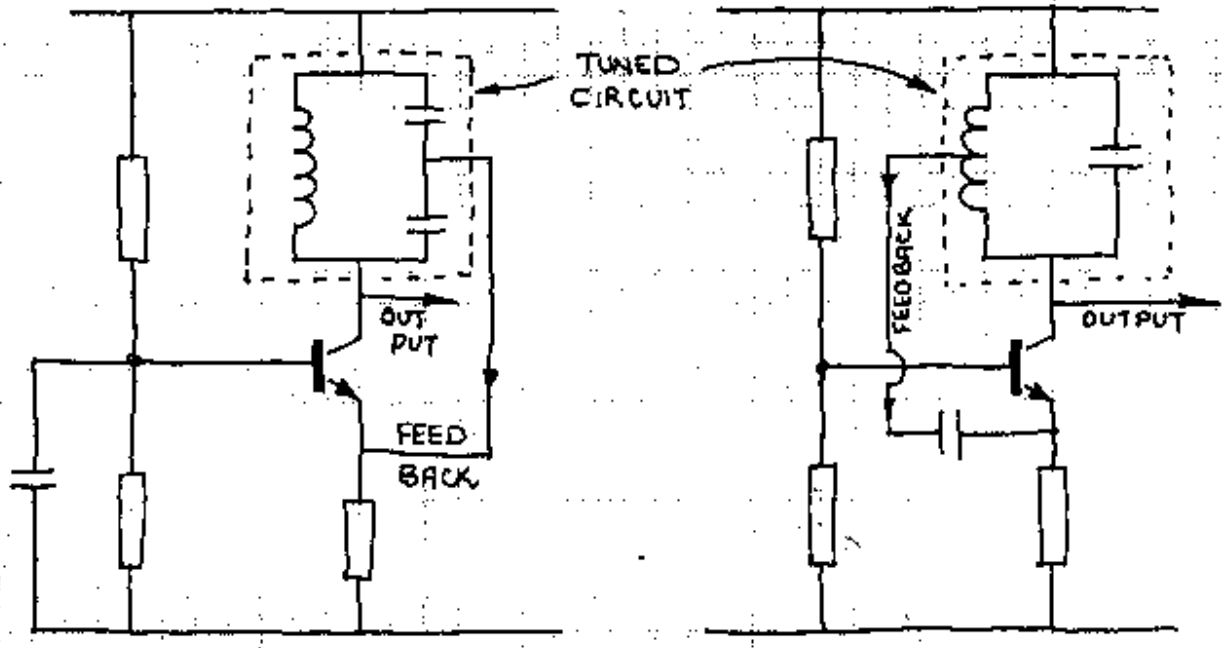
BOTH THESE CIRCUITS ARE VERY OLD IN CONCEPT & HAVE ONE MAJOR LIMITATION. THEY ARE DESIGNED AROUND A COIL OR INDUCTOR FOR THE 'L' PART OF AN L-C RESONANT CIRCUIT.

UNFORTUNATELY COILS FOR THE CIRCUITS ARE NO LONGER AVAILABLE AND WOULD BE EXPENSIVE TO MANUFACTURE.

THE MAIN DIFFERENCE BETWEEN THE TWO CIRCUITS:
A COLPITTS OSCILLATOR USES A SINGLE INDUCTOR & A TAPPED CAPACITOR NETWORK.
A HARTLEY OSCILLATOR USES A TAPPED COIL & A SINGLE CAPACITOR.

THE OUTPUT WAVEFORM OF BOTH CIRCUITS IS A SINEWAVE & THE MODERN EQUIVALENT IS A PHASE - SHIFT OSCILLATOR.

A PHASE-SHIFT OSCILLATOR USES 3 PHASE-SHIFT NETWORKS TO PRODUCE A 180° PHASE-SHIFT & THUS KEEP THE CIRCUIT OSCILLATING. THE CIRCUIT IS CHEAP TO BUILD & REQUIRES LESS SPACE.

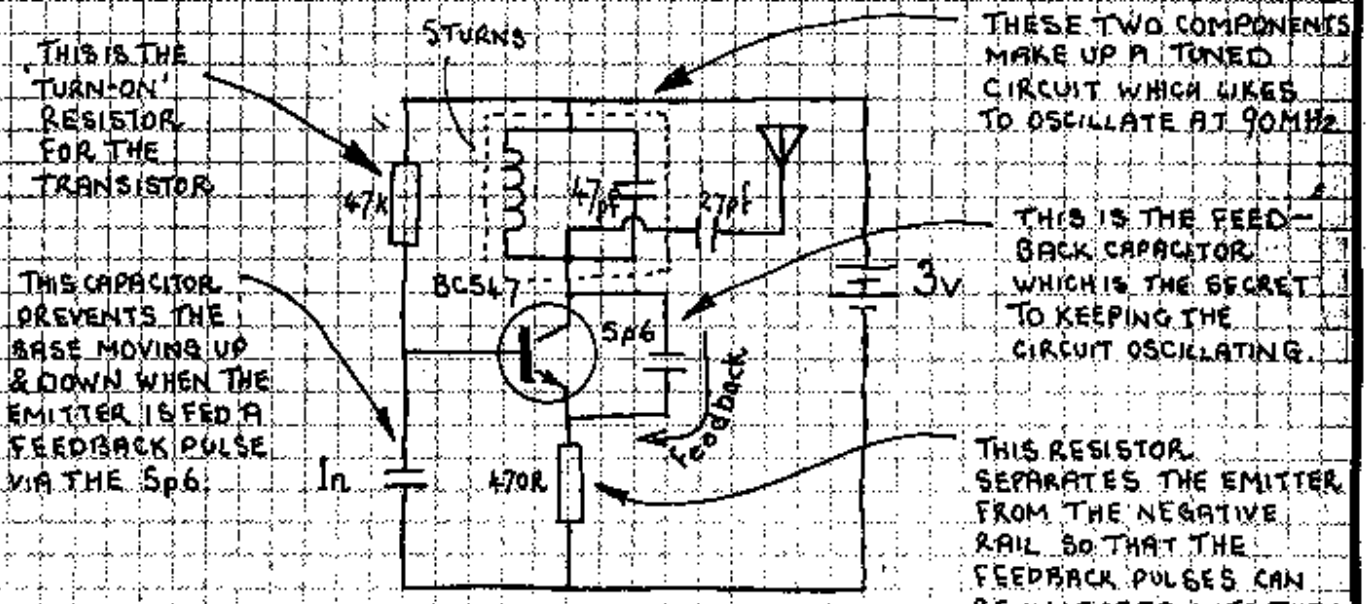


COLPITTS HARTLEY

THESE TWO CIRCUITS CAN BE COMBINED & THE COMPONENTS SELECTED TO PRODUCE A HIGH FREQUENCY OSCILLATOR CAPABLE & RADIATING ITS ENERGY — IT THEN BECOMES A TRANSMITTER!

A 90 MHz TRANSMITTER.

THIS IS A SIMPLE TRANSMITTER WHICH WILL PRODUCE A CONSTANT OSCILLATION OF 90 MHz. IT CAN BE ADJUSTED BETWEEN 88 MHz — 108 MHz BY MOVING THE 5-TURNS OF THE ANTENNA COIL CLOSER TOGETHER OR FURTHER APART.



A 90MHz TRANSMITTER

THE TRANSMITTER CAN BE DETECTED ON THE FM BAND AT '90' ON THE DIAL. THE BACKGROUND 'HISS' OR NOISE, WILL BE SILENCED WHEN THE TRANSMITTER IS 'ON CHANNEL'.

EVEN THOUGH IT PRODUCES ONLY A FEW MILLIWATTS OF RADIATED ENERGY IT WILL TRANSMIT A DISTANCE OF 200 METRES OR MORE.

AT A FREQUENCY OF 90MHz THE CAPACITIVE EFFECT OF THE JUNCTIONS OF THE TRANSISTOR CONTRIBUTE TO THE OPERATING FREQUENCY & THIS MAKES THE CIRCUIT FAIRLY COMPLEX IN OPERATION. HOWEVER THE SIMILARITY BETWEEN A COLPITTS & HARTLEY OSCILLATOR IS VERY INTERESTING.

THE FEEDBACK SIGNAL IS INJECTED INTO THE EMITTER AND THIS IS HOW THE CIRCUIT WORKS:

WHEN THE POWER IS APPLIED TO THE CIRCUIT THE COLLECTOR IS AT RAIL VOLTAGE (3v) & THE 47K RESISTOR TURNS THE TRANSISTOR ON. THE 47pf (puff) CAPACITOR IN THE TUNED CIRCUIT CHARGES & ALLOWS THE COLLECTOR VOLTAGE TO FALL.

A SMALL AMOUNT OF THIS FALLING-VOLTAGE IS FED TO THE EMITTER VIA THE 5p6. (THE 5p6 IS LIKE A PIECE OF RUBBER BEING PUSHED BY THE COLLECTOR & THE EFFECT BEING FELT BY THE EMITTER).

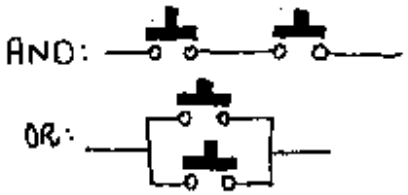
GATING WITH DIODES

GATING WITH DIODES CAN BE A VERY SIMPLE WAY OF GETTING AROUND A GATING PROBLEM. DIODES ARE VERY CHEAP AND TAKE UP VERY LITTLE SPACE, AND CAN BE LOCATED ANYWHERE ON THE PC BOARD, UNLIKE GATES WHICH ARE GROUPED IN AN IC PACKAGE.
THERE ARE TWO MAIN WAYS OF CONSIDERING A GATING PROBLEM. ONE IS CALLED POSITIVE LOGIC, THE OTHER NEGATIVE LOGIC.

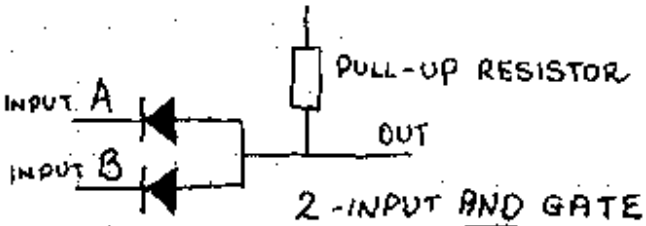
POSITIVE LOGIC IS NORMAL LOGIC & WE WILL COVER THIS SYSTEM.

THE TWO MAIN GATES ARE AND & OR.

IN ELECTRICAL TERMS THEY ARE DRAWN:



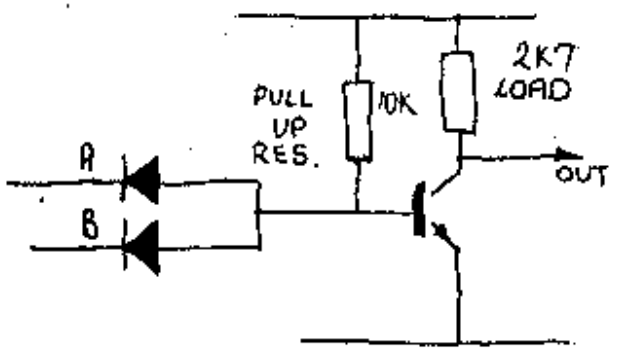
ELECRONICALLY AN AND GATE CAN BE CONSTRUCTED WITH 2 DIODES:



2-INPUT AND GATE.

THE OUTPUT LINE WILL RISE ONLY WHEN LINES A & B GO HIGH. THE PULL-UP RESISTOR DOES ALL THE PULLING-UP. NO CURRENT IS DRAWN FROM LINES A OR B.

BY ADDING A TRANSISTOR TO THE AND GATE WE GET AN INVERSION CIRCUIT. THE RESULT IS A NAND GATE.



IN THE CIRCUIT ABOVE, WHEN LINES A & B ARE AT ZERO POTENTIAL, THE ANODES OF THE GATING DIODES ARE AT A POTENTIAL OF ·6V. THIS MEANS THE TRANSISTOR IS AT THE VERGE OF CONDUCTION AND DOES NOT LEAVE ANY MARGIN FOR ERROR.

AN IMPROVED DESIGN INCLUDES AN ADDITIONAL DIODE IN THE BASE LINE. THIS DIODE WILL DROP A CONSTANT ·6V AND THIS MEANS THE BASE MUST RISE (·6V + ·6V) 1·2V BEFORE THE TRANSISTOR WILL TURN ON. — SEE NEXT PAGE.

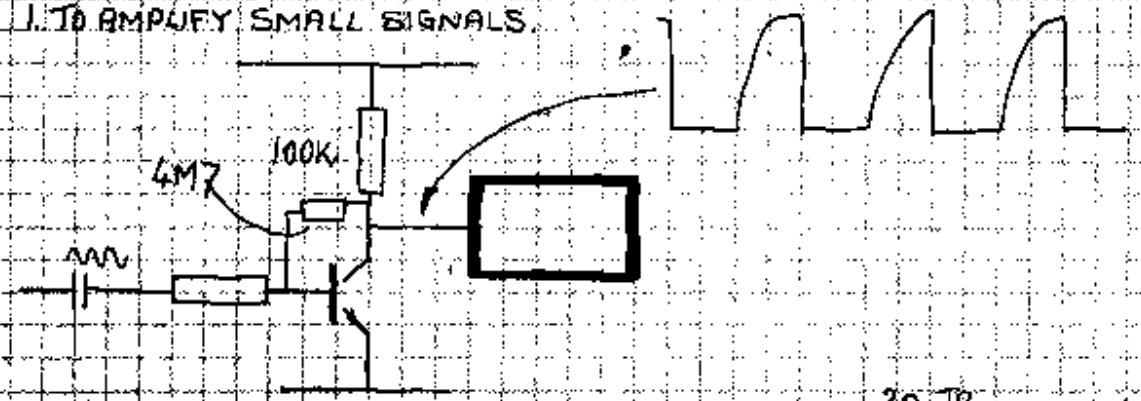
WHY DO WE NEED A TRANSISTOR STAGE?

YOU MAY ASK "WHY DO WE NEED A TRANSISTOR STAGE IN A DIGITAL CIRCUIT?"

THERE ARE AT LEAST 5 REASONS.

1. TO AMPLIFY SMALL SIGNALS.
2. TO DELIVER HEAVY CURRENTS (ABOVE 10mA)
3. TO MATCH A DIGITAL CIRCUIT OPERATING ON ONE VOLTAGE TO ONE ON A DIFFERENT VOLTAGE.
4. TO CHANGE A SLOW RISE-TIME INTO A FAST RISE-TIME.
5. TO CHANGE THE TIMING (THE PROPAGATION) OF A CIRCUIT.

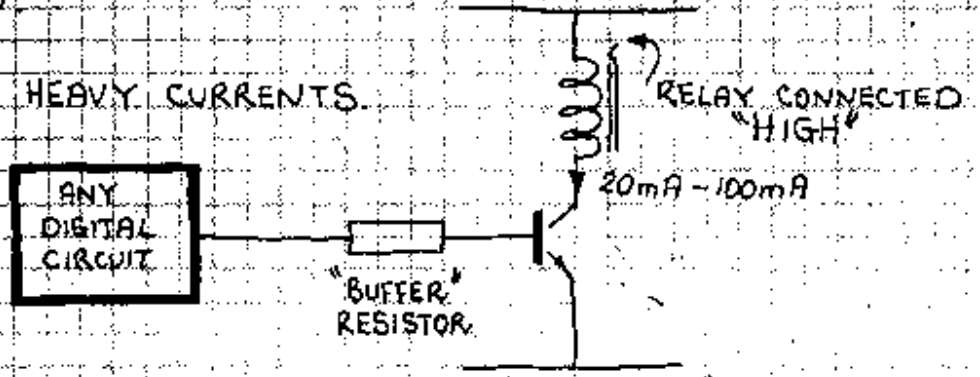
1. TO AMPLIFY SMALL SIGNALS.



20 TO 100 mV

THIS CIRCUIT WILL DETECT INPUT PULSES OF ABOUT 100 mV AND AMPLIFY THEM SO THAT THEY WILL CLOCK THE DIGITAL CIRCUIT. THIS IS QUITE OFTEN NEEDED WHEN USING SENSORS WHICH HAVE A LOW OUTPUT, e.g. A MAGNETIC PICK-UP COIL, A PHOTO EYE, AN INFRA RED RECEIVER OR AN ELECTRET MICROPHONE. IT MAY BE REQUIRED TO GET THE PULSES FROM THE DETECTOR TO THE DIGITAL CIRCUIT USING THE LEAST NUMBER OF STAGES. THE CIRCUIT ABOVE WILL DO THIS.

2. DELIVERING HEAVY CURRENTS.

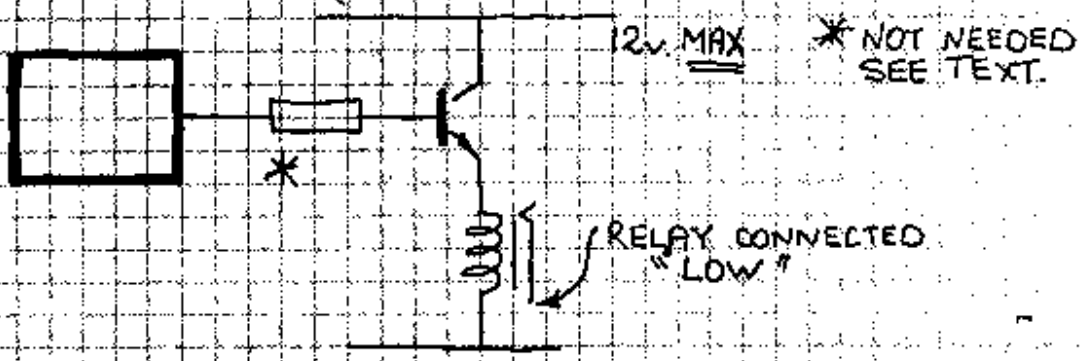


THE OUTPUT CURRENT OF A DIGITAL CIRCUIT CAN BE INCREASED FROM 10mA TO 100mA OR MORE BY INTRODUCING A TRANSISTOR DRIVER STAGE. THIS WILL ENABLE A LOAD SUCH AS A RELAY OR GLOBE TO BE OPERATED. THE CIRCUIT ABOVE IS CALLED A COMMON EMITTER STAGE (OR COMMON EMITTER AMPLIFIER) & HAS THE LOAD IN THE COLLECTOR CIRCUIT.

THIS MEANS THE RELAY IS CONNECTED TO THE POSITIVE RAIL & WE SAY IT IS CONNECTED "HIGH".

IF THE LOAD IS REQUIRED TO BE CONNECTED "LOW" (NEAR THE EARTH RAIL) THE CIRCUIT MUST BE RE-ARRANGED & THE LOAD INSERTED INTO THE EMITTER LEAD.

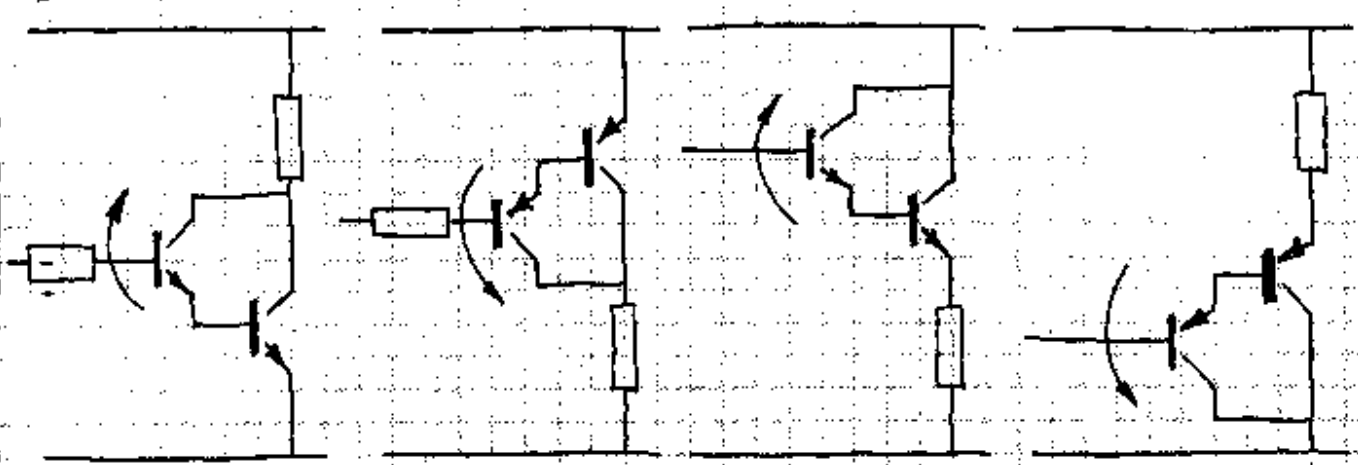
BOTH THESE CIRCUITS HAVE SIMILAR PERFORMANCE BUT IN THIS CIRCUIT THE RELAY MUST BE A 12V TYPE.



IN THE EMITTER-FOLLOWER ARRANGEMENT ABOVE THE BUFFER RESISTOR IS NOT NEEDED. ITS PURPOSE WAS TO SEPARATE THE HIGH OUTPUT VOLTAGE OF THE DIGITAL CIRCUIT FROM THE .6v MAX RISE OF THE BASE. WITH AN EMITTER FOLLOWER ARRANGEMENT THE BASE WILL RISE TO THE FULL RAIL VOLTAGE & THUS THE BASE CAN BE CONNECTED DIRECTLY TO THE OUTPUT OF THE DIGITAL CIRCUIT.

A SUPER-ALPHA PAIR CAN BE CONNECTED IF A HIGHER LOAD CURRENT IS REQUIRED. THIS TYPE OF ARRANGEMENT HAS ALREADY BEEN COVERED & THE NEED OR ABSENCE OF THE BUFFER HAS ALSO BEEN DISCUSSED.

THE CHOICE OF CIRCUIT WILL DEPEND ON:
A) THE LOAD TO BE PLACED HIGH OR LOW
B) LOAD CURRENT WHEN INPUT HIGH OR LOW.



The Electret Microphone

Almost all modern audio projects use a microphone called an ELECTRET MICROPHONE as the audio pick-up device. It is the cheapest and best on the market.

Even though the electret microphone appears to be very simple, it is really an amazing piece of electronic engineering and yet very little has been written on how it works and how it is connected to a circuit. This article should change that.

The electret microphone is one of the most recent microphones to come on the market. The earliest successful microphone was the carbon type as found in old-style telephones, then came the dynamic microphone, crystal microphone and a whole range of variations using these types of technology.

Then came the electret microphone. It is completely different. It uses the latest technology.

It is in the family of condenser microphones but uses a recently developed plastic for the diaphragm and a Field Effect device as the built-in amplifier. Its main advantage is high sensitivity and the fact that no potential is required to produce the polarising of the diaphragm.

The first devices were produced by Bell Telephone Laboratories in the USA around 1969 and by the Sony Corporation of Japan.

The electret microphone works on the principle of an electric field. This electric field is permanently applied to a sheet of plastic during manufacture and remains on the sheet for the life of the microphone. This was one of the most difficult things to achieve. As you know, an electrostatic charge soon dissipates from a charged body and getting the plastic to retain the charge was a breakthrough. This is called the electret phenomenon - the name coming from the analogy of the magnetic field in magnetism.

The electrostatic charges on the plastic diaphragm are permanently present due to the special type of metallised foil and the manufacturing process.

The first electrets used very thin sheets of metallised florocarbon or polycarbonate subjected to a strong electric field, so that the electrostatic charge remained on the material after the field was removed.

Early electrets suffered from charge deterioration, especially in hot humid conditions but this has been overcome with more-modern plastics.

The electrets we use today are really INSERTS rather than "microphones" as the term microphone is the hand-held device containing the componentry, with a cover and base etc.

The electret insert looks like an aluminium case with two leads emerging at one end. The other end has a hole for the sound to enter and move the diaphragm. Over this hole is placed a thin piece of gauze to prevent dust and moisture from entering and touching the electret material.

Inside the microphone there are only two components, the thin diaphragm (the electret material) and a Field Effect amplifying chip as shown in the first diagram.

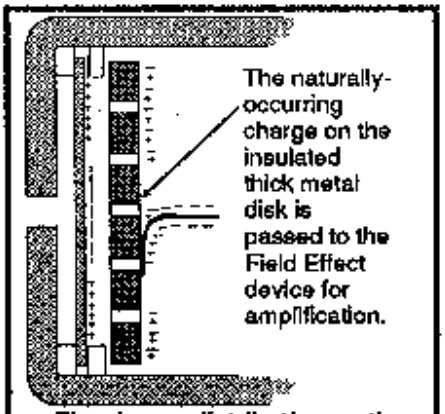
The chip has the code number K65 (or a similar number) and is either a simple FET transistor or as the early details of the electret device have stated, "an amplifying chip using Field effect devices."

In any case, the Field Effect amplifier requires only a very low voltage for it to operate.

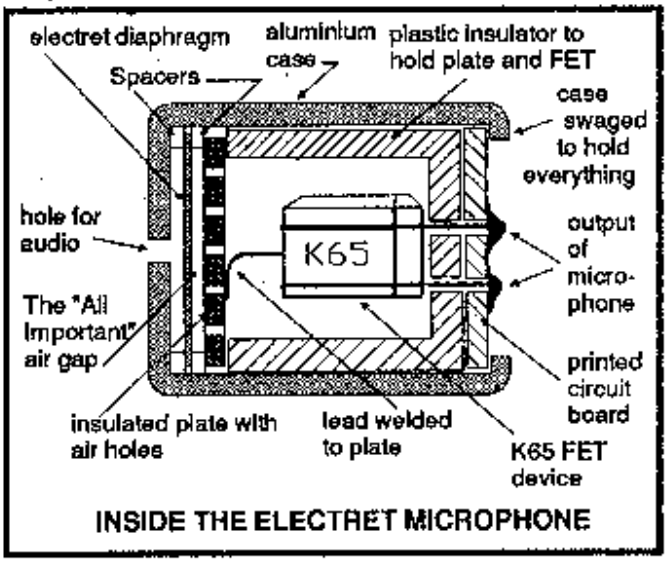
A supply voltage from .5v to 15v can be used with the appropriate load resistor. The load resistor should be at least 10k per volt. This means for a supply voltage of 3v, the load resistor should be at least 33k.

The chip will then draw its operating current and produce a voltage across the leads of the microphone of about 50mV. This is sufficient for the microphone to work. Under normal conditions the output will be about 10 - 30mV.

Some microphones will produce a voltage higher than 50mV as the DC component and this does not necessarily signify a good device or a poor device. It is one of the characteristics that cannot be altered and does not effect the operation of the microphone.



The charge-distribution on the electret microphone



INSIDE THE ELECTRET MICROPHONE

THE ELECTRET MICROPHONE

HOW IT WORKS

The audio entering the microphone moves the plastic diaphragm and this causes the naturally-occurring charge on a nearby thick metal plate to re-distribute.

The charge-movement then flows into a Field Effect chip that amplifies the charge to produce an output.

We have shown negative charges entering the Field Effect device in the second diagram but this is only diagrammatical. The positive charge may, in fact, flow into the amplifier.

THE AIR GAP

The spacer between the electret material and the plate produces the ALL-IMPORTANT air gap of the "capacitor" while the spacer on the other side is an annulus (ring shape) to hold the thin electret material in place. A plastic insulator holds the plate away from the metal case to keep it insulated.

The thick metal plate has holes in it to allow the air to pass through as the diaphragm vibrates. The air space inside the microphone allows the air to pass to and fro without any restriction.

The field effect chip is fitted inside the case with one lead welded to the metal

HOW A SWINGING MOBILE WORKS

We have all seen mobiles that swing back and forth in shop windows - they attract our attention.

These clever devices use a combination of mechanics, electrics and electronics to produce an amazing visual effect.

Their operation is so simple yet positively brilliant. Learning how they work will help you understand many other electrical and electronic components including the loudspeaker, transformer, tank circuit and how a transistor turns ON and OFF.

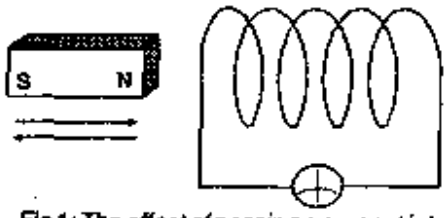


Fig 1: The effect of passing a magnet into and out of a coil

Before we go into the principle of operation of a mobile we need to cover some of the basic rules of electromagnetism.

In figure 1 we have a coil of wire connected to a centre-zero voltmeter.

(a) When the magnet is moved towards the coil, the needle will read up-scale. When it is withdrawn the needle will read down-scale. This shows voltage is produced in one direction when the magnet approaches and in the other direction when the magnet is withdrawn.

(b) If the magnet is moved quickly into the coil the needle will produce a higher reading than if moved slowly. This shows the voltage is dependent on the speed of the magnet.

(c) If the magnet is moved into the coil and held stationary, the needle will move to the centre (zero) position and remain at ZERO. This means it is NOT the magnetism that creates the voltage but the increasing or decreasing lines of magnetic force.

These are the three facts you need to remember when studying the operation of the mobile.

HOW THE MOBILE WORKS

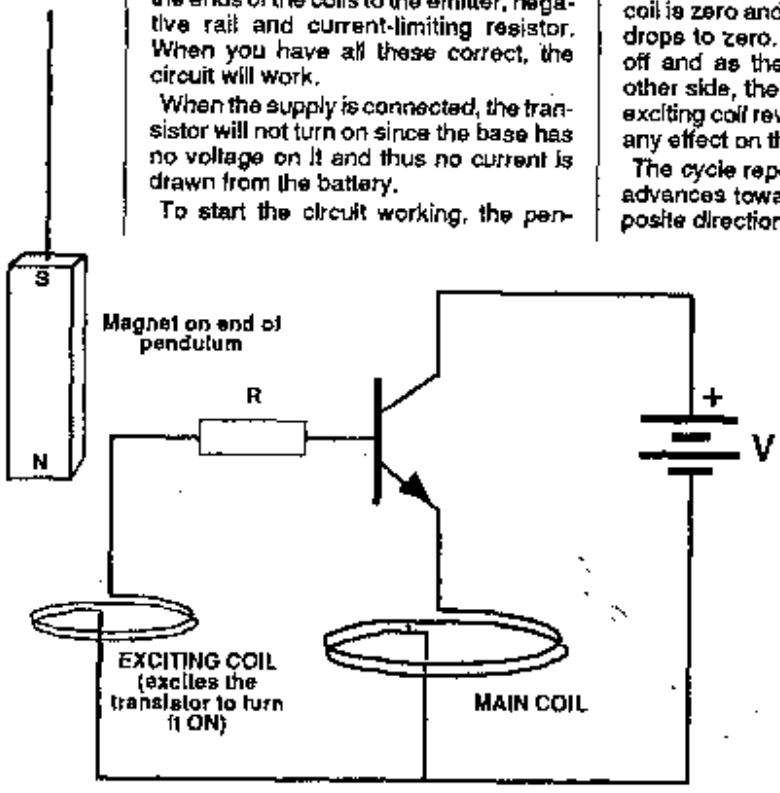
The mobile consists of two coils of wire wound on top of each other and mounted in the base of the mobile. Along with this is a transistor, a current-limiting resistor to prevent the base from being damaged and a power source such as two cells or a 9v battery.

The circuit diagram shows the coils separately but in fact they are wound together to form an electromagnet. The pendulum of the mobile contains a magnet and it is important that the north pole is down, for the circuit to work. If the south pole is down, the windings of the coils would have to be around the other way.

The direction of winding of the two coils is also important as is the connection of the ends of the coils to the emitter, negative rail and current-limiting resistor. When you have all these correct, the circuit will work.

When the supply is connected, the transistor will not turn on since the base has no voltage on it and thus no current is drawn from the battery.

To start the circuit working, the pendulum is pulled back and as it swings towards the two coils it produces a voltage in the "exciting coil" that turns on the transistor.



CIRCUIT IN BASE OF MOBILE

The transistor supplies energy to the main coil and the flux produced by this coil cuts the turns of the exciting coil and turns the transistor ON even harder. This process continues very rapidly until the transistor is fully turned on and the main coil is producing maximum flux.

This flux pulls the magnet closer and gives the pendulum a small amount of energy so that it can maintain the swinging action.

However there's an important fact we must not over-look. When the main coil is producing maximum flux, the flux is not increasing in value and thus it is not cutting the turns of the exciting coil and so the transistor is not being kept on. What is happening is the magnet is getting closer and its flux is cutting the turns of the exciting coil, thus keeping the transistor on.

When the magnet reaches the bottom of its travel, the relative forward motion between the magnet and the exciting coil is zero and so the voltage in the coil drops to zero. This turns the transistor off and as the magnet swings up the other side, the voltage produced by the exciting coil reverses and does not have any effect on the transistor.

The cycle repeats when the pendulum advances towards the coil from the opposite direction and the effect we see is "perpetual motion" as there are no wires or motors touching the pendulum - it's all done with magnetism!

The pendulum can have extra counter weights or secondary or tertiary pendulums to produce all sorts of intreguing effects.

Even a gyroscopic wheel on a curved incline operates in exactly the same way. It has a magnet imbedded in the circumference and as it passes the coil, it receives a brief pulse of energy that keeps it spinning.

Very old battery clocks using a balance wheel (a wheel with hair-spring) employ the same principle too.

A magnet attached to the balance wheel has energy imparted to it each time it passes the coil.