$4.00

ELECTRONICS NOTEBOOK

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by

Colin Mitchell

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A TALKING ELECTRONICS PUBLICATION

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CONTENTS

BEC stands for Basic Electronics Certificate. This is the name for the basic electronics course during the 1980's. It will have changed its name by now but the requirements remain the same. You need a course with an instructor to help you learn electronics, even if it's just to get the name and pronounciation of components such as LEDs, 555's, bezels and CRO's and the understanding of values such as 10n, 104, 223, etc, etc, etc.
For every hour of the course you should allow one hour for construction. That's right - making things! That's the only way you will get anywhere.

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Talking Electronics,
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INTRODUCTION

These notebooks have proven their worth, many times over. Newcomers to electronics are constantly asking for information and books that answer their questions in a way that they can understand.

That's the purpose of these notebooks. By preparing a page or two every few days, the whole of electronics will be covered. But that's a huge undertaking. I don't want to cover that already in text books but rather fill in the gaps and explain things in a different way to make them more easily understood.

Even quite complex problems can be broken down and covered at basic level. After all, most circuits consist of many simple 'blocks' and our pages aim to cover these.

Everything I do has a goal and it should be the same with you. One of your first aims should be to get a basic certificate in electronics.

The BEC is just that. The BEC is the BASIC ELECTRONICS CERTIFICATE and since its existence will be unknown to many, I have decided to promote it in this issue.

In the last section of this book you will see details on the BEC including a set of typical exam papers, complete with answers.

The beauty of this course is it comes in many forms: Full-time, part-time, self-paced and correspondence.

To find out more about the content and fees etc, you should contact your local TAFE college and they will put you in contact with the closest participating college.

After looking into the content of the BEC and reading through some past exam papers, I can thoroughly recommend it as a valuable starting point.

Three exams must be taken to cover the content of the course and a series of practical experiments must also be handed in, to gain a pass.

The exams consist of 'objective-type' questions and this allows a large range of topics to be covered. This type of questioning is very tricky as the multi-choice answers can put you off the track very easily.

To perform effectively in the exam you must have had prior experience with this mode of questioning. To this end I have included a set of questions as mentioned above. From the feed-back I get, a complete book on the exam may be produced.

Please let me know if you are doing the course and if more questions are needed.

To assist in the course, don't forget the range of Talking Electronics projects. There is no better way to learn electronics than by construction. We have nearly 100 kits available, ranging from a diode tester to a simple Z-80 based computer. I would suggest building at least 10 to 15 kits to gain the skills necessary for the course.

After the BEC, the choice is yours. At TE we only start you off. Once you climb the first rung, you will be able to see the paths that open up. It's the first, initial stage that's so difficult.

Let's hope we can start you off.

For now, Colin.

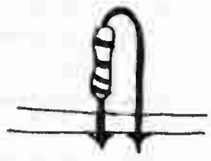
Colin. VII '88

STARTING OUT

THESE PAGES WILL HELP YOU IDENTIFY COMPONENTS & SHOW HOW TO SOLDER THEM CORRECTLY.

THE RESISTOR

THIS IS THE ACTUAL SIZE OF A ¼ WATT RESISTOR: IT CAN BE SOLDERED TO A PC BOARD IN 3 WAYS:



(A) STANDING UP

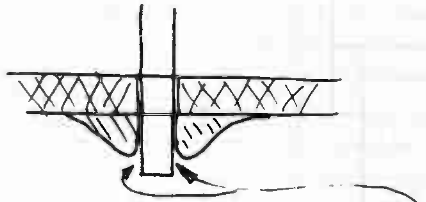
(B) LYING FLAT

(C) SOLDERED TO THE UNDERSIDE

A RESISTOR CAN BE SOLDERED 'EITHER WAY AROUND' (IT IS CALLED A NON-POLAR COMPONENT – MEANING IT IS NOT POLARISED). IT IS VERY DIFFICULT TO DAMAGE DURING SOLDERING & YOU CAN BEND THE LEADS AS CLOSE TO THE BODY AS YOU LIKE WITHOUT FEAR OF THEM BREAKING OFF.

WHEN MOUNTING A RESISTOR AS IN (A) OR (B) PUSH IT UP TO THE PC BOARD & SOLDER THE LEADS SO THAT SOLDER FLOWS AROUND THE LEAD & DOESN'T FORM A 'DRY JOINT'.

A DRY JOINT IS ONE THAT CAN BE WIGGLED AND PULLED APART. THIS IS DUE TO ① THE LEAD BEING DIRTY OR ② NOT ENOUGH NEW SOLDER BEING APPLIED OR ③ SOLDERING TOO QUICKLY. WHEN SOLDERING, KEEP THE IRON ON THE JOINT FOR A FULL 2 SECONDS SO THAT THE HOT SOLDER AND FLUX WILL CLEAN THE LEAD AND MAKE A SHINY JOINT.

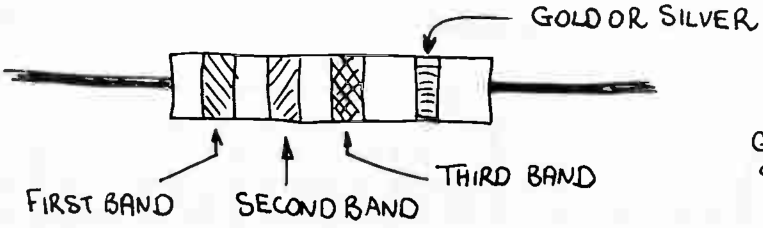


IF THE SOLDER "PULLS BACK" LIKE THIS, YOU HAVE MADE A DRY JOINT.

READING RESISTORS

THE VALUE OF RESISTANCE IS SHOWN BY COLOURED BANDS. IN THIS DISCUSSION WE WILL TALK ABOUT 5% & 10% RESISTORS — THESE RESISTORS HAVE 3 COLOURED BANDS & A TOLERANCE BAND — EITHER GOLD OR SILVER.

TO READ THESE BANDS, HOLD THE RESISTOR SO THAT THE TOLERANCE BAND IS ON THE RIGHT.



TOLERANCE:

GOLD = 5%
Silver = 10%.

TOLERANCE IS THE ACCURACY OF A RESISTOR. NOTHING CAN BE MADE 'EXACT' AND USUALLY THE ¼ WATT RANGE COMES IN 5% TOLERANCE.

THE VALUE OF RESISTANCE IS GIVEN IN OHMS (Ω). ONE THOUSAND OHMS IS 1 KILO-OHMS (WRITTEN K) – ONE MILLION OHMS IS ONE MEG OHMS (WRITTEN M). THE LETTER FOR OHMS IS R

FOR INSTANCE 2,200 OHMS = 2K2 OR 2·2K
1,000,000 OHMS = 1M
470,000 " = 470K
39,000 " = 39K
100 OHMS = 100R
4·7 OHMS = 4R7
·22 OHMS = R22
22 OHMS = 22R
2·2 OHMS = 2R2

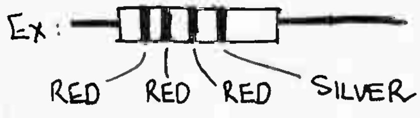
THE RESISTOR COLOUR CODE

THE RESISTOR COLOUR CODE MUST BE LEARNT BY HEART.

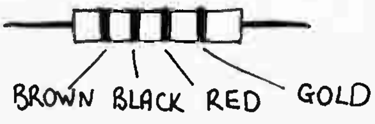
	FIRST BAND	SECOND BAND	THIRD BAND	FOURTH BAND:
BLACK	0	0	OHMS (R) eg. 47R, 68R, 82R.	
BROWN	1	1	0 R eg. 220R, 470R, 560R	
* RED	2	2	00 R eg. 2200R (2K2) 4700R (4K7)	
* ORANGE	3	3	,000 R OR K eg. 33K, 47K.	
YELLOW	4	4	0,000 R OR 0 K eg. 470K, 560K.	
GREEN	5	5	00,000 R OR 00 K OR __ • __ M	
BLUE	6	6	M eg 10M eg. 2M2, 4M7	
PURPLE	7	7	—	
GREY	8	8	—	
WHITE	9	9	—	
GOLD	—	—	÷ 10 R	5% eg. 2R2/5%
SILVER	—	—	÷ 100 R	10% eg R22/10%.

* RED & ORANGE ARE VERY HARD TO TELL APART. – SO BE CAREFUL.

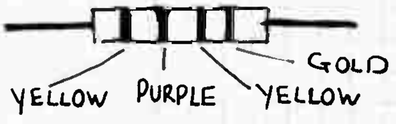
Ex:



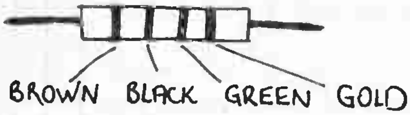
2K2 10%.



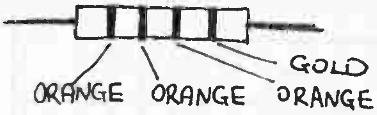
1K 5%.



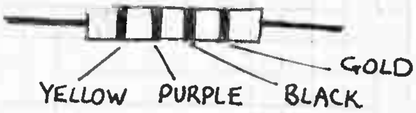
470K 5%.



1M 5%.



33k 5%



47R 5%

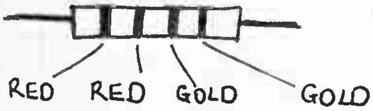
HOW TO READ VALUES LESS THAN 10R (10 OHMS)

FOR VALUES LESS THAN 10R (EG. 4·7 OHMS 3·3 OHMS 1 OHM ·47 OHMS ·22 OHMS ·1 OHMS ETC) THE THIRD BAND IS EITHER GOLD OR SILVER. THE FOURTH BAND IS STILL THE TOLERANCE (GOLD OR SILVER) & THIS GIVES RISE TO RESISTORS SUCH AS YELLOW - PURPLE - GOLD - GOLD, ORANGE - ORANGE - SILVER - GOLD.

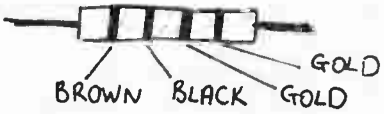
GOLD AS THE THIRD BAND MEANS YOU DIVIDE THE NUMERICAL VALUE OF BANDS 1&2 BY 10. ie. 47 ÷ 10 = 4·7R = 4R7.

SILVER AS THE THIRD BAND MEANS YOU DIVIDE THE VALUE AS FOUND FROM BANDS 1&2 BY 100. A RESISTOR SUCH AS YELLOW - PURPLE - SILVER - GOLD IS 47 ÷ 100 = ·47 OHMS = ·47R = R47.

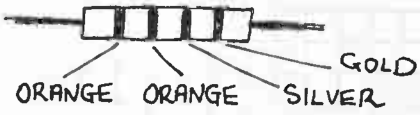
THE WAY TO REMEMBER THE DIVISION FACTOR IS: SILVER HAS MORE LETTERS THEREFORE DIVIDE BY 100. GOLD HAS LESS LETTERS IN ITS NAME THEREFORE DIVIDE BY 10!!



2R2 5%.



1R 5%.

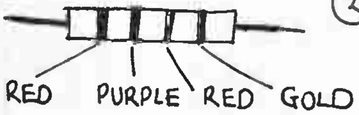


R33 5%

TO AVOID CONFUSION, THE LETTER R, K OR M IS PUT IN THE POSITION OF THE DECIMAL POINT. EG: 4·7K IS WRITTEN 4K7 2·2M IS WRITTEN 2M2 ETC. ONE OHM CAN BE WRITTEN 1R OR 1R0. DO NOT WRITE 1RΩ OR 3R3Ω OR 27KΩ OR 27ΩK OR 27KR ETC. DO NOT USE 'Ω' AS TYPEWRITERS DO NOT HAVE THIS SYMBOL!

QUIZ: WRITE DOWN THE VALUE OF THESE RESISTORS:

①



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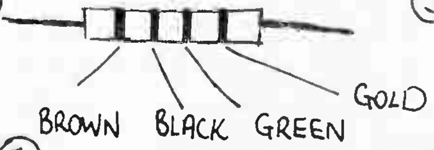

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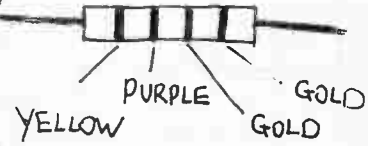

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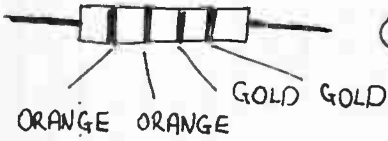

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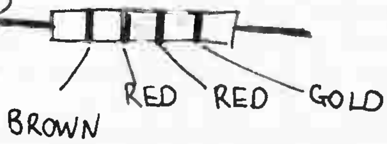

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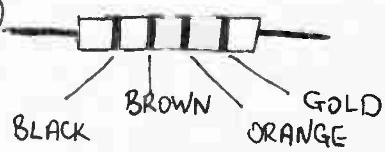
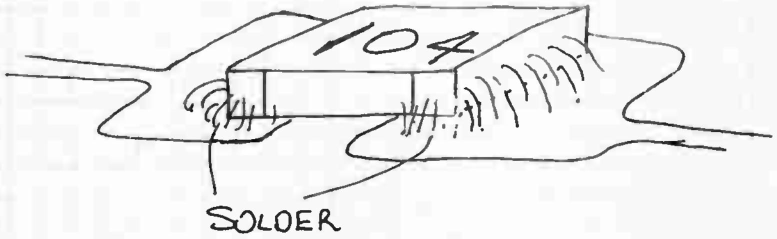


1: 2K7 5% 2: 1M 5% 3: 4R7 5% 4: 3R3 5% 5: 1K2 5% 6: 10K 5%.

SURFACE-MOUNT RESISTORS

THIS IS A SURFACE-MOUNT RESISTOR:  ACTUAL SIZE!

SURFACE MOUNT RESISTORS ARE GRADUALLY BEING INTRODUCED INTO PROJECTS AND ALTHOUGH THEY ARE VERY SMALL, IT IS POSSIBLE TO HAND SOLDER TO THE PC BOARD. THEY ARE SOLDERED TO THE COPPER SIDE OF THE BOARD BY FIRSTLY TINNING THE LANDS THEN PLACING THE CHIP RESISTOR IN POSITION.& HOLDING IT IN PLACE WITH A SMALL SCREW-DRIVER, PAPER-CLIP OR CLAMP. EACH LAND IS THEN HEATED WITH A FINE TIPPED SOLDERING IRON SO THAT THE SOLDER MELTS & FLOWS UNDER THE RESISTOR. THIS IS CALLED



REFLOW SOLDERING AS NO EXTRA SOLDER IS ADDED.

IDENTIFYING SURFACE-MOUNT RESISTORS

SURFACE MOUNT RESISTORS HAVE A 3-FIGURE NUMBER ON THEIR TOP TO IDENTIFY THE RESISTANCE IN OHMS.

THE RESISTANCE VALUE IS GIVEN BY THE FIRST TWO DIGITS & THE THIRD FIGURE GIVES THE NUMBER OF ZEROS THAT ARE PLACED AFTER THE TWO DIGITS. FOR EXAMPLE 104 ON THE RESISTOR ABOVE = 10 & 0,000 = 100,000 OHMS = 100K.

HERE ARE SOME EXAMPLES:

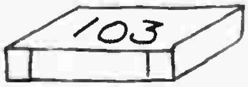
"100" = 10 OHMS
101 = 100 OHMS
102 = 1K
103 = 10K
104 = 100K
105 = 1M.

220 = 22 OHMS
221 = 220 OHMS
222 = 2K2
223 = 22K
224 = 220K
225 = 2M2

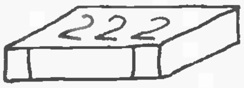
470 = 47 OHMS
471 = 470 OHMS
472 = 4K7
473 = 47K
474 = 470K
475 = 4M7

NOTE: "100" ON A RESISTOR MEANS "10" & "NO ZERO'S". = 10 OHMS
"101" " " " " "10" & "1 ZERO" = 100 OHMS.

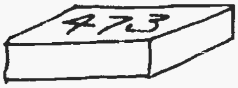
EX:



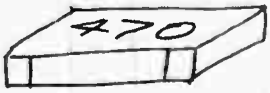
10K



2K2

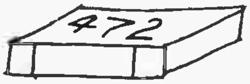


47K

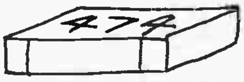


47R

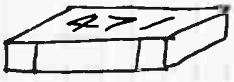
1M



4K7



470K



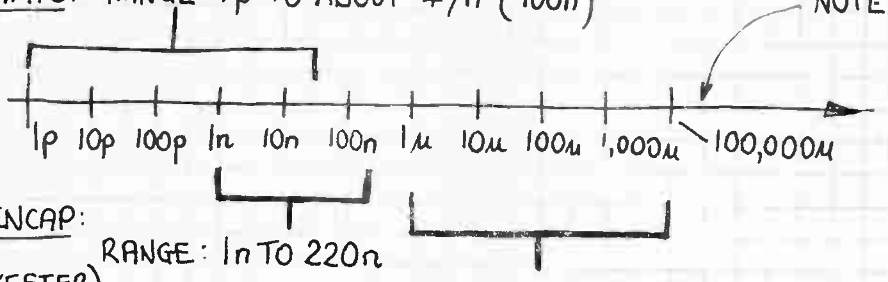
470R

CAPACITORS

CAPACITORS RANGE FROM 1p (ONE "PUFF" – 1pF) TO 100,000 µF (MICROFARAD) AND MORE! THIS IS AN ENORMOUS RANGE AND IS COVERED BY 3 TYPES OF CAPACITOR. (THERE ARE ALSO MICA, POLYPROPELENE, POLYCARBONATE TYPES)

1 CERAMIC. RANGE: 1p TO ABOUT 47n (100n)

NOTE: THIS IS NOT A LINEAR SCALE.



2. GREENCAP: (POLYESTER) RANGE: 1n TO 220n

3: ELECTROLYTIC: 1µ TO 100,000µ. – TO 1 FARAD!

CERAMIC

CERAMICS ARE GENERALLY BROWN IN COLOUR AND LOOK LIKE A FLAT DISC. THEY ARE RATED AT 50v (FOR OUR USE) & THIS MEANS THEY CAN WITHSTAND VOLTAGES (& SPIKES) UP TO 50V. (CERAMICS ARE ALSO AVAILABLE @ 100V, 1kV 5kV & MORE).

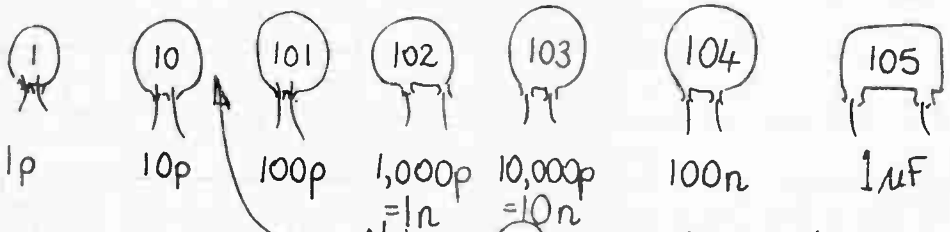
THE VALUE MARKED ON A CERAMIC IS "PUFF" VALUE ("p" & "pF" ARE THE SAME I PREFER 'p' AS IN 5p6, 10p, 220p AND WHEN ASKING FOR A VALUE SAY: "5p6" OR 10p OR "10 PUFF" SO THAT THE OTHER PERSON KNOWS EXACTLY WHAT YOU ARE ASKING FOR)

WITH LARGER VALUES WE USE THE LETTER 'n' TO SIGNIFY 'nano'. WE USE THIS LETTER WHEN ORDERING VALUES SUCH AS 1n (ONE 'ENN') 22n, 47n, 100n.

1,000 p = 1n (1 Nanofarad)

& 1,000n = 1µ (1 microfarad)

THE EASIEST WAY TO REMEMBER THE VALUES IS AS FOLLOWS: NOTE THE 'FACTOR OF 10' STEPS. ALL OTHER VALUES FIT BETWEEN THESE STEPS.



Note: (100) = 100p NOT 10p!

MONOBLOCKS

TO REDUCE THE PHYSICAL SIZE OF A CERAMIC, MULTILAYER CERAMICS CALLED MONOBLOCKS OR MONOLITHIC CAPACITORS ARE PRODUCED. THESE ARE GENERALLY BLUE OR ORANGE WITH MARKINGS SUCH AS 102, 103, 223, 473, 104 ETC.

CERAMICS CAN BE FITTED EITHER WAY AROUND AND ARE STABLE ENOUGH TO BE USED IN HIGH FREQUENCY CIRCUITS.

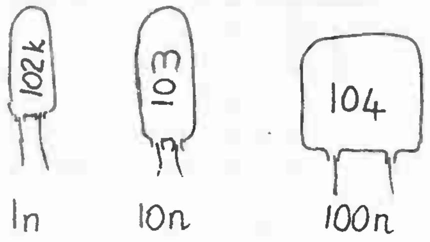
'NPO' MARKINGS MEAN THE CAPACITANCE DOES NOT CHANGE IF THE TEMPERATURE OF THE CIRCUIT RISES OR FALLS.

CHEAP CERAMICS DRIFT CONSIDERABLY AND ARE ONLY USED FOR COUPLING, WHERE EXACT VALUES ARE NOT CRITICAL & THE CHANGE IN CAPACITANCE DOES NOT UPSET THE OPERATION OF THE CIRCUIT.

WHEN SOLDERING A CERAMIC, HOLD IT IN YOUR FINGERS. IF YOU CAN'T, THE CERAMIC IS GETTING TOO HOT. IF YOU GET THE CERAMIC TOO HOT, THE LEADS WILL FALL OFF! THEY ARE SOLDERED TO THE SUBSTRATE WITH LOW-TEMP SOLDER.

GREENCAPS

THESE ARE CALLED GREENCAPS BECAUSE THE FIRST MANUFACTURER DIPPED HIS POLYESTER CAPACITORS IN GREEN EPOXY. GREENCAPS RANGE FROM 1,000p (1n OR 102) TO ·1µ (100n OR '104') (ALSO ·22, ·27 ·33, ·47 ie. 220n, 270n, 330n, 470n BUT THESE ARE VERY EXPENSIVE)



THE LETTER 'K' INDICATES 10% TOLERANCE ANY OTHER NUMBERS ARE THE DATE CODE OR BATCH CODE, OR VOLTAGE RATING.

CONVERSIONS

102 = 1n = ·001µ = 1,000p

103 = 10n = ·01µ = 10,000p

104 = 100n = ·1µ

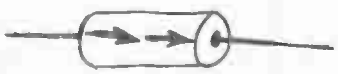
THESE CONVERSIONS MUST BE REMEMBERED.

GREENCAPS CAN BE SOLDERED EITHER WAY AROUND IN A CIRCUIT & THEY GENERALLY STAND UP ON THE PC BOARD. THEY ARE A VERY RELIABLE COMPONENT & DO NOT SUFFER FROM DRIFT, OPEN LEADS, LEAKAGE, INTERMITTENT CONTACTS, SHORTS OR FAILURE.

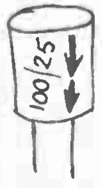
THERE ARE VERY FEW PLACES WHERE THEY CAN'T BE USED & THE ONLY CASE I HAVE COME ACROSS IS AS A YOKE COUPLING IN TV'S. — THEY GET HOT & START TO SMELL. (USE A POLYCARBONATE)

ELECTROLYTICS

ELECTROLYTICS COME IN 3 BASIC MOUNTINGS:

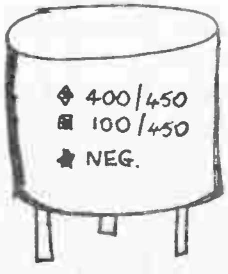


DOUBLE-ENDED (RT - FOR RADIAL TAIL)



SINGLE ENDED (RB - FOR PC MOUNTING)

CAN TYPE FOR CHASSIS MOUNTING.



WITH EACH CASE STYLE THERE IS A BROAD RANGE OF SIZES TO CATER FOR THE CAPACITANCE & VOLTAGE RATING.

HERE ARE SOME OF THE VOLTAGE RATINGS: 3v, 4v, 6v, 10v, 16v, 25v, 35v, 63v, 100v, 200v, 315v, 450v,

WHEN ORDERING AN ELECTROLYTIC YOU MUST SPECIFY CAPACITANCE, VOLTAGE & CASE STYLE.

EG. 100 MICROFARAD, 16 VOLT, PC MOUNT.

= 100/16 RB.

MOST OF OUR PROJECTS USE PC MOUNT (RB) ELECTROLYTICS — THEY LOOK NEAT ON THE BOARD. ALWAYS DESIGN WITH THESE ELECTROLYTICS. HERE IS THE RANGE WE SUGGEST: 1µ 2µ2 4µ7 10µ 22µ 47µ 100µ 470µ & 1,000µ. MOST CIRCUITS CAN BE DESIGNED AROUND THIS RANGE. THE OTHER FACTOR TO REMEMBER IS THE VOLTAGE RATING. IN MOST CASES 16v OR 25v ELECTRO'S CAN BE USED. IT IS ONLY NECESSARY TO GO TO 35v ELECTRO'S IN THE CASE OF POWER SUPPLIES WHERE THE VOLTAGE BEFORE THE REGULATOR MAY BE HIGHER THAN NORMAL.

SURFACE MOUNT CAPACITORS

SURFACE MOUNT CAPACITORS POSE AN ENORMOUS PROBLEM. VERY FEW (IF ANY) OF THESE ARE MARKED AND IT IS IMPOSSIBLE TO DETERMINE THEIR CAPACITANCE BY LOOKING AT THEM. QUITE OFTEN A 47p CAN BE THE SAME SIZE AS A 22n.

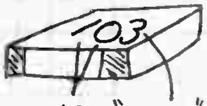
FOR THOSE CAPACITORS THAT ARE MARKED, A 3 DIGIT CODE EXACTLY LIKE THE RESISTOR CODE APPLIES, THE BASIC UNIT IS pF (PUFF) AND THE DIGITS ARE READ EXACTLY LIKE THOSE ON SURFACE MOUNT RESISTORS.

VALUES ON CIRCUIT DIAGRAMS MUST BE CONVERTED TO THE 'STANDARD FORM' & HERE IS A GUIDE:

CIRCUIT DIAGRAM VALUES:	VALUE WRITTEN ON CAPACITOR:
10p 10pF	10 (ON CERAMIC) 100 (ON CHIP CAPACITOR)
100p 100pF	100(" ") OR 101 (ON CERAMIC OR CHIP)
1,000p, ·001µ, 1n	102 (ON GREENCAP CERAMIC OR CHIP CAP.)
10,000p ·01µ OR 10n	103 (" " " " " ")
·1µ, 100n	104 (ON GREENCAP, CERAMIC, MONOBLOCK, TANTALUM OR CHIP CAPACITOR)
1µ, 1µF, 1mfd	105 (ON TANTALUM & MONOBLOCKS)

WHEN ORDERING OR TALKING ABOUT CAPACITOR VALUES YOU MUST USE WORDS THAT CANNOT BE MISTAKEN OR MISUNDERSTOOD. THAT'S WHY YOU SAY THINGS LIKE "10 puff" "100 puff" "ONE ENN" (1n) "TEN ENN" (10n) "ONE HUNDRED ENN" (100n) "ONE MICKEY" (1µ) "10 MICKEY" (10µ).

IDENTIFYING SURFACE MOUNT CAPACITORS



10 "000" p = 10n

THE FIRST TWO DIGITS ON A SURFACE MOUNT CAPACITOR ARE WRITTEN DOWN EXACTLY AS THEY APPEAR ON THE CAPACITOR & ZERO'S ARE ADDED ACCORDING TO THE THIRD DIGIT.
THE ANSWER IS GIVEN IN pF. IF THE 3RD DIGIT IS ZERO, ADD NO ZERO'S TO THE FIRST TWO DIGITS & CALL THE RESULT 'pF'. IF THE THIRD DIGIT IS '1' ADD ONE ZERO & CALL THE ANSWER pF. IF THE THIRD DIGIT IS '2', ADD TWO ZERO'S AND CALL THE ANSWER pF. THE SAME APPLIES TO 3,4 & 5 AS THE THIRD DIGIT.

= 22 "00" p = 2n2

= 10 '000' p = 10n

= 10 '0000' = 100n

THE NEXT STEP IS TO DIVIDE THE ANSWER BY 1,000 AND GIVE THE RESULT IN TERMS OF 'nanofarad'.

HERE ARE SOME EXAMPLES:

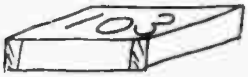
10p

47p

470p

1n

4n7



10n

47n

100n

SERVICE HINTS

IF A SURFACE MOUNT CAPACITOR IS SUSPECT AND NOT IDENTIFIED VIA THE THREE DIGIT CODE SHOWN ABOVE, YOU MUST REFER TO THE CIRCUIT DIAGRAM OR LAYOUT DIAGRAM. DO NOT GUESS THE VALUE. SIZE IS NO INDICATION.

A SURFACE-MOUNT CAPACITOR CAN GO 'OPEN' DUE TO ROUGH HANDLING &/OR SOLDERING. — THE METALLISED END CAPS CAN COME ADRIFT FROM THE METALLISED LAYER OR LAYERS WITHIN THE CAPACITOR WHEN EXCESS HEAT IS APPLIED OR WHEN THE BOARD IS TWISTED.

THIS FAULT IS IMPOSSIBLE TO FIX BY RESOLDERING & THE CHIP MUST BE REPLACED. IT IS NOT POSSIBLE TO SEE THIS FAULT AS THE CAPACITOR WILL TO BE SOLDERED PERFECTLY.

THE ONLY WAY YOU WILL PICK UP A FAULT LIKE THIS IS WITH A CRO OR BY KNOWING THE SYMPTOMS OF A PARTICULAR OPEN CAPACITOR. RESISTORS CAN BE MEASURED AFTER BEING SOLDERED IN POSITION BUT CAPACITORS ARE MUCH MORE DIFFICULT.

THE ELECTROLYTIC – A FEW MORE FACTS.

THE ELECTROLYTIC IS A SELDOM DESCRIBED COMPONENT THAT REQUIRES CARE WHEN SELECTING – MORE CARE THAN YOU THINK. HERE ARE SOME FACTS.

VOLTAGE RATING – THE VOLTAGE RATING OF AN ELECTROLYTIC IS ITS DC WORKING VOLTAGE. WHEN AN ELECTROLYTIC IS MADE, IT IS 'FORMED' (i.e. IT IS TURNED INTO A CAPACITOR) BY APPLYING A VOLTAGE ACROSS THE LEADS.

AN OXIDE LAYER FORMS ON THE SURFACE OF THE FOIL & THE SPIRAL OF FOIL & IMPREGNATED PAPER TURNS INTO A CAPACITOR CAPABLE OF HOLDING A CHARGE.

IF THE ELECTROLYTIC IS NOT USED FOR A LONG TIME, THE DIELECTRIC BREAKS DOWN & THE CAPACITY IS REDUCED. TO BUILD IT UP AGAIN YOU NEED ONLY APPLY A VOLTAGE EQUAL TO THE WORKING VOLTAGE AND THE ELECTROLYTIC IS 'FORMED' AGAIN.

IF YOU APPLY A VOLTAGE HIGHER THAN THE RATED VOLTAGE (MORE THAN ABOUT 20% HIGHER) YOU RUN THE RISK OF PUNCTURING THE PAPER & OXIDE LAYER & CREATING AN INTERNAL SHORT.

ON THE OTHER HAND, IF THE VOLTAGE IS ONLY ABOUT 50% OF THE RATED WORKING VOLTAGE, THE 'FORMING' WILL BREAK DOWN & THE CAPACITANCE WILL BE REDUCED.

THESE CHANGES ARE ONLY MARGINAL BUT IF YOU WONDER WHY A PROJECT DOESN'T WORK AFTER YEARS OF STORAGE, THIS MAY BE WHY. AFTER A FEW MINUTES OF USE THE ELECTROLYTIC WILL BE 'FORMED' AGAIN.

SIZE – THE SIZE OF AN ELECTROLYTIC DEPENDS ON 3 FACTORS: ① CAPACITANCE ② VOLTAGE RATING & ③ RIPPLE CURRENT. TWO 1000/63V ELECTRO'S MAY BE DIFFERENT SIZES – THE SMALLER UNIT WILL HANDLE LESS RIPPLE CURRENT. ONE MAY HANDLE 45mA OF RIPPLE WHILE THE OTHER MAY HANDLE 100mA OF RIPPLE. THE EASIEST WAY TO MEASURE RIPPLE IS TO PLACE AN AC MILLIAMP METER IN SERIES WITH THE ELECTRO.

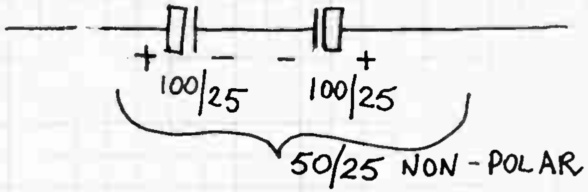
RIPPLE FACTOR IS RARELY MENTIONED IN TEXT BOOKS & THE ONLY WAY TO DETERMINE THE PHYSICAL SIZE IS TO PLACE A UNIT IN CIRCUIT. IT SHOULD STAY COLD OR ONLY GET VERY SLIGHTLY WARM UNDER MAX LOAD. ANY HEATING UP WILL BOIL THE ELECTROLYTE & BLOW THE ELECTROLYTIC APART.

REVERSE VOLTAGE — ELECTROLYTICS CAN ONLY WITHSTAND A FEW VOLTS IN THE REVERSE DIRECTION AS THIS VOLTAGE REMOVES THE INSULATING LAYER QUITE QUICKLY. THE RESULT IS THE ELECTROLYTIC BECOMES 'LEAKY' & THIS WILL ADD TO ITS HEATING UP – EVEN WHEN PLACED IN THE CIRCUIT AROUND THE CORRECT WAY.

NON-POLAR ELECTROLYTIC —— A NON-POLAR ELECTROLYTIC IS MADE BY PLACING TWO ELECTROLYTICS BACK-TO-BACK. WHEN DOING THIS, THE VOLTAGE & CAPACITANCE IS EQUAL

TO 1/2 ONE OF THE UNITS.

FOR INSTANCE, TWO 100/25V ELECTROLYTICS PLACED BACK-TO-BACK CREATES A 50/25 NON-POLAR UNIT.



THIS TYPE OF ELECTROLYTIC IS USED IN AC SITUATIONS AND AT ANY PARTICULAR INSTANT IN TIME ONE ELECTROLYTIC WILL BE IN REVERSE BIAS AND PLAY NO PART IN THE CAPACITANCE & VOLTAGE RATING.

LEAKAGE — IT IS ADVISABLE NOT TO USE AN ELECTROLYTIC IN A LONG TIME-DELAY CIRCUIT. (GREATER THAN 2 MINS) AS THE CHARGING CURRENT MAY BE LESS THAN THE LEAKAGE CURRENT AS THE ELECTRO GETS OLDER. THIS WILL RESULT IN THE TIMER NEVER 'TIMING OUT'. IT IS BETTER TO USE A CLOCK CIRCUIT (SUCH AS A SCHMITT TRIGGER OSCILLATOR) FEEDING A DIVIDER CHIP (SUCH AS 4024, 4040, 4020 etc).

IF LOW LEAKAGE IS REQUIRED, LOW-LOSS RBLL ELECTROLYTICS CAN BE USED OR YOU CAN USE THE VERY EXPENSIVE TANTALUMS.

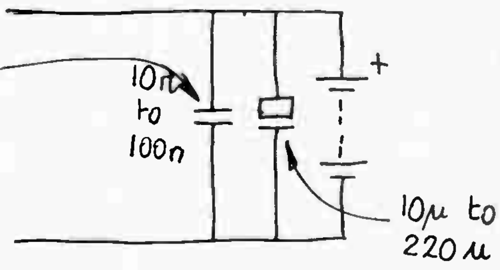
TANTALUMS — TANTALUMS HAVE THE LOWEST LEAKAGE AND LOWEST INTERNAL IMPEDANCE. ALSO THEY DO NOT LIKE SPIKES. A TANTALUM IS MORE LIKELY TO SHORT-OUT UNDER SPIKE CONDITIONS, THAN AN ELECTROLYTIC. — A POINT TO REMEMBER.

CAPACITANCE — THE CAPACITANCE VALUE MARKED ON AN ELECTROLYTIC IS ONLY APPROXIMATE. IT CAN VARY AS MUCH AS +100% OR -50%! THAT'S WHY THE VALUE SHOWN IN A CIRCUIT IS QUITE ARBITARY. — IN MANY CASES.

A BATTERY DECOUPLER (ACROSS THE BATTERY) CAN BE 47µ, 100µ OR 220µ. AN EMITTER BYPASS CAN BE 22µ, 33µ OR 47µ. A STAGE DECOUPLER CAN BE 10µ, 22µ OR 47µ — IT USUALLY MAKES VERY LITTLE DIFFERENCE.

FILTERING — ELECTROLYTICS DO NOT FILTER HIGH FREQUENCY SPIKES OR WAVEFORMS. A CERAMIC (10n to 100n) IS NEEDED TO DO THIS

THE VALUE REQUIRED FOR BOTH CAPACITORS CAN ONLY BE OBTAINED BY BUILDING THE CIRCUIT & OBSERVING THE RIPPLE ON THE SUPPLY RAIL, WITH A CRO.

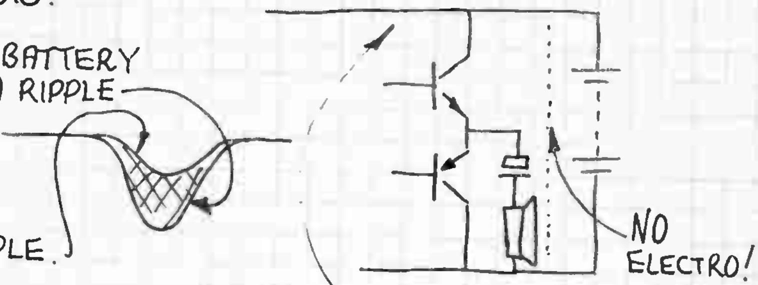


HOW AN ELECTROLYTIC FILTERS (REDUCES RIPPLE) — AN ELECTROLYTIC ACROSS A BATTERY REDUCES THE IMPEDANCE OF THE SUPPLY RAIL. IN OTHER WORDS THE SUPPLY RAIL (THE POSITIVE RAIL, AS WE CONSIDER THE NEGATIVE RAIL TO BE FIXED AT ZERO VOLTS AND NOT CONTAIN ANY RIPPLE) WILL BE CAPABLE OF DELIVERING THE NECESSARY CURRENT WITHOUT DROPPING (OR DROOPING) IN VOLTAGE.

TAKE THE CASE OF A POCKET RADIO.

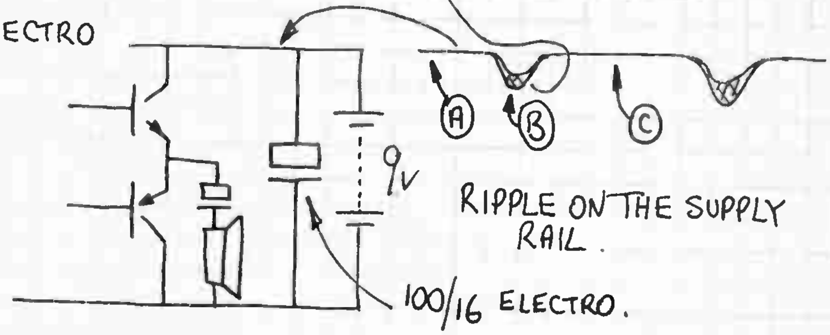
WITHOUT AN ELECTRO ACROSS THE BATTERY THE SUPPLY RAIL WILL CONTAIN A RIPPLE DUE TO THE HEAVY DEMAND OF THE OUTPUT STAGE.

AN ELECTROLYTIC ACROSS THE BATTERY WILL REDUCE THE RIPPLE.



YOU CAN THINK OF THE ELECTRO AS A MINIATURE 9V RECHARGEABLE BATTERY.

AT POINT Ⓐ IT IS FULLY CHARGED (IT IS CHARGED FROM THE 9V SUPPLY).



AT POINT Ⓑ IT BEGINS TO DELIVER ENERGY AS SHOWN VIA THE SHADED PART AND IS CHARGED UP AGAIN BY THE TIME Ⓒ. IN TECHNICAL TERMS THE ELECTROLYTIC REDUCES THE IMPEDANCE OF THE RAILS.

LOW IMPEDANCE RAILS ARE CAPABLE OF DELIVERING MORE CURRENT AND THATS WHAT AN ELECTRO DOES. – IT ALLOWS THE SUPPLY TO DELIVER MORE CURRENT WHEN IT IS NEEDED.

THE REASON WHY THE VOLTAGE DROPS IS DUE TO THE INTERNAL IMPEDANCE OF THE BATTERY. THE INTERNAL IMPEDANCE OF AN ELECTRO IS VERY SMALL & IT PARALLELS THIS IMPEDANCE WITH THAT OF THE BATTERY TO PROVIDE A LOWER VALUE.

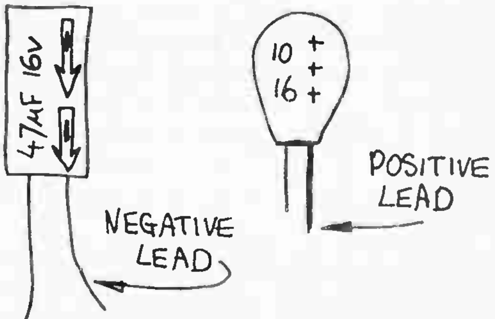
WE SAY IMPEDANCE BECAUSE AN ELECTROLYTIC OR BATTERY, DOES NOT HAVE A RESISTANCE VALUE THAT CAN BE MEASURED WITH AN OHM METER. EVEN THOUGH WE SAY IMPEDANCE WE MEAN 'RESISTANCE'.

POLARITY – ELECTROLYTICS AND TANTALUMS MUST BE CONNECTED SO THAT THE POSITIVE LEAD GOES TO THE POSITIVE RAIL.

IF YOU ARE NOT SURE WHICH WAY TO CONNECT AN ELECTRO OR TANTALUM, REFER TO THE DIAGRAMS OPPOSITE.

THE NEGATIVE LEAD ON AN ELECTRO IS THE SHORTER OF THE TWO AND THE BODY HAS BLACK ARROWS OR NEGATIVE SIGNS.

THE MARKINGS ON A TANTALUM ARE PRINTED SO THAT THE POSITIVE LEAD IS ON THE RIGHT.



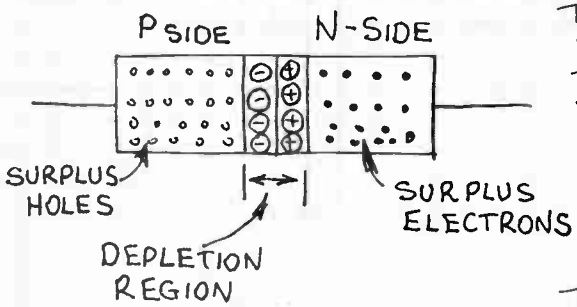
THE MARKINGS ON AN ELECTRO & TANTALUM.

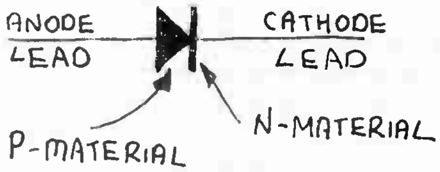
THE DIODE

THE WAY IN WHICH A DIODE WORKS IS QUITE COMPLEX. YOU WOULD HAVE TO LEARN PHYSICS TO UNDERSTAND CRYSTAL LATTICE, DOPING, MINORITY CARRIERS ETC. ETC. WE WILL EXPLAIN IT IN SIMPLE TERMS, WHILE STILL COVERING ITS CHARACTERISTICS.

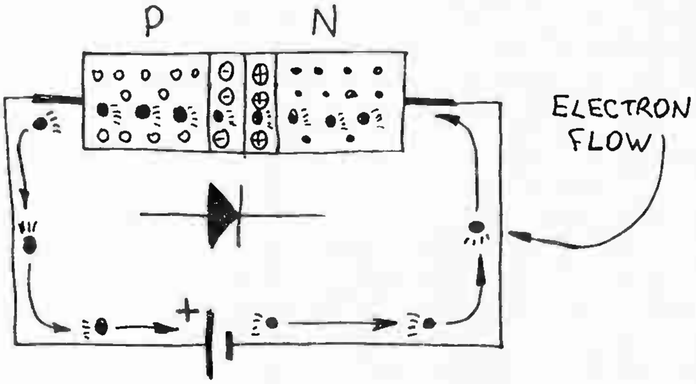
THE MOST IMPORTANT CHARACTERISTIC IS A DIODE CONDUCTS IN ONLY ONE DIRECTION. HERE'S WHY:

A DIODE IS MADE UP OF P-MATERIAL & N-MATERIAL. A REGION FORMS BETWEEN THE P&N MATERIALS CALLED THE DEPLETION LAYER (OR POTENTIAL BARRIER OR TRANSITION REGION) WHEN THE TWO MATERIALS ARE JOINED (OR DIFFUSED) TOGETHER. SOME HOLES MOVE TO THE N-MATERIAL LEAVING BEHIND A NEGATIVE CHARGE & SOME ELECTRONS MOVE TO THE P-SIDE, LEAVING BEHIND A POSITIVE CHARGE.



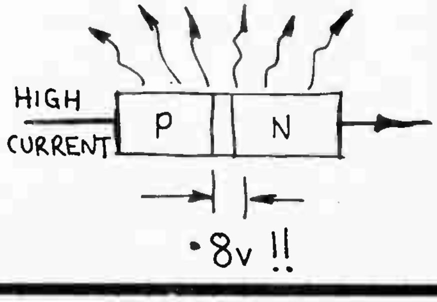


THE CHARGE PRODUCED AT THE JOIN OF THE TWO MATERIALS PREVENTS FURTHER MOVEMENT OF HOLES OR ELECTRONS AND EQUILIBRIUM IS REACHED.



THE DIAGRAM SHOWS A FORWARD-BIASED DIODE. IF THE BATTERY VOLTAGE IS BELOW •6V NO CURRENT FLOWS IN THE DIODE DUE TO THE DEPLETION LAYER ACTING AS AN INSULATOR. AT •6V OR HIGHER (SAY •7V) ELECTRONS CROSS THE "BARRIER" & DIFFUSE THROUGH THE P-MATERIAL TO THE OUTER CIRCUIT, MADE UP OF THE "ELECTRON PUMP" (THE BATTERY) — THEY ENTER THE N-MATERIAL, DRIFT THROUGH THE JUNCTION & DIFFUSE THROUGH THE P-MATERIAL TO CREATE 'ELECTRON FLOW.'

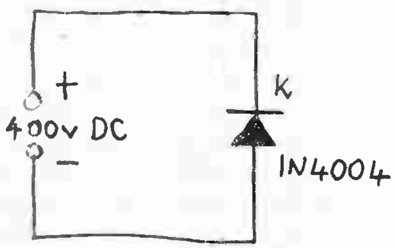
THE POINT TO NOTE IS THE DIODE HAS A CHARACTERISTIC •7V DROP ACROSS THE JUNCTION. IF THE CURRENT FLOW IS MORE THAN THE DIODE IS CAPABLE OF HANDLING, THE JUNCTION VOLTAGE WILL INCREASE. AT •8V OR HIGHER THE DIODE WILL BE DAMAGED, MAINLY DUE TO TEMPERATURE RISE OF THE JUNCTION.



WHEN THE SUPPLY IS REVERSED, THE NATURAL INSULATING LAYER (THE DEPLETION REGION) IS INCREASED IN WIDTH DUE TO ELECTRONS BEING DRAWN AWAY FROM THE 'GAP'.

AS THE VOLTAGE IS INCREASED, A POINT IS REACHED WHERE THE ELECTRONS WILL 'JUMP THE GAP' & REVERSE VOLTAGE BREAKDOWN WILL OCCUR. FOR A 400v POWER DIODE, THIS VOLTAGE WILL BE 400v.* THIS IS HOW DIODE VOLTAGES ARE DETERMINED.

WHEN THE VOLTAGE JUMPS THE GAP THE DIODE IS DAMAGED. IT IS SAID TO BE 'PUNCTURED' OR 'BLOWN'.



THE 400v DIODE WILL BE DAMAGED DUE TO REVERSE VOLTAGE BREAKDOWN.

*THE ACTUAL PIV RATING OF A DIODE IS ABOUT 120% OF ITS FORWARD VOLTAGE RATING. ie. A IN4004 WILL HAVE A PIV OF $\frac{120}{100} \times 400 = 480$v

A DIODE WILL BE DAMAGED MUCH FASTER DUE TO A HIGH VOLTAGE SPIKE THAN A HIGH CURRENT SURGE. IT TAKES TIME FOR THE JUNCTION TO HEAT UP VIA EXCESS CURRENT BUT A SPIKE WILL PUNCTURE THE INSULATING LAYER INSTANTANEOUSLY.

WHEN SELECTING THE PIV RATING FOR DIODES IN A BRIDGE, THERE ARE A NUMBER OF FACTORS TO TAKE INTO ACCOUNT.

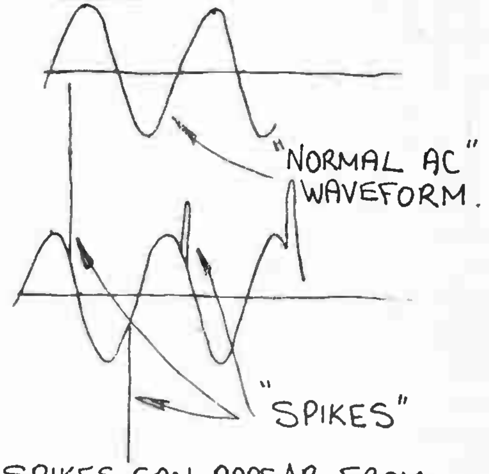
EVEN THOUGH YOU MAY BE MAKING A 12v POWER SUPPLY, THE SPIKES THAT CAN APPEAR ON THE SECONDARY (12v WINDING) CAN BE AS HIGH AS 100 − 180 VOLTS!

A BATTERY-CHARGER MANUFACTURER Ⓐ INFORMED US THAT PIV RATINGS SHOULD BE DERATED BY 50% AND A NEW TERM "DC WORKING CREST" SHOULD BE USED.

ALL THIS MEANS THAT A 12v WINDING WITH 180v SPIKES NEED 400v DIODES IN THE BRIDGE − HE TRIED 50v, 100v & 200v DIODES AND THEY ALL FAILED WHEN THE BATTERY CHARGERS WERE SWITCHED ON OR OFF!

(SEE ALSO OUR PIV NOTES IN "POWER SUPPLY DESIGN" − PROJECT BOOK 3)

SPIKES:



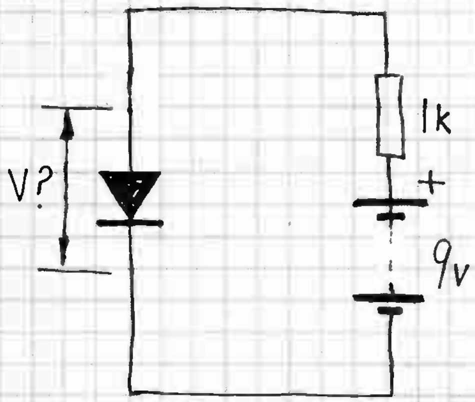
SPIKES CAN APPEAR FROM NO-WHERE − BUT MAINLY APPEAR WHEN A SWITCH IS OPENED (OR CLOSED)

Ⓐ ENJA MANUFACTURING − BATTERY CHARGER MANUFACTURERS (03) 459 1156.

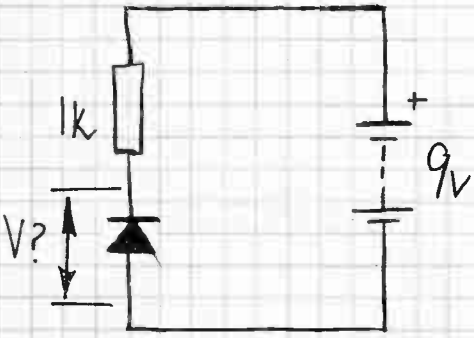
DIODE PROBLEMS

WE WILL ASSUME ALL DIODES ARE SILICON & DROP ·7v ACROSS THEIR JUNCTION (GERMANIUM DIODES DROP ·3v BUT ARE RARELY USED).

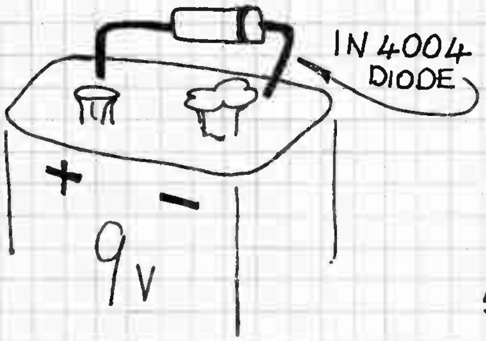
1. WHAT IS THE VOLTAGE DROP ACROSS THE DIODE ?



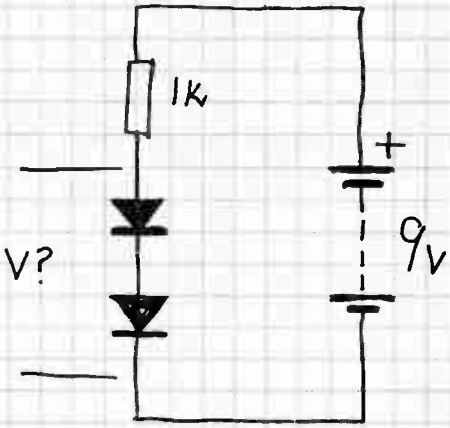
2. WHAT IS THE VOLTAGE ACROSS THE DIODE ?



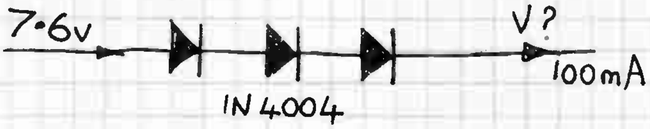
3. EXPLAIN WHAT WILL HAPPEN :



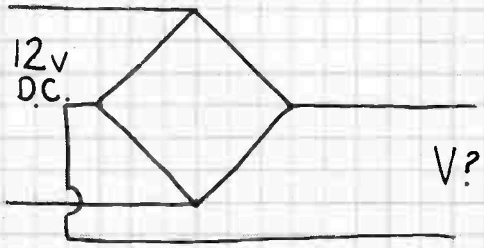
4. WHAT IS THE VOLTAGE ACROSS THE TWO DIODES :



5. WHAT IS THE VOLTAGE DROP ACROSS THIS NETWORK :



6. a) DRAW THE 4 DIODE SYMBOLS
b) WHAT IS THE VOLTAGE OUTPUT OF THE BRIDGE ?



ANSWERS: 1. ·7v 2. 9v (THE DIODE IS REVERSE-BIASED) 3. THE DIODE IS FORWARD-BIASED & WILL PUT A "SHORT" ACROSS THE BATTERY. 4. 1·4v 5. 2·1v (OUTPUT = 5·5v) 6. 10·6v. (1·4v IS DROPPED OR 'LOST' ACROSS THE BRIDGE & THIS IS IMPORTANT TO REMEMBER).

TRANSISTORS

THERE ARE OVER 20,000 DIFFERENT TYPES OF TRANSISTOR & HUNDREDS OF DIFFERENT CASE STYLES!

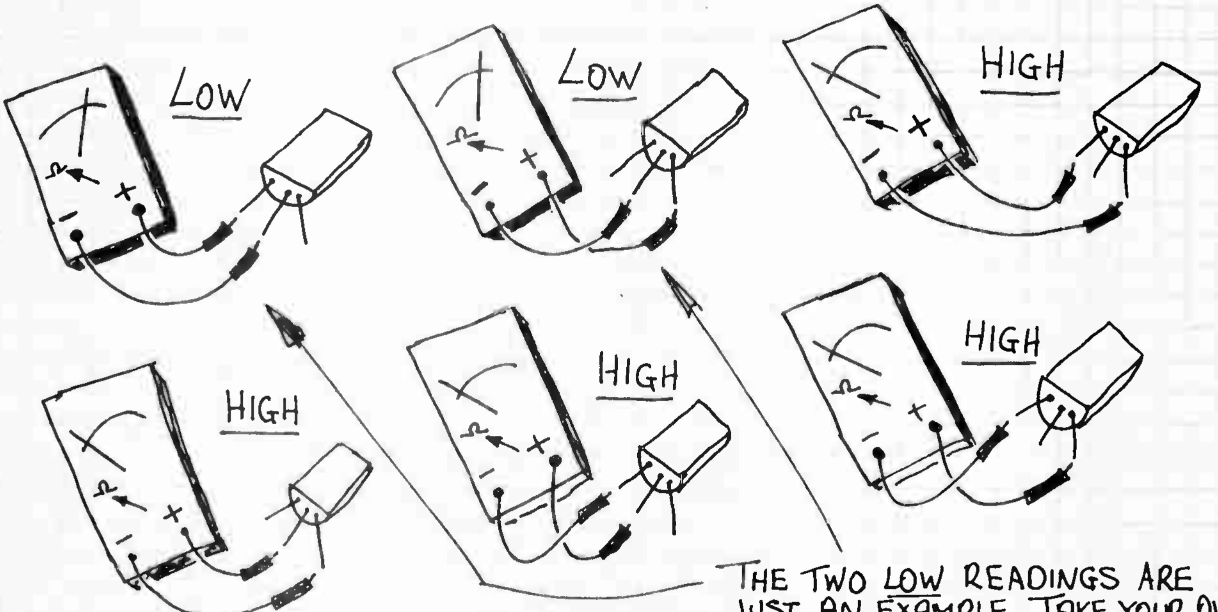
WE COULD NOT BEGIN TO COVER THEM ALL & YOU WILL ONLY COME ACROSS ABOUT 20-50 DIFFERENT TYPES IN YOUR WHOLE ELECTRONICS EXPERIENCE. IN ALL OF OUR PROJECTS WE USE ONE TYPE OF SMALL SIGNAL PNP TRANSISTOR, ONE SMALL-SIGNAL NPN, ONE TYPE OF RF & ONE TYPE OF POWER TRANSISTOR. THIS IS TO KEEP OUR PROJECTS SIMPLE.

IN THIS SECTION WE WILL SHOW HOW TO TEST AN UNKNOWN TRANSISTOR WITH A MULTIMETER AND DETERMINE:

(a) IF IT IS GOOD OR FAULTY.
(b) PNP OR NPN
(c) LOCATE THE BASE, COLLECTOR & EMITTER LEADS.
(d) DETERMINE IT'S APPROXIMATE GAIN.

THIS IS HOW IT IS DONE:

1. YOU DO NOT HAVE TO KNOW ANY OF THE TRANSISTOR LEADS TO CARRY OUT THIS TEST. — CARRY OUT THE 6 TESTS AS SHOWN BELOW. PROVE THAT ONLY 2 TESTS SHOW A LOW READING. THE OTHER 4 TESTS ARE 'HIGH'.



THE TWO LOW READINGS ARE JUST AN EXAMPLE. TAKE YOUR OWN

THESE DIAGRAMS SHOW ALL THE 6 WAYS OF PLACING THE LEADS OF A MULTIMETER ON A TRANSISTOR. NOTE: ONLY 2 READINGS ARE LOW.

THESE DIAGRAMS SHOW A MULTIMETER SET TO "OHMS" (IT'S BEST TO USE 'HIGH OHMS'). WHEN A MULTIMETER IS SET TO OHMS, THE BATTERY INSIDE THE METER IS WIRED TO GIVE NEGATIVE OUT THE POSITIVE LEAD & POSITIVE OUT THE NEGATIVE LEAD! THAT'S WHY YOU MUST FOLLOW THESE TESTS EXACTLY AND DON'T START TO LOOK AT THE POLARITY SITUATION.

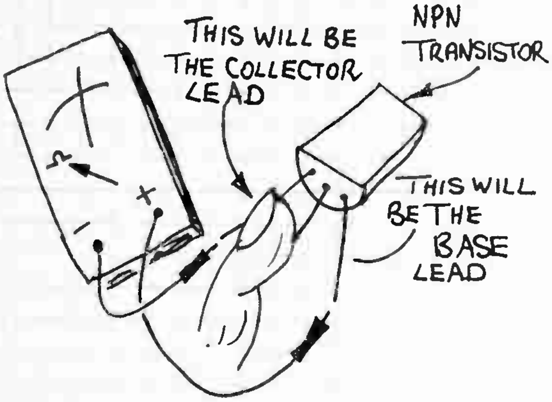
2. CONCENTRATE ON THE TWO TESTS THAT ARE LOW. ONE PROBE WILL REMAIN ON A LEAD. THIS PROBE IDENTIFIES THE BASE

IF THE PROBE IS BLACK, THE TRANSISTOR IS NPN.
IF THE PROBE IS RED, THE TRANSISTOR IS PNP.

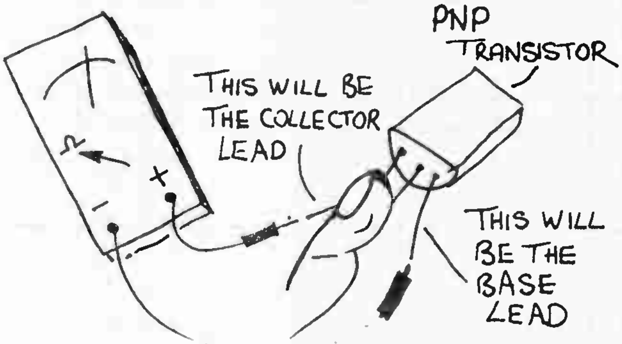
FINDING THE COLLECTOR & EMITTER LEADS

SO FAR WE HAVE FOUND THE BASE LEAD & IF THE TRANSISTOR IS NPN OR PNP. TO FIND THE COLLECTOR & EMITTER LEADS PLACE THE MULTIMETER ON THESE LEADS (IT DOES NOT MATTER WHICH WAY AROUND).

PLACE A MOISTENED FINGER BETWEEN THE BASE LEAD & ONE OF THE UNKNOWN LEADS. IF THE NEEDLE MOVES UP-SCALE THE COLLECTOR AND EMITTER LEADS ARE AS SHOWN IN THE DIAGRAM. IF IT DOESN'T DEFLECT, TRY THE OTHER LEAD AND THE BASE. — REVERSE THE MULTIMETER LEADS AND TRY THE FINAL TWO TESTS AS ONE WILL GIVE A READING.



LOCATING THE COLLECTOR & EMITTER LEADS OF AN NPN TRANSISTOR



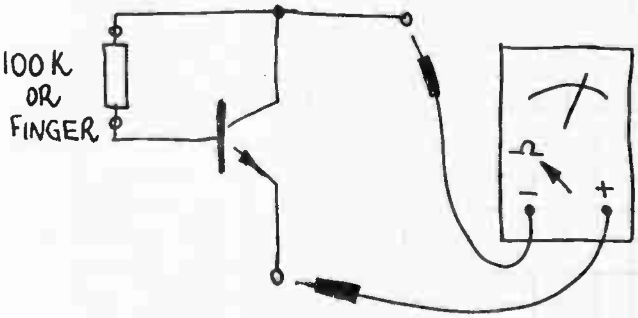
LOCATING THE COLLECTOR & EMITTER LEADS OF A PNP TRANSISTOR

TRANSISTOR GAIN

THE GAIN OF ONE TRANSISTOR CAN BE COMPARED WITH OTHERS BY NOTING THE DEFLECTION OF THE NEEDLE IN THE TEST ABOVE.

THE SECRET IS YOU HAVE TO SQUASH THE TWO LEADS THE SAME AMOUNT IN EACH CASE & THE FURTHER THE NEEDLE MOVES, THE HIGHER THE GAIN.

YOU CAN SUBSTITUTE YOUR FINGER FOR A 100K RESISTOR TO GIVE A MORE ACCURATE READING.



THE CIRCUIT FOR THE TRANSISTOR GAIN. - FOR AN NPN TRANSISTOR.

SUBSTITUTING A TRANSISTOR

WHEN SUBSTITUTING A TRANSISTOR, DON'T GET CARRIED AWAY WITH 'NUMBERS'. ONE US MANUFACTURER HAS A RANGE OF 200 TRANSISTORS TO REPLACE 20,000 DIFFERENT TYPES — AND THIS IS THE APPROACH WE TAKE.

HUNDREDS OF DIFFERENT TRANSISTORS CAN BE LUMPED TOGETHER AND REPLACED WITH ONE THAT HAS A HIGH VOLTAGE RATING, GOOD GAIN & FAIRLY HIGH FREQUENCY OF OPERATION. THIS WILL BE COVERED IN A FUTURE ARTICLE & FOR THE MOMENT HERE'S THE SIMPLE APPROACH:

FIRSTLY LOOK AT THE OUTLINE OF THE TRANSISTOR. IF IT IS A POWER DEVICE, YOU MUST USE ONE OF THE SAME SIZE. THE SAME APPLIES IF IT IS MEDIUM SIZE OR A SMALL SIGNAL DEVICE.

NEXT LOOK AT THE VOLTAGE ON THE CIRCUIT. IF THE RAIL VOLTAGE IS 25V OR LESS, ANY TRANSISTOR CAN BE USED. ONCE THE VOLTAGE GOES OVER 40V (RAIL VOLTAGE) YOU MUST TAKE VOLTAGE INTO CONSIDERATION.

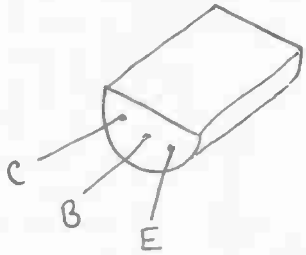
RAIL VOLTAGE OVER 100V MEANS YOU MUST USE HIGH-VOLTAGE TRANSISTORS. HIGH VOLTAGES CAN PUNCTURE A TRANSISTOR VERY EASILY AND VERY QUICKLY. A HIGH VOLTAGE SPIKE WILL DAMAGE A TRANSISTOR MUCH FASTER THAN A CURRENT OVERLOAD AND A SPIKE IS VERY HARD TO DETECT.

A TRANSISTOR DRIVING A TRANSFORMER, CHOKE, COIL OR WINDING WILL SEE SPIKES THAT CAN BE HUNDREDS OF VOLTS AND EVEN 1,000'S OF VOLTS AND THESE MUST BE TAKEN INTO ACCOUNT WHEN CHOSING A REPLACEMENT.

TRY TO GET A DIRECT REPLACEMENT BUT IF THIS IS NOT POSSIBLE, OR TOO EXPENSIVE, LOOK AT THE CIRCUIT & DETERMINE COLLECTOR, BASE & EMITTER LEADS. DETERMINE IF THE TRANSISTOR IS PNP OR NPN.

CHECK THE VOLTAGE ON THE POWER RAIL & FIND THE CHEAPEST SUBSTITUTE (FROM A MANUAL ETC). MOST OF THE TIME ALMOST ANYTHING WILL WORK PERFECTLY & YOU WILL WONDER WHY A SUPPLIER WANTS $10 FOR A DIRECT REPLACEMENT WHEN A 50¢ TRANSISTOR WILL DO!

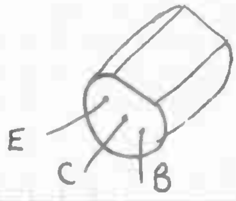
HERE ARE SOME OF THE MOST COMMON OUTLINES & THE TRANSISTOR TYPES THAT GO WITH THEM:



PHILIPS TRANSISTORS START WITH 'BC'. THIS IS THE 'PHILIPS' OUTLINE.

NPN: BC337,8, BC546,7,8,9. BC550.

PNP: BC327,8 BC 556,7,8,9 BC 560.



THIS IS THE SMALL-SIGNAL JAPANESE OUTLINE:

ALL "2SA" & "2SB" ARE PNP EG.

ALL "2SC" & "2SD" ARE NPN. e.g. "C 828"

THESE ARE MEDIUM-POWER TRANSISTORS (5-45W) & HAVE A VOLTAGE RATING. 40-100V

FOR ANY DISSIPATION OVER 20 WATTS, THEY MUST BE ATTACHED TO A LARGE HEATSINK WITH THERMAL COMPOUND. I DON'T CONSIDER THEM TO BE A GOOD CHOICE OF TRANSISTOR FOR ANY NEW DESIGNS AND PREFER 'TO3' OR 'TO 66' FOR HIGH POWER APPLICATIONS.

NPN: TIP 29, 31, 41. BD 201, 3.

PNP: TIP 30, 32, 42. BD 202.

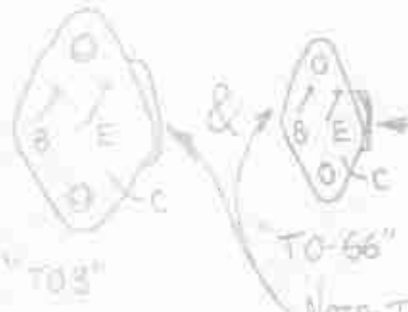
THESE ARE ALSO MEDIUM-POWER TRANSISTORS WITH A RATING 3-15 WATTS. THE VOLTAGE RATING IS 100V WITH SOME TYPES CAPABLE OF HANDLING 250-300V.

NPN: BD 131, 5, 7, 9. BD 233, 5, 7. BD 433, 5, 7, 9.

PNP: BD 132, 6, 8. BD 140. BD 234, 6, 8. BD 434, 6, 8.

PLASTIC FRONT

NOTE THE TWO CASE STYLES CAN'T BE INTERCHANGED — SILLY ISN'T IT?

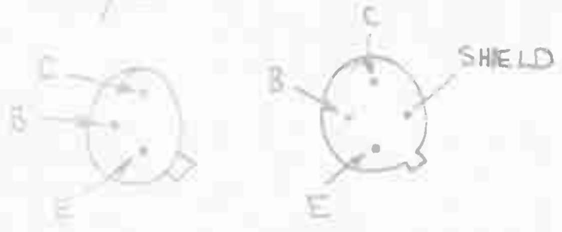


ALL TO-3 & TO-66 OUTLINES HAVE THE SAME PIN-OUT (THANK GOODNESS!)

THE CASE IS THE COLLECTOR TERMINAL & SOMETIMES YOU HAVE TO ISOLATE THE CASE FROM THE HEATSINK BECAUSE IT MAY BE AT EARTH POTENTIAL OR SHARED WITH ANOTHER TRANSISTOR.

NOTE THE LEADS ARE NEAR THE TOP MOUNTING HOLE. THIS IS HOW YOU HOLD THE TRANSISTOR TO IDENTIFY THE BASE & EMITTER LEADS.

GENERALLY THE EMITTER LEAD IS NEAREST THE 'TAB' ON THIS TYPE OF TRANSISTOR AND THE FOURTH LEAD IS A SHIELD.



NPN: BC 108, 9.

PNP: 2N 2906, 7

METAL-CASE TRANSISTORS ARE GRADUALLY DISAPPEARING. SO DON'T DESIGN WITH THEM.

THE FUSIBLE RESISTOR

THE FUSIBLE RESISTOR IS A VERY SUCCESSFUL WAY OF PROVIDING CIRCUIT PROTECTION. TO DETERMINE WHERE IT CAN BE USED, A NUMER OF POINTS MUST BE UNDERSTOOD.

1. A FUSIBLE RESISTOR WILL DROP A SMALL VOLTAGE (IN OTHER WORDS A SMALL VOLTAGE WILL BE PRODUCED ACROSS IT). THIS MAY BE $1/10^{th}$V to 1V, UNDER NORMAL CONDITIONS & WILL RISE WHEN A FAULT OCCURS.
2. A FUSIBLE RESISTOR MAY GET WARM OR HOT UNDER NORMAL OPERATION & WILL GET VERY HOT & BURN OUT WHEN A HEAVY LOAD OCCURS. – FOR THIS REASON IT MUST NOT BE PLACED NEAR FLAMMABLE COMPONENTS, TEMP SENSITIVE COMPONENTS OR AGAINST THE PC BOARD.

A FUSIBLE RESISTOR IS SIMPLY A NORMAL (LOW OHM) RESISTOR PLACED IN A CIRCUIT SO THAT A HIGH CURRENT WILL BURN IT OUT. THE PRINCIPLE OF OPERATION IS THE FACT THAT THE POWER (ENERGY) LOST IN A RESISTOR RISES VERY FAST WHEN THE CURRENT INCREASES. IN FACT IT RISES AS THE SQUARE OF THE CURRENT AS SHOWN IN THE FOLLOWING EQUATION:

$$P_{POWER} = I^2R$$

[WE SAY: "I SQUARED R LOSSES"]

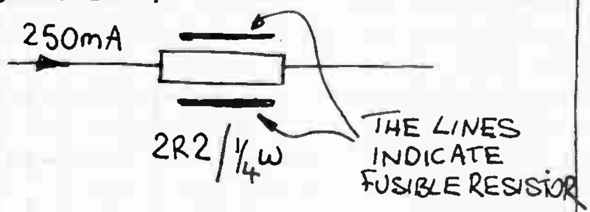
FOR EXAMPLE: IF THE CURRENT DOUBLES, THE POWER DISSIPATED INCREASES FOUR TIMES. ALSO: IF THE CURRENT IS HALVED, THE I^2R LOSSES ARE REDUCED TO ONE-QUARTER.

IF A FUSIBLE RESISTOR OPERATES JUST BELOW ITS RATED DISSIPATION UNDER NORMAL CONDITIONS, AN INCREASE IN CURRENT WILL OVER-TAX IT CONSIDERABLY. – A POINT WILL OCCUR WHEN IT BURNS OUT.

THE ADVANTAGE OF A FUSIBLE RESISTOR IS IT WILL WITHSTAND SURGES AND IS EQUIVALENT TO A '<u>DELAY FUSE</u>'.

HERE ARE SOME EXAMPLES:

1. WHEN WILL THIS FUSIBLE RESISTOR BURN OUT?



$P = I^2R$

$= \cdot 25 \times \cdot 25 \times 2\cdot 2$

$\approx 1/8$ WATT.

AT 250mA, THE DISSIPATION IS $\frac{1}{8}$ WATT. YOU WILL NOTICE THE TERM 'VOLTAGE' DOES NOT COME INTO THE EQUATION.

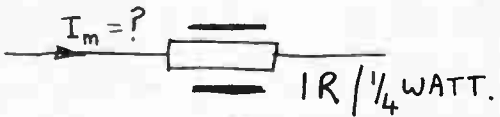
IF THE CURRENT INCREASES TO 500mA, THE POWER DISSIPATION IS:

$= \cdot 5 \times \cdot 5 \times 2\cdot 2$

$= \cdot 55$ WATTS.

AT 500mA THE RESISTOR WILL BURN OUT.

2. WHAT IS THE MAX CURRENT?



(THE RESISTOR WILL BURN OUT WHEN ½W IS BEING DISSIPATED)

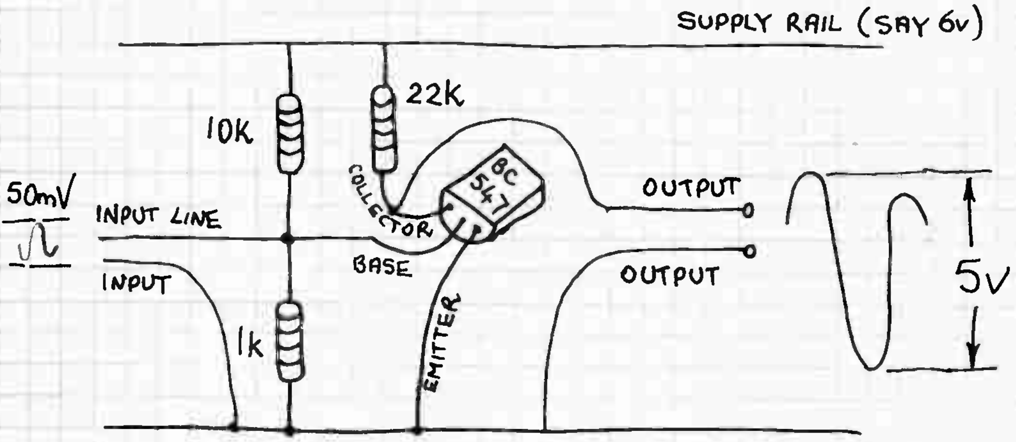
$P = I^2R$

$\cdot 5 = I^2 \times 1$

$I = \cdot 7$ AMPS

HOW A TRANSISTOR WORKS.

— WE WILL COVER 7 POINTS.



1. A TRANSISTOR DOES NOT BEGIN TO OPERATE UNTIL THE BASE IS ·55v HIGHER THAN THE EMITTER. IN THE CIRCUIT ABOVE, TWO RESISTORS (10K & 1K) FORM A VOLTAGE DIVIDER TO PUT ·55v ON THE BASE. AT ·65v THE TRANSISTOR IS FULLY TURNED ON, SO WE HAVE ONLY 100mV (·65 - ·55v) FOR THE INPUT SIGNAL TO CHANGE THE TRANSISTOR BETWEEN THE STATES OFF & ON.

2. A FULLY TURNED ON TRANSISTOR IS CALLED SATURATED & A FULLY TURNED OFF TRANSISTOR IS CALLED CUT-OFF.

3. BETWEEN THESE TWO EXTREMES THE TRANSISTOR IS IN ITS OPERATING RANGE & AS THE INPUT SIGNAL CHANGES BY 1mV, THE OUTPUT WILL CHANGE BY ABOUT 100mV. IF WE DELIVER A 50mV INPUT SIGNAL AS SHOWN ON THE DIAGRAM ABOVE, THE OUTPUT WILL BE 100 × 50 mV = 5V.

4. ONE OF THE CHARACTERISTICS OF THE ABOVE CIRCUIT IS IT INVERTS THE SIGNAL. WHEN THE INPUT IS RISING, THE OUTPUT IS FALLING AND VICE VERSA.

5. YOU WILL NOTICE ONE OF THE INPUT TERMINALS IS CONNECTED TO THE EMITTER AS IS ONE OF THE OUTPUT TERMINALS. THIS IS WHY THE STAGE IS CALLED A "COMMON EMITTER STAGE".

6. TO BE MORE TECHNICAL, THE BASE SHOULD BE SITTING MIDWAY BETWEEN ·55v & ·65v SO THAT IT WILL AMPLIFY BOTH THE POSITIVE EXCURSIONS OF THE INPUT SIGNAL AS WELL AS THE NEGATIVE EXCURSIONS. THUS THE BASE SHOULD BE AT ·6v.

7. THE GAIN OF A TRANSISTOR IS A CHARACTERISTIC OF THE MANUFACTURING PROCESS. SOME TRANSISTORS HAVE A GAIN OF 20, OTHERS 50-150 & HIGH GAIN TRANSISTORS HAVE A GAIN OF 250-450. WHEN A TRANSISTOR IS PLACED IN A CIRCUIT, THESE GAIN FIGURES DROP APPRECIABLY DUE TO THE EFFECT OF BIASING COMPONENTS (STABILISING COMPONENTS) & COUPLING CAPACITORS ETC. A SMALL SIGNAL TRANSISTOR WITH A SPECIFIED GAIN OF 250 WILL HAVE A GAIN OF 50-70 WHEN PUT IN A CIRCUIT.

TESTING TRANSISTORS

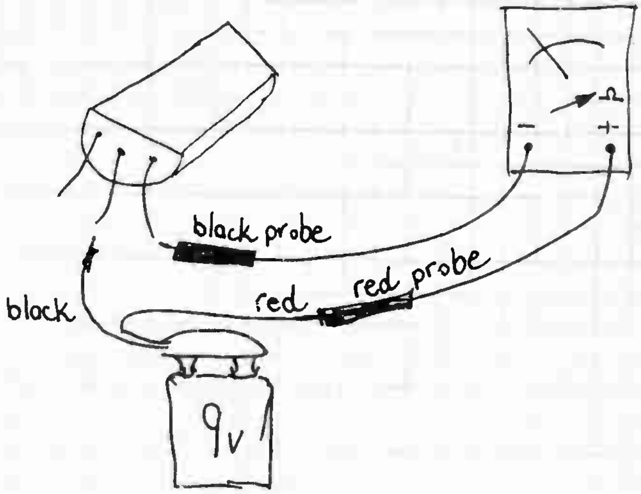
WE HAVE SHOWN HOW TO USE A MULTIMETER TO LOCATE THE BASE LEAD OF A TRANSISTOR. THIS PROCEDURE CAN ALSO BE USED TO CHECK A TRANSISTOR FOR "GO" "NO-GO" & LEAKAGE.

LEAKAGE IS A VERY CRITICAL FACTOR AS IT REDUCES THE GAIN & CAUSES THE TRANSISTOR TO DRAW MORE CURRENT THAN NORMAL. THIS CAN CAUSE LOAD RESISTORS TO OVER-HEAT, OUTPUTS TO BECOME DISTORTED, VERTICAL DEFLECTION CIRCUITS TO FOLD-OVER & THE TRANSISTOR ITSELF TO OVER-HEAT.

WHEN CHECKING A TRANSISTOR WITH A MULTIMETER, ALWAYS USE THE HIGH-OHMS RANGE & THIS APPLIES FOR BOTH PNP & NPN TYPES:— YOU SHOULD GET TWO "LOW READINGS" (THE NEEDLE WILL SWING ALMOST FULL-SCALE-DEFLECTION) & 4 "HIGH READINGS" (THE NEEDLE WILL HARDLY DEFLECT AT ALL).

SOME MULTIMETERS HAVE A 9V BATTERY FOR THE HIGH-OHMS RANGE AND THIS WILL REVEAL A LEAKY TRANSISTOR VERY QUICKLY — THE NEEDLE WILL MOVE ONE OR TWO CM.

IF YOUR MULTIMETER HAS A 3V BATTERY FOR THE OHMS RANGE, YOU CAN ADD A 9V BATTERY AS SHOWN TO CAUSE A LEAKY TRANSISTOR TO BREAK DOWN & DEFLECT THE POINTER (3V IS NOT SUFFICIENT TO OVERCOME THE 'BARRIER VOLTAGE' IN SOME POWER TRANSISTORS.)



USING A 9V BATTERY TO DETECT A LEAKY JUNCTION.

TRANSISTORS CAN DEVELOP MANY MANY FAULTS AND AFTER FIXING 20,000 TV SETS, YOU WILL AGREE THAT "YOU CANNOT TEST A TRANSISTOR!"

I HAVE HAD SOME DEVELOP A FAULT AFTER 1 MIN, 10 MINS AND EVEN 30 MINS OF OPERATION. IT ALL DEPENDS ON A 'CRITICAL TEMPERATURE'. A VERY LIGHT SPRAY FROM A CAN OF FREEZE WILL LOCATE A THERMAL FAULT & YOU CAN SOMETIMES HEAT IT UP AGAIN WITH A SOLDERING IRON TO REPRODUCE THE FAULT.

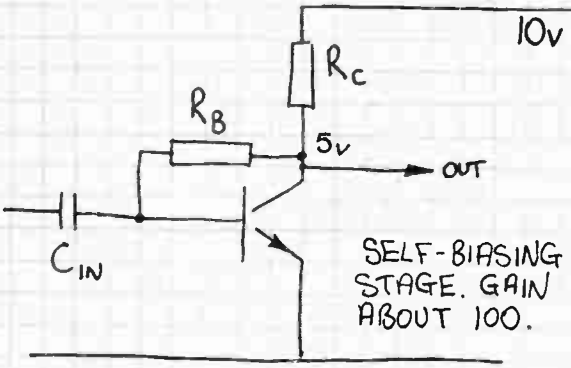
MOST FAULTY TRANSISTORS CANNOT BE MADE TO FAULT OUT-OF-CIRCUIT AS IT IS IMPOSSIBLE TO DUPLICATE THE SAME CONDITIONS. SOME OF THE FAULTS I HAVE FOUND WHILE REPAIRING TV SETS INCLUDE: LEAKAGE, NOISE, INTERMITTENT OPEN CIRCUIT, LOSS OF GAIN, THERMAL RUNAWAY, SELF-OSCILLATION, & ZENERING — MAYBE YOU WILL FIND OTHERS.

THE ONLY REAL FAULT YOU CAN DETECT WITH A MULTIMETER IS A COMPLETELY DAMAGED TRANSISTOR — SUCH AS A "LOW-LOW" JUNCTION.

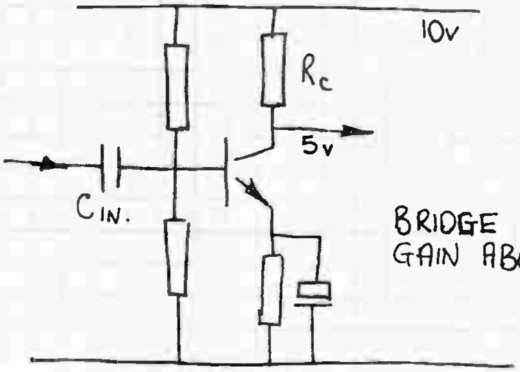
STAGE GAIN

IN THE PREVIOUS FRAME WE SAID THE GAIN OF A STAGE IS ONLY ABOUT 50–70 WHEREAS THE GAIN OF THE TRANSISTOR MAY BE 250 –450. WHY IS THE STAGE-GAIN MUCH LOWER THAN THE GAIN OF THE TRANSISTOR?

THE REASON IS DUE TO COUPLING (THE CAPACITOR CONNECTING THE STAGES) & BIASING, (THE RESISTORS CONNECTED TO THE BASE.)



SELF-BIASING STAGE. GAIN ABOUT 100.



BRIDGE BIASING. GAIN ABOUT 22!

THE GAIN OF ANY STAGE IS THE RATIO OF THE OUTPUT WAVEFORM OVER THE INPUT WAVEFORM. IN THE CIRCUIT ABOVE, THE TWO THINGS THAT WORK AGAINST THIS ARE ① THE INPUT CAPACITOR, AND ② THE BIASING RESISTOR R_B.

THE CIRCUIT IS BIASED SO THAT THE VOLTAGE ON THE COLLECTOR IS HALF-RAIL VOLTAGE. THE CURRENT THROUGH R_B, $I_{R_B} = \frac{5v}{R_B}$. TO TURN THE TRANSISTOR OFF, THE INPUT CURRENT (VIA THE CAPACITOR) MUST OPPOSE THIS. WHEN THE TRANSISTOR IS SWITCHED OFF, THE COLLECTOR VOLTAGE WILL BE FULL-RAIL VOLTAGE & THUS THE CURRENT THROUGH R_B WILL BE: $I_{R_B} = \frac{10v}{R_B}$. THIS IS TWICE THE QUIESCENT CURRENT & EFFECTIVELY MEANS THE INPUT WAVEFORM MUST BE TWICE THE AMPLITUDE TO ACHIEVE THE CUT-OFF CONDITION.

IN SIMPLE TERMS WE CAN SAY A TRANSISTOR WITH A GAIN OF 250 HAS BEEN REDUCED TO 125.

THE SECOND FACTOR WORKING AGAINST US IS THE INPUT CAPACITOR. A WAVEFORM ON THE INPUT SIDE OF THE CAPACITOR WILL BE SLIGHTLY REDUCED ON THE BASE SIDE DUE TO THE CHARGING OF THE CAPACITOR.

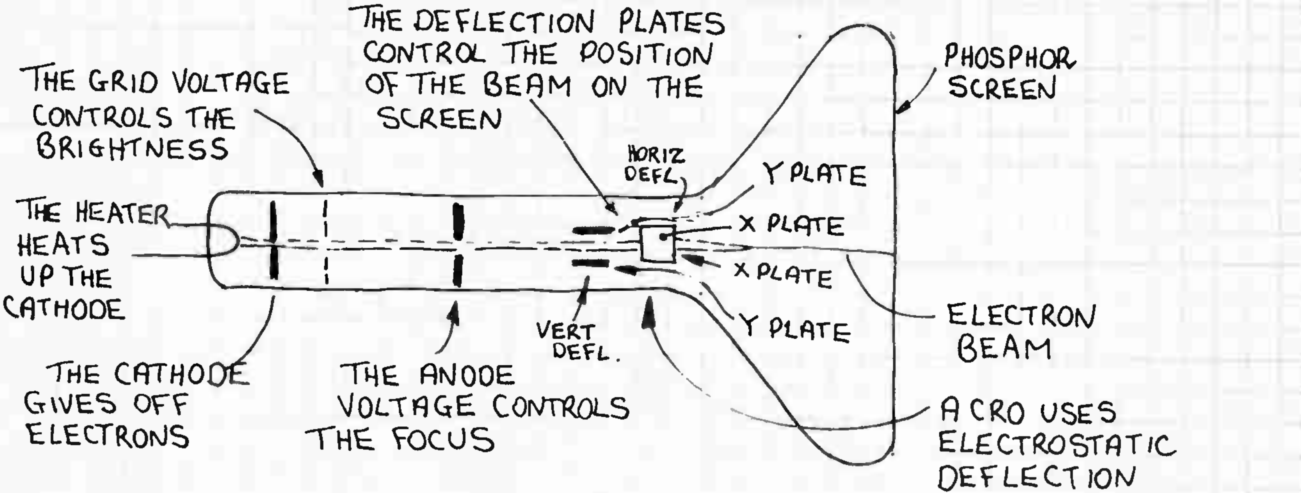
THE VALUE OF THE CAPACITOR IS CHOSEN SO THAT ITS TIME CONSTANT IS LARGE COMPARED WITH THE FREQUENCY IT IS REQUIRED TO PASS. HOWEVER THE CAPACITOR WILL CHARGE TO ABOUT 10-15% DURING EACH CYCLE & THUS THE GAIN CAN BE REDUCED BY A FURTHER 15%, MAKING A GAIN OF ABOUT 100 FOR THE STAGE.

IN THE SECOND CIRCUIT, THE GAIN IS EVEN LOWER DUE TO THE EFFECT OF THE BASE BIASING RESISTORS. THE DESIGN FACTOR FOR THESE RESISTORS IS TO BLEED 10 TIMES THE CURRENT REQUIRED BY THE BASE, TO PROVIDE GOOD CIRCUIT STABILITY. THIS MEANS THAT 90% OF THE INPUT SIGNAL IS DIVERTED THROUGH THE LOWER RESISTOR & ONLY 10% PASSES INTO THE BASE! A TRANSISTOR WITH A GAIN OF 250 IS REDUCED TO 25 IN THIS ARRANGEMENT. IF THE INPUT CAPACITOR TRANSFERS 85% THE STAGE GAIN BECOMES ABOUT 22!

THE CRO – THE BASICS.

A CRO LOOKS COMPLICATED – MAINLY BECAUSE THE CONTROLS DON'T GIVE A DIRECT READING IN HERTZ, KHz OR MHz. ONCE YOU LEARN TO "READ THE SCREEN", & CONVERT THE SWEEP TO HERTZ, YOUR FEAR WILL VANISH.

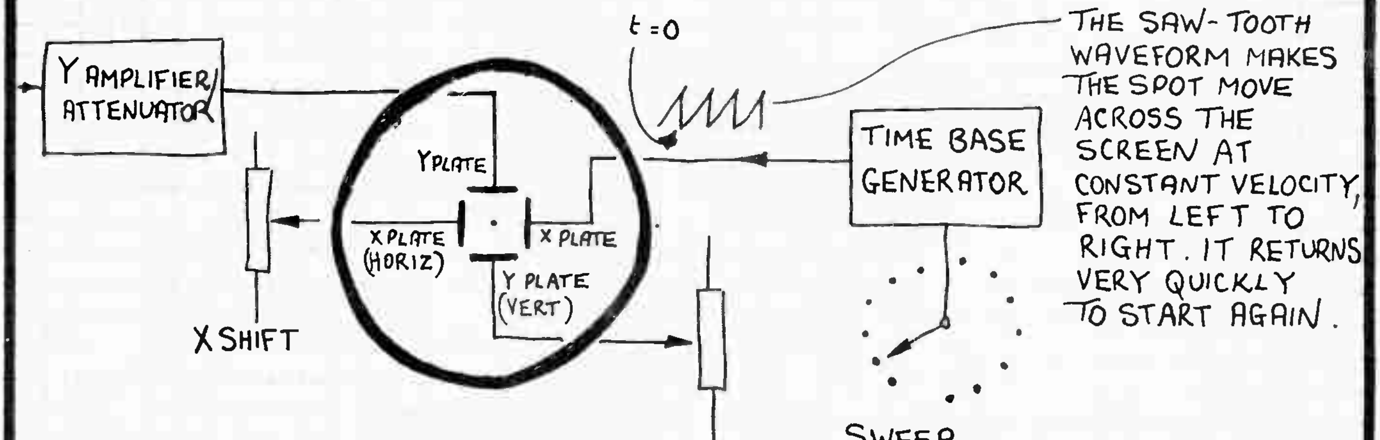
ALTHOUGH A CRO IS NOT USED VERY MUCH IN "SIMPLE ELECTRONICS", IT IS IMPORTANT TO KNOW HOW IT WORKS. HERE ARE THE BASICS:



THE ELECTRODE ARRANGEMENT

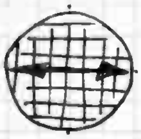
THE ELECTRONS ARE GIVEN OFF BY THE CATHODE (THE HEATER HEATS THE CATHODE & CAUSES THE ELECTRONS TO "JUMP OFF".) THEY ARE ATTRACTED TO THE ANODE AND PASS THROUGH A SMALL HOLE CALLED THE GRID.

THIS CREATES A NARROW BEAM CALLED THE ELECTRON BEAM. THE ANODE ACCELERATES THE ELECTRONS & THE BEAM PASSES BETWEEN TWO SETS OF PLATES CALLED THE DEFLECTION PLATES, BEFORE HITTING THE PHOSPHOR SCREEN.

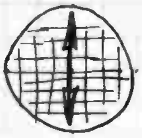


THE DEFLECTION PLATES

THE POSITION ON THE SCREEN (FOR THE TRACE) IS DETERMINED BY THE 'X SHIFT' & 'Y SHIFT'.



X SHIFT



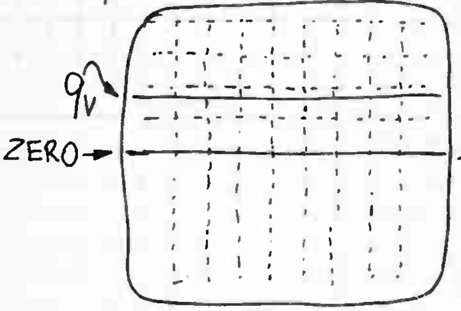
Y SHIFT

THE CRT (CATHODE RAY TUBE) PRODUCES A 'SPOT' OF ELECTRONS & THIS SPOT IS MOVED ACROSS THE SCREEN VIA THE VOLTAGE PRODUCED ON THE RIGHT-HAND X PLATE (THE TIME-BASE CIRCUIT DOES THIS). IT LEAVES A TRAIL BEHIND, JUST LIKE A COMET.

AS THE SPOT MOVES FASTER, THE TAIL APPEARS LONGER, AND EVENTUALLY A LINE APPEARS ACROSS THE SCREEN. THE TAIL IS DUE TO THE "PERSISTANCE" OR "AFTER GLOW" OF THE PHOSPHOR.

THE Y AMPLIFIER MOVES THE SPOT UP AND DOWN AND SINCE THE BEAM IS BEING DRAWN ACROSS THE SCREEN AT A RATE DETERMINED BY THE SWEEP SPEED, THE RESULTING TRACE WILL HAVE A VERTICAL DEFLECTION.

FOR EXAMPLE: IF WE MEASURE A 9V BATTERY, THE TRACE WILL 'JUMP' TO THE 9V MARK ON THE SCREEN.



THIS IS THE NORMAL ZERO LINE SO THAT BOTH POSITIVE & NEGATIVE WAVEFORMS CAN BE DISPLAYED. BUT THE TRACE CAN BE SHIFTED TO THE BOTTOM OF THE SCREEN TO MAKE FULL USE OF THE SCREEN FOR DISPLAYING POSITIVE WAVEFORMS.

VOLTS/CM CONTROL SET TO 5 (5 VOLTS/CM)

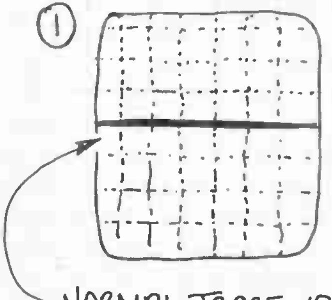
MEASURING VOLTAGE

THE CRO CAN BE USED AS A HIGH-IMPEDANCE VOLTMETER (ABOUT 1MΩ INPUT IMPEDANCE) AND SAVES BUYING AN EXPENSIVE MULTIMETER.

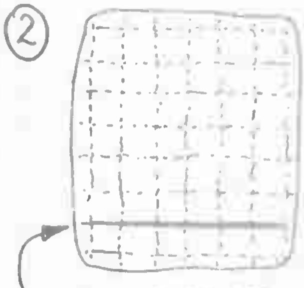
VOLTAGE MEASUREMENTS ARE SIMPLE:

1. SET THE SWEEP SPEED TO ANY SPEED (THIS ONLY APPLIES TO DC VOLTAGE MEASUREMENTS)
2. SET THE INPUT SWITCH TO DC (THE OTHER SETTINGS ARE "AC" & "GND")
3. SET THE VOLTS/CM SWITCH TO 20V/CM (ALWAYS SET TO MAXIMUM IF THE VOLTAGE IS UNKNOWN)
4. PLACE THE EARTH CLIP ON THE NEGATIVE OF THE BATTERY & THE PROBE TIP TO POSITIVE. IF THE TRACE DOES NOT 'JUMP UP' VERY HIGH — REDUCE THE VOLTS/CM SETTING. A CRO WILL READ UP TO ABOUT 200V DC & IF IT HAS A 10:1 PROBE, THE READING WILL BE UP TO ABOUT 2,000 VOLTS.

NORMALLY THE 'ZERO LINE' IS ACROSS THE CENTRE OF THE SCREEN BUT THE TRACE CAN BE MOVED DOWN TO THE LOWEST MARKING (OR UP TO THE HIGHEST MARKING) TO ACHIEVE FULL SCREEN DEFLECTION, TO GET THE MAXIMUM ACCURACY.



NORMAL TRACE IS ACROSS THE MIDDLE



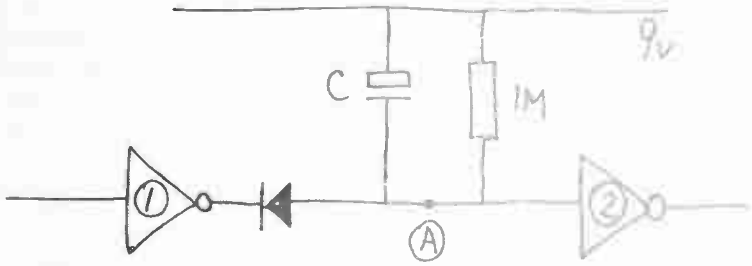
TO GET MORE ACCURACY, MOVE TRACE DOWN

SET VOLTS/CM TO 2VOLTS/CM TRACE WILL 'JUMP UP' TO THE 9V MARK

ONE IMPORTANT FACT TO REMEMBER WHEN USING THE CRO AS A DC VOLTAGE DETECTOR, IS THE INPUT RESISTANCE.

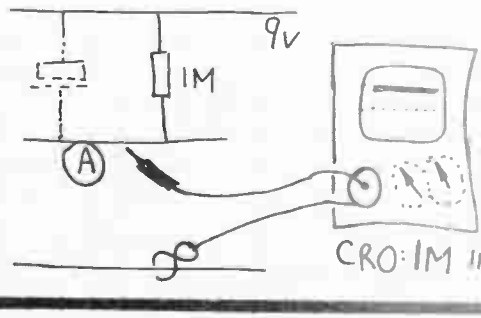
MANY CRO'S HAVE A FIXED INPUT RESISTANCE OF 1M & WHEN MEASURING HIGH IMPEDANCE CIRCUITS, THIS WILL LOAD THE CIRCUIT CONSIDERABLY

TAKE THE FOLLOWING EXAMPLE:



THE CIRCUIT IS A TIME DELAY IN WHICH INVERTER ① GOES LOW FOR AN INSTANT AND CHARGES C VIA THE DIODE.

THIS CAUSES INVERTER ② TO CHANGE. THE 1M SLOWLY DISCHARGES THE CAPACITOR & AFTER A TIME DELAY THE VOLTAGE ON THE INPUT OF INVERTER ② IS HIGH AND THE GATE CHANGES STATE. IF WE PROBE THE CIRCUIT AT POINT Ⓐ WITH A CRO WE PRODUCE A VOLTAGE DIVIDER MADE UP OF THE 1M RESISTOR IN THE CIRCUIT & THE 1M IN THE CRO:



CRO: 1M INPUT RESISTANCE.

THIS MEANS POINT Ⓐ WILL NEVER RISE ABOVE ½ RAIL VOLTAGE AND INVERTER ② WILL NOT CHANGE STATE

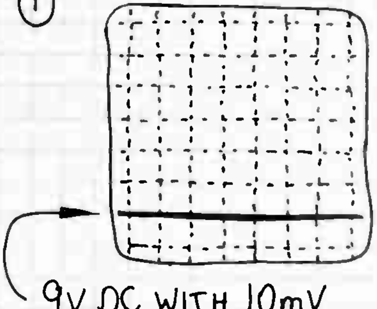
ACCURACY

IN ALL CASES, THE OBJECT OF CHANGING THE VOLTS/CM SETTING IS TO GET THE LARGEST WAVEFORM THAT WILL FIT ONTO THE SCREEN. IN THE EXAMPLE MENTIONED PREVIOUSLY, SUPPOSE THE 9v DC HAD A 10mV RIPPLE PRESENT. TO VIEW THE RIPPLE, THIS IS THE PROCEDURE:

① SWITCH THE INPUT TO 'AC'. (THE OTHER SETTINGS ON THE SWITCH ARE "DC" & "GND" - GROUND)

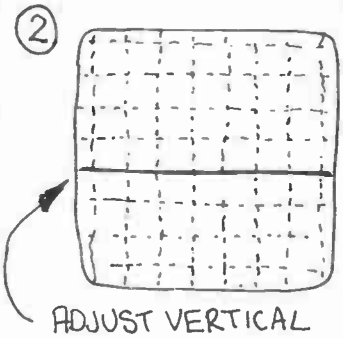
THIS WILL CAUSE THE TRACE TO JUMP DOWN TO THE LOWEST MARKING ON THE SCREEN (OR ACROSS THE MIDDLE - DEPENDING WHERE THE TRACE WAS SET). AT THIS STAGE YOU WILL NOT BE ABLE TO SEE THE RIPPLE AS THE CRO SETTING IS NOT SENSITIVE ENOUGH.

①



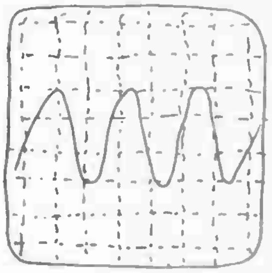
9V DC WITH 10mV RIPPLE. INPUT SET TO "AC". SENSITIVITY 2v/CM

②



ADJUST VERTICAL SHIFT TO CENTRE TRACE

③



INPUT SENSITIVITY: 2 OR 5 mv/CM TO VIEW THE "10mV" RIPPLE

② SHIFT THE TRACE TO THE MIDDLE OF THE SCREEN SO THAT READINGS CAN BE TAKEN - SO THAT BOTH POSITIVE & NEGATIVE EXCURSIONS CAN BE VIEWED & SO THAT BEST SENSITIVITY CAN BE SELECTED.

③ ADJUST THE INPUT SENSITIVITY SO THAT THE TRACE FILLS THE SCREEN. YOU MAY NEED 2mV/DIV (SAME AS 2mV/CM) OR 5mV/CM. READ THE WAVEFORM AND DETERMINE IF IT IS 8mV, 9mV, 10mV OR 12mV. MAKE A RECORD OF THE VALUE & NOTE THE RIPPLE WILL BE 100 Hz.

THE 10:1 PROBE

THIS SETTING ACTUALLY DIVIDES THE SIGNAL BY 10!

MOST CRO'S COME WITH A PROBE HAVING A 10:1 FEATURE. THIS IS A SWITCH ON THE PROBE INDICATING "10:1" OR "NORM."

FIRSTLY YOU MUST BE VERY CAREFUL NEVER TO LEAVE THE PROBE IN THE 10:1 POSITION AS THIS WILL MAKE THE READINGS ON THE SCREEN ONLY 1/10th THEIR NORMAL HEIGHT.

YOU CAN IMAGINE THE TROUBLE THIS WOULD CREATE. WAVEFORMS WOULD APPEAR SMALLER THAN EXPECTED & YOU MAY THINK THE CIRCUIT UNDER TEST IS NOT AMPLIFYING SUFFICIENTLY. WHEN MEASURING DC VOLTAGES, THE 10:1 POSITION CAN BE USED FOR VOLTAGES ABOVE 200v & THE SCALE ON THE VOLTS/CM CONTROL IS MULTIPLIED BY 10. FOR INSTANCE THE SETTING "10 VOLTS/CM" BECOMES 100 VOLTS/CM.

MAX FREQUENCY

THE ONE FACTOR THAT DETERMINS THE COST OF A CRO IS THE MAXIMUM FREQUENCY THAT THE Y AMPLIFIER (THE AMPLIFIER THAT PROCESSES THE SIGNAL) CAN HANDLE. IN TECHNICAL TERMS THE MAXIMUM FREQUENCY IS THE POINT WHERE THE TRACE SHOWS ONLY 71% OF THE TRUE AMPLITUDE OF THE SIGNAL (CALLED THE −3dB POINT).

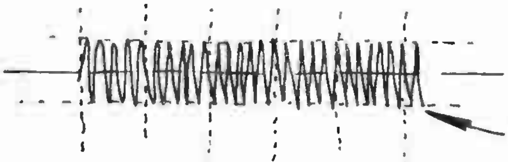
BUT THIS IS NOT THE ONLY FACTOR TO LOOK FOR.

WHEN YOU ARE READING HIGH FREQUENCIES, NOT ONLY WILL THE WAVEFORM BE REDUCED BY THE LIMITATIONS OF THE Y AMPLIFIER BUT THE LOADING EFFECT OF THE CRO WILL REDUCE THE OUTPUT OF THE CIRCUIT UNDER TEST. SO HEIGHT OF WAVEFORM IS NOT A MAJOR CONSIDERATION.

THE MORE-IMPORTANT FACTOR — AND THIS HAS NEVER BEEN MENTIONED BEFORE — IS THE NUMBER OF CYCLES PER DIVISION THAT WILL BE DISPLAYED AT MAXIMUM FREQUENCY.

FOR INSTANCE, A 15MHz CRO WITH MAX SWEEP TIME OF ·5µS/CM WILL SHOW 7½ COMPLETE CYCLES PER CM FOR A 15MHz SIGNAL.

IT WILL BE ALMOST IMPOSSIBLE TO COUNT THIS MANY CYCLES PER DIVISION AS THE SCREEN WILL BE FILLED WITH THE WAVEFORM LIKE THIS:



THIS WAVEFORM IS SO COMPACT YOU CAN'T READ IT.

X5 MAGNIFICATION

MANY CRO's HAVE A **X5** MAGNIFICATION KNOB THAT INCREASES THE SWEEP SPEED BY 5. IN THE EXAMPLE ABOVE, THE ·5µS/CM IS EXTENDED TO ·1µS/CM (100nS/CM) SO THAT ABOUT 1 CYCLE IS DISPLAYED PER DIVISION.

WHAT IS THE MAXIMUM FREQUENCY OF A CRO?

THE ANSWER IS COMPLEX AND INVOLVES A NUMBER OF FACTORS. THESE ARE: 1. THE BANDWIDTH OF THE Y AMPLIFIER. 2. THE MAXIMUM SWEEP SPEED — THE PRESENCE OF A X5 MAGNIFICATION KNOB. & 3. THE NUMBER OF CYCLES YOU ARE PREPARED TO ACCEPT, PER DIVISION.

IF YOU ARE PREPARED TO ACCEPT 4 COMPLETE CYCLES PER DIVISION, THE CRO IN THE EXAMPLE ABOVE IS DISPLAYING A 40MHz SIGNAL. IF YOU COUNT 10 COMPLETE CYCLES PER DIVISION, THE CRO IS DISPLAYING 100MHz!!

YOU CAN SEE HOW THE BANDWIDTH HAS LITTLE OR NOTHING TO DO WITH THE MAX FREQUENCY THAT CAN BE DISPLAYED. FOR INSTANCE, THE COMPARASON BETWEEN 2 CRO'S, SUCH AS 15MHz & 30MHz, MAY MEAN BOTH INSTRUMENTS SHOW THE SAME NUMBER OF COMPLETE CYCLES PER DIVISION AT MAX FREQUENCY BUT THE 30MHz CRO WILL HAVE A HIGHER (BETTER) WAVEFORM.

COMPARING CRO'S

HERE'S A SIMPLE WAY TO COMPARE TWO CRO'S – IT ALSO SHOWS YOU HOW USELESS SOME OF THE SIMPLE CRO'S ARE (MINIMUM USEFUL RESOLUTION FOR DIGITAL WORK IS 10MHz)

WE WILL BASE OUR COMPARISON ON ONE COMPLETE CYCLE PER DIVISION AT MAXIMUM FREQUENCY & THE FIRST THING TO LOOK FOR IS THE MAX SWEEP SPEED.

IF IT IS 1µS/CM THE MAXIMUM FREQUENCY OF THE CRO IS 1MHz
" " " •5µS/CM " " " " " " " 2 "
" " " •2 " " " " " " " " 5 "
" " " •1 " " " " " " " " 10 "

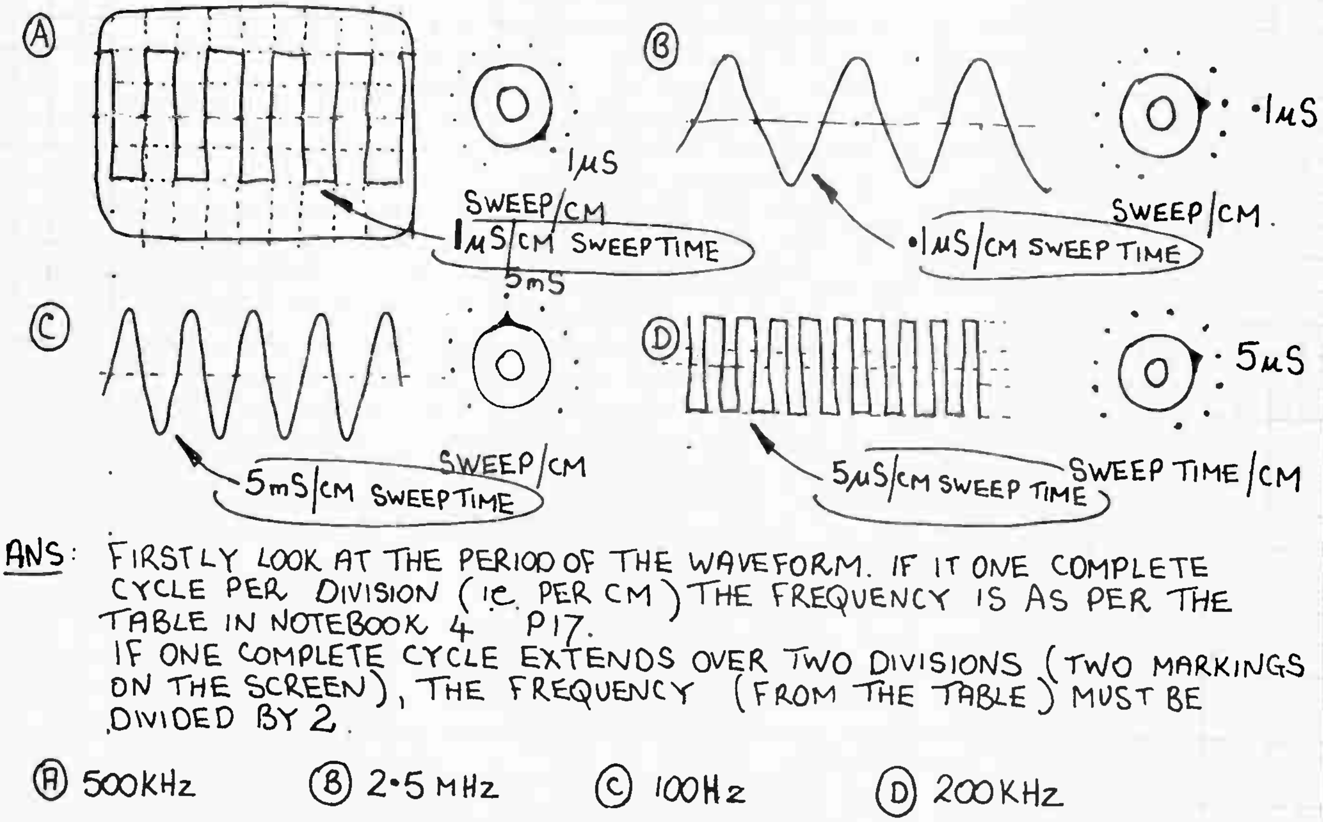
IF THE CRO HAS A X5 MAGNIFICATION KNOB THE MAX FREQ IS AS FOLLOWS:

FOR 1µS/CM SWEEP SPEED THE MAX FREQ IS 5MHz
" •5µS/CM " " " " " " 10 "
" •2 " " " " " " " 25 "
" •1 " " " " " " " 50 "

IF YOU ACCEPT 2 COMPLETE CYCLES PER DIVISION, THE FIGURES ABOVE CAN BE DOUBLED.

TEST:

WHAT IS THE FREQUENCY OF THESE WAVEFORMS:



ANS: FIRSTLY LOOK AT THE PERIOD OF THE WAVEFORM. IF IT ONE COMPLETE CYCLE PER DIVISION (ie. PER CM) THE FREQUENCY IS AS PER THE TABLE IN NOTEBOOK 4 P17.
IF ONE COMPLETE CYCLE EXTENDS OVER TWO DIVISIONS (TWO MARKINGS ON THE SCREEN), THE FREQUENCY (FROM THE TABLE) MUST BE DIVIDED BY 2.

Ⓐ 500KHz Ⓑ 2•5 MHz Ⓒ 100Hz Ⓓ 200KHz

CRO HINTS

DON'T LET ANYONE TOUCH YOUR CRO. THEY MAY LEAVE THE 'X5' MAGNIFYING KNOB ON OR THE 'X10' (ON THE PROBE) SWITCHED ON.

KEEP THE CONVERSION TABLE (SEE NOTEBOOK 4, P.17) HANDY. USE IT WHEN YOU NEED TO CONVERT A WAVEFORM INTO A FREQUENCY (ACTUALLY A PERIOD INTO A FREQUENCY.)

WHEN WORKING ON TV'S AND OTHER EQUIPMENT THAT DON'T HAVE A POWER TRANSFORMER (SOME NORDEMENDE, SIEMENS, FINLUX, ASA, SABA & BLAUPUNKT SETS HAVE SWITCH-MODE POWER SUPPLIES & NO MAINS TRANSFORMER OR A SIMPLE SCR REGULATOR. THE CHASSIS CAN BE 120V ABOVE EARTH!), THE EARTH LEAD OF THE CRO MUST BE REMOVED OTHERWISE THE TV WILL 'BLOW A FUSE' WHEN THE EARTH LEAD ON THE CRO IS ATTACHED TO THE CHASSIS.

IF YOU HAVE A DUAL TRACE CRO, MARK ONE LEAD WITH A SILVER 'TEXTA' SO THAT YOU KNOW WHICH LEAD IS CHANNEL 1 (OR A) & WHICH IS CHANNEL 2 (OR B). KEEP THE SILVER LEAD AS CHANNEL 1 AND ALWAYS USE IT AS THE INPUT TO THE CIRCUIT UNDER TEST. DISPLAY CH 1 ABOVE CH 2. (OR ON TOP) — AND YOU WILL BE ABLE TO COMPARE INPUT-TO-OUTPUT.

THE PROBES OF A CRO CAN QUITE OFTEN UPSET THE OPERATION OF A CIRCUIT. THIS IS ESPECIALLY EVIDENT WHEN PROBING HIGH-IMPEDANCE CIRCUITS, RF CIRCUITS & WAVEFORMS WITH A CRITICAL SHAPE.

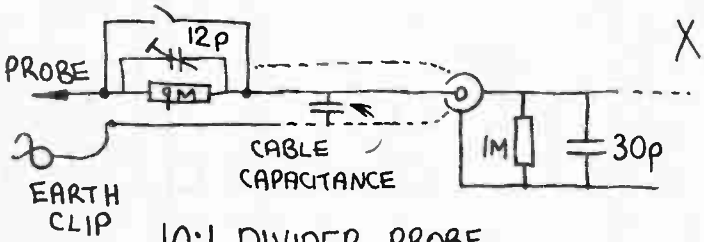
SOMETIMES THE EARTH LEAD WILL INTRODUCE HUM AND/OR THE PROBE WILL PREVENT A CIRCUIT FROM CLOCKING OR FUNCTIONING CORRECTLY.

THIS IS A CLEAR INDICATION THAT THE CRO IS LOADING THE CIRCUIT & THE WAVEFORM DISPLAYED ON THE SCREEN IS CONSIDERABLY DIFFERENT TO THE ACTUAL SHAPE.

THE CRO USUALLY DOESN'T AFFECT THE FREQUENCY OF THE WAVEFORM, JUST THE AMPLITUDE (ESPECIALLY SPIKES) & THE SHAPE OF THE RISING & TRAILING EDGES.

USING THE 10:1 DIVIDER ON THE PROBE WILL REDUCE THE CAPACITIVE EFFECT OF THE LEAD & THE VERTICAL AMPLITUDE READING WILL NEED TO BE INCREASED TO COMPENSATE FOR THE ATTENUATION.

THE CAPACITIVE EFFECT OF THE LEAD IS ABOUT 100pF AND AT 10MHz THIS REPRESENTS AN IMPEDANCE OF ABOUT 160 OHMS. THE 10:1 DIVIDER REDUCES THE LOADING EFFECT TO ABOUT 10pF.



10:1 DIVIDER PROBE

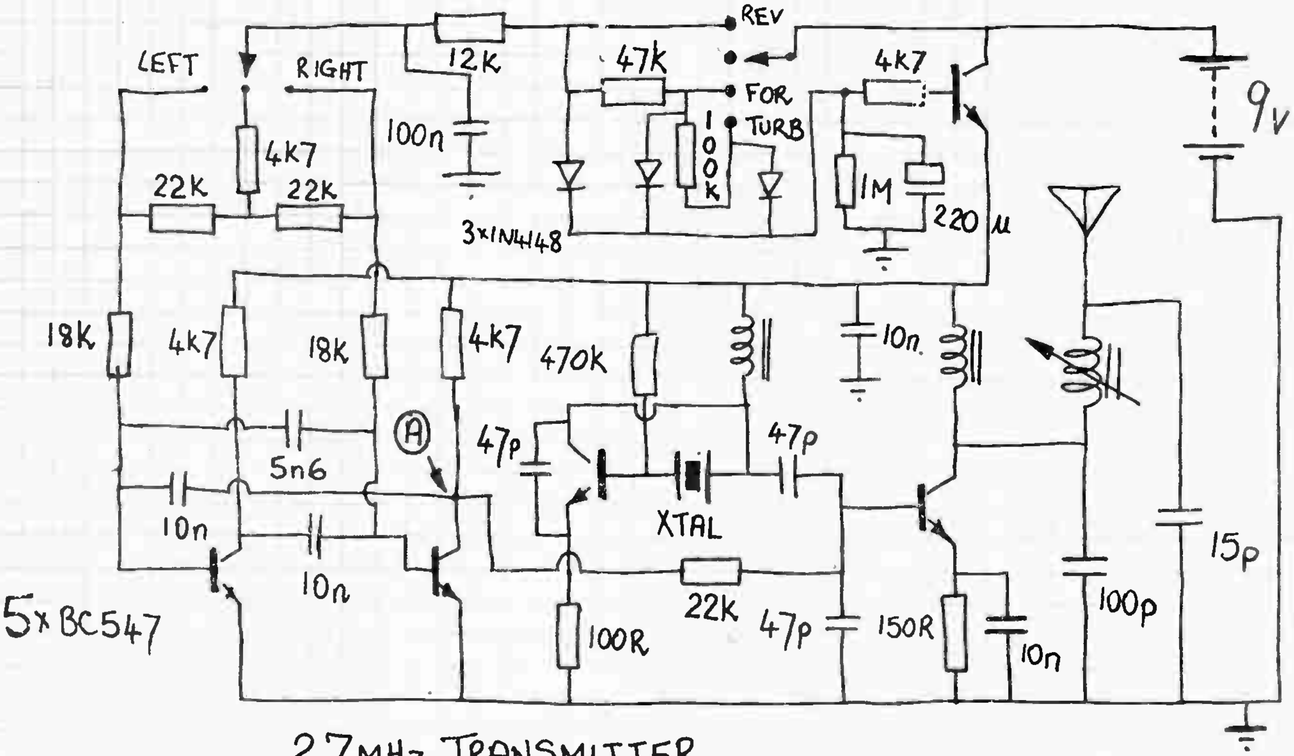
$$X_c = \frac{10^6}{2\pi f C}$$

$$= \frac{\cancel{10^6}}{2 \times 3{\cdot}14 \times 10 \times \cancel{10^6} \times 100 \times 10^{-6}}$$

$$= \frac{1}{6} \times \frac{10^6}{10 \times 100} = \frac{10^3}{6} = 160 \text{ OHMS}$$

USING A CRO TO FIX A 27MHz TOY

SOON AFTER WRITING THE CRO ARTICLE ON THE PREVIOUS PAGES, I NEEDED TO FIX A 27MHz REMOTE CONTROL TRANSMITTER. HERE'S THE CIRCUIT & THE WAVE SHAPES PRODUCED BY THE MULTIVIBRATOR 'FRONT-END'. NOTE FORWARD-REVERSE & TURBO DETERMINES THE FREQUENCY OF THE TONE & LEFT-RIGHT DETERMINES THE MARK-SPACE RATIO.



27MHz TRANSMITTER

FROM THE CIRCUIT, A NUMBER OF FEATURES EMERGE. 'POWER ON' IS OBTAINED VIA THE 'TURN ON' SECTION AT TOP. WHEN REVERSE-FORWARD OR TURBO IS SELECTED, ONE OF THE GATING DIODES CHARGES THE 220µ ELECTROLYTIC AND TURNS ON THE EMITTER FOLLOWER TRANSISTOR.

THE 'FRONT END' OF THE CIRCUIT IS A MULTIVIBRATOR (SQUARE-WAVE OSCILLATOR) WITH THE FREQUENCY & MARK-SPACE RATIO DETERMINED BY THE 'CONTROLS.' NOTE THE SYMMETRY OF THE OSCILLATOR. THE CRO DIAGRAMS ARE TAKEN AT POINT Ⓐ & BY KNOWING THE SWEEP SPEED (·5mS/div) YOU CAN CALCULATE THE FREQUENCY OF THE OSCILLATOR. BUT MORE IMPORTANT, THE CRO SHOWS THE MARK-SPACE RATIO AS NEEDED BY THE RECEIVER TO DETERMINE THE PREDOMINANTLY HIGH OR LOW SIGNAL FOR LEFT/RIGHT FUNCTIONS.

REVERSE

FORWARD

TURBO.

GETTING YOUR B.E.C.

(BASIC ELECTRONICS CERTIFICATE)

THIS SECTION IS AIMED AT GETTING YOUR BEC.

THIS CERTIFICATE IS A 'FEATHER IN YOUR CAP' AND IS THE STARTING POINT TO FURTHER LEARNING. ALTHOUGH THE EXAM IS SIMPLE (TO SOME) IT CERTAINLY COVERS A LOT OF TOPICS AND TO GAIN A CREDIT (OR PASS) YOU WILL HAVE TO BE ALERT TO A GOOD DEAL OF BASIC ELECTRONIC KNOWLEDGE.

EXAMS FRIGHTEN EVERYONE AND QUITE OFTEN YOU DON'T DO AS WELL AS EXPECTED BECAUSE YOU ARE NOT FAMILIAR WITH THE REQUIREMENTS, APPROACH OR CONTENT OF THE EXAM.

IN THE PAGES THAT FOLLOW, WE COVER SOME TYPICAL QUESTIONS AND SHOW YOU HOW TO DO YOUR BEST. THERE ARE LOTS OF TRICKS AND TRAPS IN THE QUESTIONS & WE WILL POINT THESE OUT ALONG THE WAY.

NO MATTER WHEATHER YOU WANT TO GO FOR YOUR BEC THIS YEAR OR NEXT, THESE PAGES WILL HELP YOU ENORMOUSLY. WORK THROUGH THEM AT YOUR LEISURE & ATTEMPT THE FINAL PAPER UNDER TEST CONDITIONS.

I HOPE YOU LEARN A LOT.

* * *

MANY OF THE QUESTIONS ARE MULTI-CHOICE. THIS IS CALLED "OBJECTIVE TESTING" AND YOU MUST PICK THE CORRECT ANSWER FROM 3 OR 4 POSSIBILITIES.

WHEN ANSWERING THIS TYPE OF QUESTION YOU MUST DECIDE ON THE ANSWER BEFORE LOOKING AT THE CHOICES. PUT YOUR ANSWER IN THE MARGIN THEN LOOK AT THE CHOICES.

THIS TYPE OF QUESTION LOOKS EASY BUT IS THE MOST DIFFICULT OF ALL TO ANSWER AS THE CHOICES WILL MUCK YOU UP VERY EASILY.

IT IS ESSENTIAL TO WRITE YOUR "GUESSES" FIRST TO PREVENT BEING DISTRACTED.

SECONDLY

MULTI-CHOICE QUESTIONS TAKE A LONG TIME TO READ, STUDY & ANSWER. BUT EACH IS WORTH ONLY ONE OR TWO MARKS SO DON'T SPEND TOO LONG ON ANY ONE QUESTION.

*THE BEC WAS DEVELOPED IN VICTORIA AND IS CONDUCTED AT ALMOST ALL TAFE COLLEGES IN MELBOURNE, SURROUNDING SUBURBS & COUNTRY AREAS. IT IS ALSO AVAILABLE AS A CORRESPONDENCE COURSE (FOR LESS THAN 100!) AND IS CALLED OFF-CAMPUS STUDY.

YOU MUST ALSO CARRY OUT A NUMBER OF PRAC EXPERIMENTS FOR WHICH THERE IS A LABORATORY TRAINER KIT (VALUED AT $750) AVAILABLE ON LOAN (DEPOSIT MUST BE PAID). APPLY AT YOUR NEAREST TAFE COLLEGE FOR DETAILS.

FOR THOSE IN OTHER STATES, APPLY TO YOUR LOCAL COLLEGE & THEY SHOULD BE ABLE TO HELP. A NUMBER OF SETS OF NOTES (EACH ABOUT 15CM THICK!) HAS BEEN SENT TO ALL STATES IN AN ATTEMPT TO MAKE THE BEC AN AUSTRALIA-WIDE, UNIVERSALLY-APPROVED COMMENCEMENT CERTIFICATE. IF YOU DON'T GET HELP — WRITE TO ME, AS A LAST RESORT.

THE BEC IS EXAMINED IN 1/3 : 1/3 : 1/3 PARTS & YOU MUST CARRY OUT A NUMBER OF PRAC EXPERIMENTS.

THE FIRST EXAM COVERS TOPICS 1,2,3,4 & 14 AND IS HEADED "ELECTRICAL PRINCIPLES."

THE SECOND EXAM COVERS TOPICS 5,6,7,8 & 9 AND IS HEADED "ANALOGUE PRINCIPLES.

THE THIRD EXAM COVERS TOPICS 10,11 & 12 AND IS HEADED "DIGITAL PRINCIPLES".

THE EXAM PAPERS TO DATE CONTAIN A NUMBER OF POOR QUESTIONS, QUESTIONS WITH NO ANSWER! QUESTIONS I DON'T LIKE & SOME VERY DIFFICULT QUESTIONS. SO BE WARNED! THE EXAM (EACH OF THEM) IS QUITE DIFFICULT. YOU WILL HAVE TO REALLY THINK HARD IF YOU DON'T WANT TO MAKE ANY SILLY MISTAKES.

I DO NOT HAVE ANY DETAILS AS TO HOW THE MARKS ARE APPORTIONED, HOWEVER THAT DOESN'T MATTER AT THE MOMENT. ATTEMPT THE FOLLOWING PAPERS UNDER TEST CONDITIONS THEN READ THE FULLY ANNOTATED ANSWERS. THESE WILL SHOW YOU HOW TO APPROACH THE QUESTION & HOW TO GET AN ANSWER VIA TWO DIFFERENT METHODS SO YOU CAN "DOUBLE-CHECK" YOUR OWN WORK.

<u>PLEASE NOTE</u>: THE POSSIBILITY THAT THESE QUESTIONS ARE SIMILAR TO PAST BEC PAPERS IS MERE COINCIDENCE. THEY HAVE BEEN ENTIRELY GENERATED BY MYSELF. IT IS NOT TO BE ASSUMED THAT THE COURSE COVERS EVERY QUESTION.

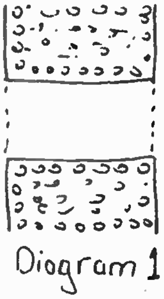
*MY OWN INTERPRETATION.

BASIC ELECTRONICS CERTIFICATE
(ELECTRICAL PRINCIPLES)

This paper carries 60 marks. Section A: 48 x 1 mark questions + 2 questions @ 2 marks. Section B: 10 marks as allocated.

For each question, pick the best answer (or answers).

1. A bobbin is to be filled with enamelled wire. See diagram 1. If the gauge of wire is changed from 26B&S to 22 B&S, the resistance of the coil will:



(a) increase,
(b) decrease, or
(c) remain the same as the same volume has to be filled.

2. If the bobbin above is filled with 22 B&S tinned copper wire, will the resistance be the same as above?

(a) yes,
(b) no.

3. The resistance of a conductor depends on its:

(a) length only,
(b) cross-sectional area only,
(c) cross-sectional area and resistivity, or
(d) length, resistivity and cross-sectional area.

4. The unit of charge is the:

(a) volt,
(b) ampere,
(c) ohm,
(d) coulomb.

5. A resistor having the colour bands yellow, purple, yellow, gold has a value of:

(a) 47k 5%
(b) 460k 10%
(c) 470k 5%
(d) 470k 10%

6. A brown, black, orange, silver resistor is measured on a multimeter, select the closest reading:

(a) 110k,
(b) 105k,
(c) 11k,
(d) 8k.

7. An analogue meter connected between neutral and earth will register the following:

(a) 240v AC,
(b) 325v peak
(c) 0v,
(d) A varying voltage between +325v and -325v AC.

8. Sometimes a ½watt resistor will be the same size as a ¼watt resistor. This is due to

(a) the resistance of the resistor,
(b) It's temperature of operation,
(c) depending on its use for either AC or DC circuits,
(d) the voltage rating of the resistor.

9. The maximum current that a 10k 10watt wire wound resistor can carry is:

(a) 330mA
(b) 3.3mA,
(c) 33mA,
(d) 00mA

10. Which of the following multimeters loads the circuit the least:

(a) 10k ohms per volt
(b) 20k ohms per volt
(c) 30k ohms per volt
(d) 50k ohms per volt.

11. A 1 metre rod of copper is stretched, what will happen to its resistance (measured between the two ends)

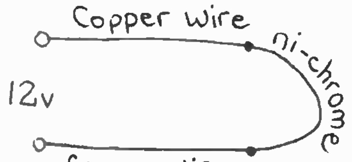
(a) It will increase,
(b) It will decrease,
(c) it will remain the same,
(d) cannot be determined.

12. Before using an extension cord, why must it be unwound?

____

13. In diagram 2, the three pieces of wire are the same length and the same thickness. The resistance of the circuit is 6 ohms. Explain what will happen when 12v is applied:

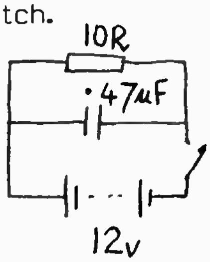
(a) the three wires will get hot,
(b) only the ni-chrome wire will get hot,
(c) only the copper wires will get hot,
(d) cannot be determined.



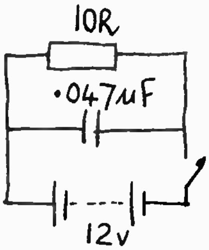
Diag. 2

Note: Ni-chrome wire is used in radiator bars and wire-wound resistors.

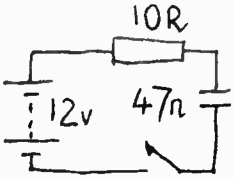
14. Which of the following circuits represents this description: A 10R resistor in parallel with a 47n capacitor, connected across a 12v battery, with an on/off switch.



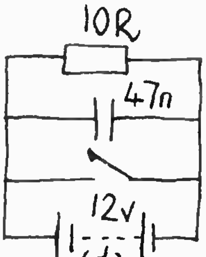
(a)



(b)



(c)



(d)

15. A 9v battery is measured with a multimeter and reads 8.5v. When fitted to a circuit the voltage falls to 7.5v. Why?

(a) All batteries are designed to do this,
(b) the battery is leaky,
(c) the battery is dead,
(d) the battery has an internal resistance.

16. Across two equal resistors in parallel,

(a) the voltage is doubled,
(b) the wattage is halved,
(c) the resistance is doubled,
(d) the resistance is halved.

17. Refer to dia 3. The total resistance of the circuit is:

(a) 36k,
(b) 58k,
(c) 69k,
(d) 91k.

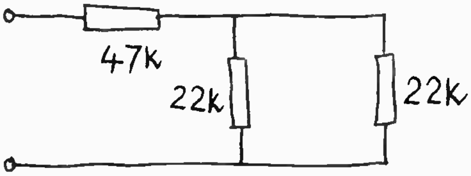


Diagram 3

18. A $\frac{1}{4}$watt and $\frac{1}{2}$watt resistor are connected in series. Which resistor will burn out first?

(a) the $\frac{1}{4}$watt resistor,
(b) the $\frac{1}{2}$watt resistor,
(c) depends on the voltage across the combination,
(d) depends on the resistance of each resistor.

19. You have two 1k pots. One is linear and the other log. How do you tell them apart?

(a) They will be stamped 'lin' and 'log,'
(b) you cannot determine the difference,
(c) Rotate the shaft to mid position and measure the resistance between centre and each end,
(d) one will rotate 270^{0} and the other 300^{0}.

20. Refer to dia 4. Which resistor will get hotter:

(a) the 8R resistor,
(b) the 4R resistor,
(c) both will be the same temperature,
(d) cannot be determined.

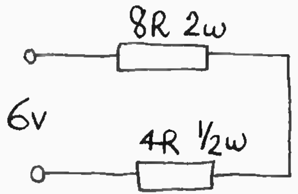


Diagram 4

21. Refer to diagram 5. The current through the 20R resistor is:

(a) 40mA,
(b) 80mA,
(c) 120mA,
(d) 60mA.

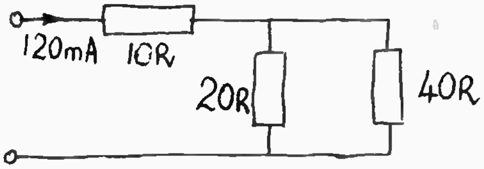


Diagram 5

22. Any resistor getting hot in a circuit represents wasted energy.

(a) true,
(b) false,
(c) sometimes true.

23. Refer to dia 6. What is the value of R_3.

(a) 22k,
(b) 10k,
(c) 2k2,
(d) 4k7.

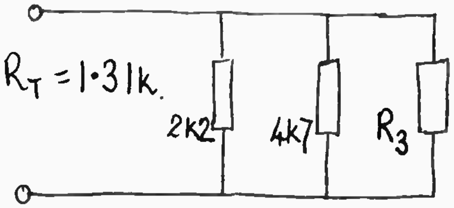


Diagram 6

24. One cell of a 6v battery pack is fitted around the wrong way. What is the output voltage of the pack?

(a) zero,
(b) 1.5v,
(c) 3v,
(d) 4.5v

25. Refer to dia 7. Determine the voltage of the supply.

(a) 15v,
(b) 55v,
(c) cannot be determined.

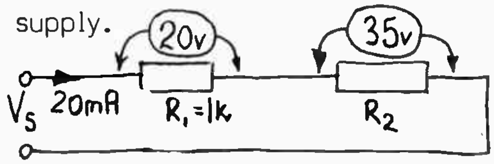


Diagram 7

26. Refer to dia 8. Determine the value of I_3.

(a) 18mA,
(b) 43mA,
(c) 7mA,
(d) cannot be determined.

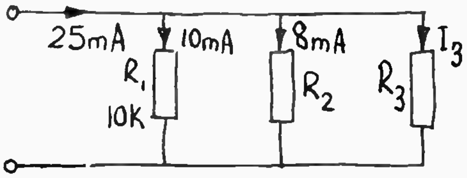


Diagram 8

27. Refer to diagram 8. Determine the value of R_2.

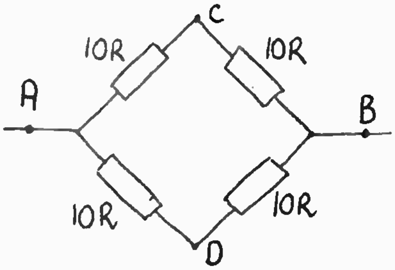
(a) 8k,
(b) 10k,
(c) 12.5k,
(d) 15k.

28. If the voltage across a resistor is doubled, what will happen to the wattage being dissipated?

(a) It will double, (2X)
(b) it will triple, (3X)
(c) It will increase four-fold, (4X)
(d) it will remain the same.

29. Refer to diagram 9. If the voltage between points A and B is 20 volts, what is the voltage between points C and D?

(a) 20v,
(b) 0v,
(c) 10v,
(d) about 2 volts.



30. Refer to dia 10. Determine the current through the 2 ohm resistor:

(a) 3.5 amp,
(b) 1 amp,
(c) 2 amp,
(d) 0.5 amp.

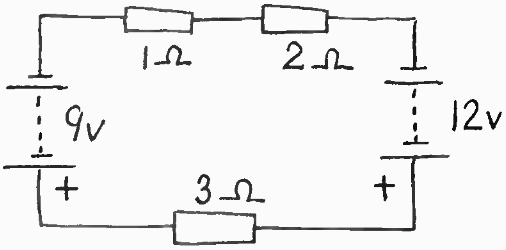


Diagram 10.

31. Two inductors are connected in series. The inductance of the circuit will:

(a) increase,
(b) decrease,
(c) remain the same,
(d) depends on the value of the inductors.

32. Maximum power will be delivered by a battery with internal resistance of 2 ohms when the resistance of the load is:

(a) high compared to the internal resistance of the battery,
(b) low compared to the internal resistance of the battery.
(c) when half the battery emf is dropped across the load,
(d) 2 ohms,
(e) when maximum current is flowing.

33. What is the purpose of the "OFF" position on an analogue multimeter?

(a) to save the battery in the multimeter,
(b) to prevent the needle swinging across the scale when it is being moved,
(c) to put a 'short' across the probes,

34. Flux density is:

(a) the number of magnetic lines per unit area,
(b) inversely proportional to permeability,
(c) the total number of lines of magnetic flux.

35. If a capacitor is tested with a multimeter set to 'high ohms' and the needle deflects towards zero and returns towards 'infinity,' the test shows the capacitor is:

(a) good,
(b) open,
(c) shorted,
(d) leaky.

36. If a magnet is passed over a wire, a current is produced. It follows that a magnet moved over the same wire at a faster rate, in the opposite direction, will produce:

(a) a higher current in the opposite direction,
(b) no current,
(c) the same current in the opposite direction,
(d) a higher current in the same direction.

37. Two identical 30VA transformers are connected back to back as shown in diagram 11. If we assume they are ideal transformers, the output voltage will be:

(a) unknown,
(b) 240v DC,
(c) 240v AC,
(d) this arrangement cannot be done.

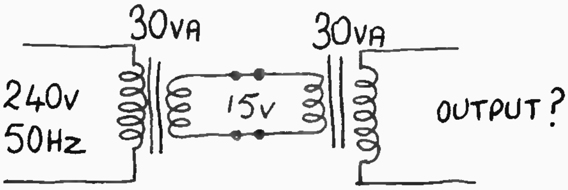


Diagram 11.

38. The value printed on a capacitor is 393. Its value in nanofarads is:

(a) 3n9,
(b) 39n,
(c) 33n,
(d) 3n3

39. Three capacitors are connected in parallel. Their values are 100n, 105, and 102. Determine their total capacitance.

(a) 1.101uF,
(b) 1.11uF,
(c) 1.011uF,
(d) 2.11uF.

40. The leakage current in a capacitor is due to:

(a) external components in a circuit,
(b) the resistance of the dielectric,
(c) the shelf life,
(d) the type of foil used for the plates.

41. Refer to dia 12. Determine the value of total capacitance:

(a) 46.7uF,
(b) 9uF,
(c) 32uF,
(d) 28uF.

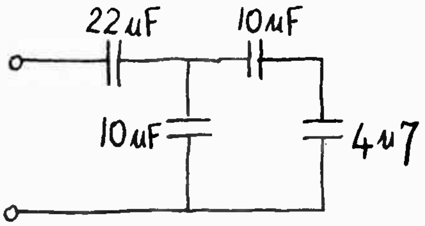


Diagram 12

42. The reactance of a 100uF capacitor at 50Hz is:

(a) .032 ohms,
(b) 3.2 ohms,
(c) 32 ohms,
(d) 320 ohms.

43. Refer to dia 13. Determine the impedance of the circuit:

(a) 16 ohms,
(b) 84 ohms,
(c) 116 ohms,
(d) 101.3 ohms.

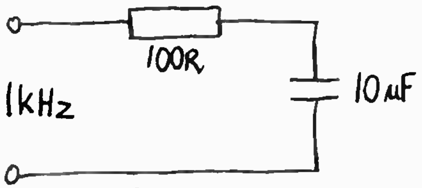


Diagram 13.

44. How many 1pF capacitors are needed to make 1uF?

(a) 100,000
(b) 10^6
(c) 10,000
(d) 10,000,000

45. Refer to diagram 14. Determine the supply voltage E.

(a) 70v AC,
(b) 110v AC,
(c) 50v AC,
(d) 14.7v AC.

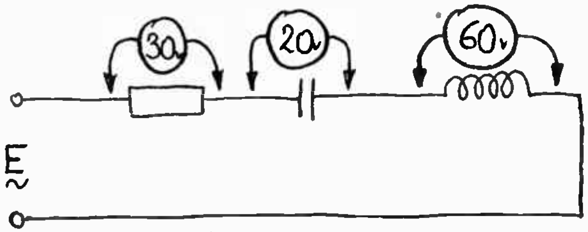


Diagram 14.

46. Refer to diagram 15. Determine the value of current I:

(a) 30mA,
(b) 14.1mA,
(c) 20mA,
(d) 10mA.

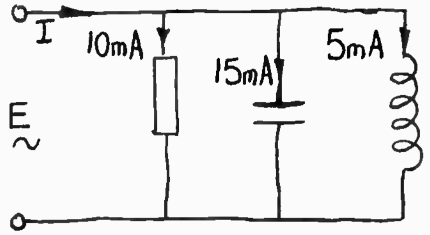


Diagram 15

47. Two 100uF/25v electrolytics are connected in parallel. The resulting capacitance of the combination is:

(a) 200uF/50v,
(b) 100uF/50v,
(c) 200uF/25v,
(d) 50uF/50v.

48. Removing the iron core from an inductor will:

(a) reduce the inductance,
(b) increase the voltage across the coil,
(c) reduce the current flow,
(d) change the circuit characteristics.

PART B

Short answer section.

49. What is the combined value of these five resistors connected in series: 2M2, 220k, 4k7, 470R, 3R3.

1 mark

50. Describe what you know about the minimum voltage and current that will kill you.

3 marks

51. Describe how to wire up a 3-pin plug.

3 marks

52. Why is a radiator and toaster earthed but an electric drill is not.

1 mark.

53. What will happen if a radiator is connected to an extension lead that has the earth and active leads reversed?

2 marks.

UP TO NOW EVERY BEC EXAM HAS HAD A NUMBER OF POOR QUESTIONS, QUESTIONS WITHOUT AN ANSWER & QUESTIONS WITH TWO OR MORE ANSWERS. MAKE SURE YOU ARE TOLD ABOUT THESE BEFORE COMMENCING.

THE MARKING WILL BE ADJUSTED ACCORDINGLY SO DON'T WORRY ABOUT LOSING A MARK. HOPEFULLY THE SLANT & BIAS OF THE QUESTIONS WILL IMPROVE IN THE FUTURE & FOLLOW SOMEWHAT ALONG THE LINES OF THIS PAPER.

DON'T BE TRAPPED INTO PROVIDING ANSWERS BEYOND THE ACCURACY OF THE QUESTION. FOR INSTANCE: A REACTANCE VALUE OF 39·38 OHMS FOR A 20µF CAPACITOR MUST BE WRITTEN AS 39 OHMS AS THE QUESTION IS ACCURATE TO WHOLE NUMBERS ONLY. APART FROM THIS, CAPACITORS HAVE A TOLERANCE OF ±10%, ±20% AND EVEN ±50%!

THE APPORTIONMENT OF MARKS SHOULD BE AS FOLLOWS:

1ST EXAM — 15% TOWARDS FINAL MARK.
1ST PRAC — 5% " " "
2ND EXAM — 25% " " "
2ND PRAC — 5% OR 10% " " "
3rd EXAM — 35% " " "
3rd PRAC — 10% OR 15% " " "

So far the marks are 33%, 33%, 33%.

LET'S HOPE THE EXAMINERS SEE IT THIS WAY.

ANSWERS — ELECTRICAL PRINCIPLES:

1 (b) Decrease. THE RESISTANCE WILL DECREASE DRAMATICALLY. THE REASON IS LESS TURNS OF THE THICKER WIRE WILL FIT ON THE BOBBIN & THE RESISTANCE OF THE WIRE WILL BE LESS.

2 (a) & (b) YES & NO! THIS IS A TRICK QUESTION. 22 B&S ENAMELLED WIRE HAS THE SAME RESISTANCE/METRE AS TINNED COPPER WIRE, BUT IF YOU USE TINNED COPPER WIRE, THE TURNS WILL SHORT TOGETHER & THE RESISTANCE OF THE WINDING WILL ONLY BE A FRACTION OF AN OHM!

3. (d)

4. (d)

5. (c)

6. (c)

7 (c) THERE SHOULD BE NO VOLTAGE BETWEEN NEUTRAL & EARTH.

8. (b) RESISTOR SIZE IS MAINLY DETERMINED BY ITS TEMPERATURE OF OPERATION. FOR EXAMPLE A SMALL ½ WATT RESISTOR IS DESIGNED TO RISE TO 70°C WHEREAS A LARGE ½ WATT RESISTOR WILL RISE TO ABOUT 50°C.

9 (c) POWER = I^2R (SPOKEN AS "$\overset{I}{\text{EYE}}$ SQUARED 'R' LOSSES)

$$I^2 = \frac{P}{R} = \frac{10}{10^4}$$

$$I = \sqrt{\frac{10}{10^4}} = \frac{\sqrt{10}}{10^2} = \frac{3\cdot3}{10^2} = \cdot033 \text{ Amp} = 33\text{mA}.$$

10 (d) THESE VALUES ARE CALLED THE 'SENSITIVITY' VALUES & THE HIGHER THE OHMS/VOLT VALUE, THE LESS CURRENT A MULTIMETER TAKES FROM A CIRCUIT TO DRIVE THE MOVEMENT. AFTER ALL, THE ENERGY TO DEFLECT THE NEEDLE COMES FROM THE CIRCUIT!

11. (a)

12. CONNECTING A COILED EXTENSION LEAD TO A RADIATOR OF WILL CAUSE THE LEAD TO HEAT UP DUE TO THE I^2R LOSSES IN THE LEAD. (THIS IS DUE TO THE RESISTANCE OF THE LEAD). THE LEAD MAY GET TOO HOT.

13. (b) Ni-CHROME WIRE IS USED IN RADIATOR & ALL TYPES OF HEATING ELEMENTS. THE 6Ω RESISTANCE WILL BE DUE TO THE Ni-CHROME WIRE. THUS THE Ni-CHROME WIRE WILL GET HOT. THE RESISTANCE OF THE COPPER WIRE IS VERY SMALL & WILL NOT HEAT UP.

14 (b)

15. (d)

16 (d) THIS IS AN IMPORTANT FACT TO REMEMBER.

17. (b) WORK OUT THE VALUE OF THE TWO 22K RESISTORS IN PARALLEL (11K) AND ADD 47K + 11K = 58K.

18. (d) IT DEPENDS ON THE WATTAGE BEING DISSIPATED IN EACH RESISTOR. SINCE THEY ARE IN SERIES, THE CURRENT THROUGH EACH WILL BE THE SAME & THUS THE ONLY OTHER VARIABLE IN THE FOLLOWING EQUATION IS 'R'.

$$P = I^2R.$$

FOR EXAMPLE: IF THE LOSSES IN THE ½ WATT RESISTOR ARE GREATER THAN ½ WATT AND THE LOSSES IN THE ¼ WATT RESISTOR ARE LESS THAN ¼ WATT, THEN THE ½ WATT RESISTOR WILL BURN OUT FIRST.

19 (c) TRY IT YOURSELF.

20. (b) WORK OUT THE CURRENT REQUIRED TO FULLY LOAD THE ½ WATT RESISTOR AND SEE WHAT WATTAGE IS BEING DISSIPATED BY THE 2 WATT RESISTOR.

$$P = I^2R \qquad I^2 = \frac{P}{R} = \frac{1/2}{4} \quad \therefore \quad I = \sqrt{\frac{1}{8}} \text{ AMP.}$$

POWER LOST IN 8R $= \left(\sqrt{\frac{1}{8}}\right)^2 \times 8 = \frac{1}{8} \times 8 = 1$ WATT.

THUS THE ½ WATT RESISTOR WILL BURN OUT FIRST.

21 (b) LET V BE THE VOLTAGE ACROSS THE 20R AND 40R COMBINATION.
FOR THE 20R RESISTOR $V = I_1 \times 20$.
" " 40R " $V = I_2 \times 40$.
V IS THE SAME FOR BOTH & THUS $20I_1 = 40I_2$.
$I_1 = 2I_2$.

NOW $I_1 + I_2 = 120$(mA)
SUBSTITUTING: $(2I_2) + I_2 = 120$.
$3I_2 = 120$
$I_2 = 40\text{mA}$.
& $I_1 = 120 - 40 = 80\text{mA}$.

22. (a) ALWAYS TRUE. IT MAY BE NECESSARY TO HAVE A HIGH WATTAGE RESISTOR IN A CIRCUIT BUT THE FACT STILL REMAINS — ANY HEAT LOST IS WASTED ENERGY.

23. (b)
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}.$$
$$\Rightarrow \frac{1}{R_3} = \frac{1}{R_T} - \frac{1}{R_1} - \frac{1}{R_2}.$$
$$= \cdot 76 - \cdot 45 - \cdot 21.$$
$$= \cdot 76 - \cdot 66 = 0{\cdot}1$$
$$\Rightarrow R_3 = \frac{1}{0{\cdot}1}$$
$$= 10\text{k}.$$

24. (c) TRY IT.

25. (b) SIMPLY ADD THE READINGS ON THE VOLTMETERS.

26. (c) $I_3 + 8 + 10 = 25$
$\Rightarrow I_3 = 7\text{mA}$.

27 (c) LET V BE THE VOLTAGE ACROSS THE COMBINATION.
$V = I_1R_1 \quad V = I_2R_2$
V IS THE SAME FOR EACH.
$I_1R_1 = I_2R_2$
$10\text{mA} \times 10\text{K} = 8\text{mA} \times R_2$.
$$\Rightarrow R_2 = \frac{10 \times 10{,}000}{8} = 12{\cdot}5\text{K}.$$

28. (c) $P = \frac{V^2}{R}$ IF 'V' CHANGES FROM 'V' TO 2V, THE EQUATION BECOMES $\frac{(2v)^2}{R} = \frac{4V^2}{R}$. TAKE AN EXAMPLE OF 5v CHANGING TO 10v. $5^2 = 25$; $10^2 = 100$. $\underline{100} : 25 = 4:1$!!

29.(b) THIS IS A BRIDGE CIRCUIT IN WHICH EACH ARM IS IDENTICAL. THE VOLTAGE AT POINT C, WITH RESPECT TO POINTS A AND B, IS 10V. THE VOLTAGE AT POINT D, WITH RESPECT TO POINTS A AND B, IS 10V. THUS C AND D ARE AT THE SAME POTENTIAL AND THIS MEANS A VOLTMETER CONNECTED BETWEEN POINTS C AND D WILL SHOW A ZERO READING.

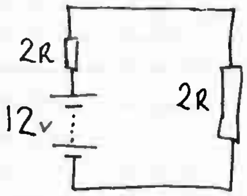
30.(d) THE TWO BATTERIES ARE OPPOSING EACH OTHER. 12V − 9V = 3V FLOWING IN A CLOCKWISE DIRECTION AROUND THE CIRCUIT. TOTAL RESISTANCE OF THE CIRCUIT IS: 1 + 2 + 3 = 6R.

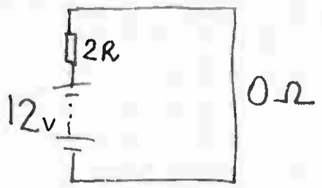
$V = IR$ $\quad 3 = I \times 6 \quad \Rightarrow I = \cdot 5$ AMP

31.(b) ALSO (d) WHEN TWO INDUCTORS ARE CONNECTED IN SERIES, THE VALUE OF THE ARRANGEMENT IS ALWAYS LESS THAN EITHER OF THE VALUES.

32 (c) & (d) TO UNDERSTAND THIS QUESTION DRAW TWO DIAGRAMS.

ASSUME A BATTERY VOLTAGE OF 12V FOR THE DISCUSSION.





AT 2R LOAD, THE CURRENT FLOW = 3 AMP & THE VOLTAGE ACROSS THE LOAD = 6V. THUS 18 WATT IS DISSIPATED BY THE LOAD. AT MAX CURRENT FLOW THE LOAD RESISTANCE IS ZERO AND OBVIOUSLY NO WATTAGE IS BEING DISSIPATED IN THE LOAD. TRY OTHER VALUES TO PROVE A 2 Ω LOAD RESISTOR IS OPTIMUM.

33(b) 34(a) 35(a) 36(a) 37(c) 38(b) 39000pF = 39n

39(a)
100n = ·1µ
105 = 1·0µ
102 = ·001µ
1·101µ

40(b)

41 (b) DETERMINE THE VALUE OF 10µ & 4µ7 IN SERIES:

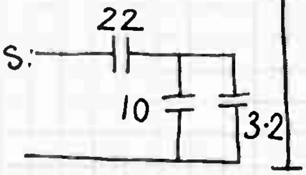
$$\frac{1}{C} = \frac{1}{10} + \frac{1}{4{\cdot}7}$$

$$= \cdot 1 + \cdot 213$$

$$= \cdot 313$$

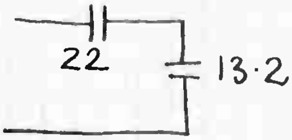
$$\Rightarrow C = 3{\cdot}2$$

THE CIRCUIT BECOMES:



ADD: 10µ & 3·2 = 13·2

THE CIRCUIT BECOMES:



DETERMINE THE VALUE OF 22µ & 13·2µ IN SERIES:

$$\frac{1}{C} = \frac{1}{22} + \frac{1}{13{\cdot}2}$$

$$= \cdot 045 + \cdot 075 = \cdot 110$$

$$\Rightarrow C = 9\mu.$$

42(c) $X_c = \frac{1}{2\pi fc}$

$$= \frac{10^6}{2 \times 3{\cdot}14 \times 50 \times 100} = \frac{10^3}{2 \times 3{\cdot}14 \times 5} = \frac{10^2}{3{\cdot}14} = 32 \text{ OHMS}$$

43(d) $X_c = \frac{1}{2\pi fc}$

$$= \frac{10^6}{2 \times 3{\cdot}14 \times 10^3 \times 10} = \frac{10^2}{2 \times 3{\cdot}14} = 16 \text{ OHMS}$$

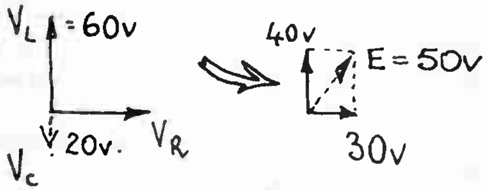
THE TOTAL IMPEDANCE OF THE CIRCUIT:

$$Z = \sqrt{R^2 + X_c^2}$$

$$= \sqrt{100^2 + 16^2} = \sqrt{10{,}256} = 101{\cdot}3 \text{ OHMS.}$$

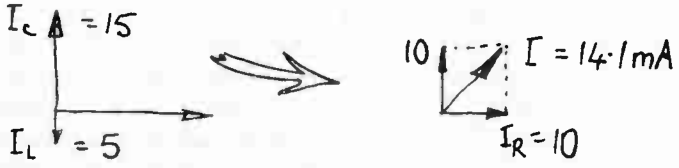
44(b)

45 (c) THE VOLTAGE ACROSS THE CAPACITOR AND THE VOLTAGE ACROSS THE INDUCTOR ARE VECTORS OF OPPOSITE SIGN AND THE RESULTANT IS OBTAINED BY SUBTRACTION. DRAW THE VECTOR DIAGRAM TO SCALE.



(THIS WILL HELP YOU GET THE CORRECT ANSWER)

46(b) THE CURRENT ‘THROUGH’ THE CAPACITOR AND THE CURRENT THROUGH THE INDUCTOR ARE VECTORS OF OPPOSITE SIGN AND RESULT IS DETERMINED BY SUBTRACTING THE SMALLER FROM THE LARGER. DRAW A VECTOR DIAGRAM TO SCALE TO ASSIST YOU.



47. (c)
48. (a) & (d)

PART B:

49 2,425,173·3 OHMS.

52. THE OUTER CASE OF THE DRILL IS PLASTIC — IT IS ‘DOUBLE INSULATED’

53. THE FRAME OF THE RADIATOR WILL BECOME ‘LIVE’ — TOUCHING THE RADIATOR & A METAL SINK (FOR EXAMPLE) WILL KILL YOU.
— THE RADIATOR WILL NOT WORK.

BASIC ELECTRONICS CERTIFICATE
(ANALOGUE ELECTRONICS)

This paper carries 60 marks. Section A: 25 x 2 mark questions. Section B: 10 marks as allocated.

1. Refer to diagram 1. Identify the following FET symbols:

(a) 1. n channel E MOSFET 2. p channel J FET
3. n channel J FET 4. p channel D MOSFET

(b) 1. p channel J FET 2. n channel E MOSFET
3. p channel D MOSFET 4. n channel J FET

(c) 1. n channel J FET 2. n channel D MOSFET
3. P channel E MOSFET 4. p channel J FET

(d) 1. n channel D MOSFET 2. p channel J FET
3. n channel J FET 4. p channel E MOSFET

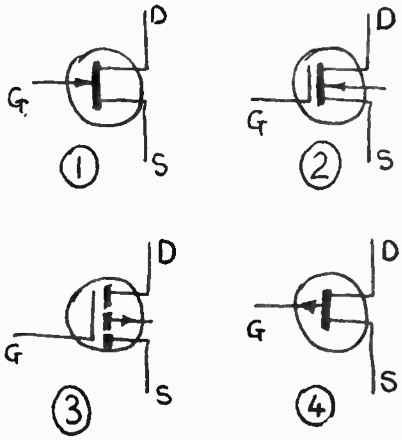


Diagram 1

2. When testing an NPN transistor with a multimeter, the readings on an ohms scale for a good device should be:

(a) base-collector high/low, collector-emitter high/low, base-emitter high/low
(b) base-collector high/low, collector-emitter high/high, base-emitter high/low
(c) base-collector high/low, collector emitter high/high, base-emitter high/high
(d) base-collector high/high, collector-emitter high/low, base-emitter high/high

3. The transistor in diagram 2 is replaced with one having a higher gain. To maintain the same operating point, the resistor R_1 must be:

(a) increased,
(b) decreased,
(c) remain the same,
(d) decreased in resistance but
increased in wattage rating.

4. An emitter resistor added to the circuit in diagram 2 will:

(a) increase the gain of the stage,
(b) decrease the gain of the stage,
(c) improve the low frequency response,
(d) convert the stage to an emitter follower.

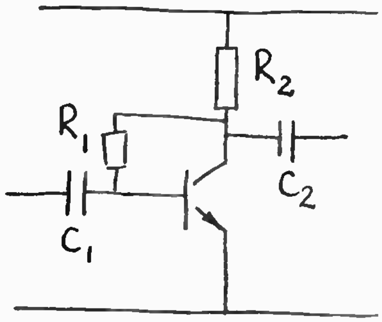


Diagram 2.

5. A 1,000uF / 25v electrolytic is always larger than a 1,000uF / 16v type:

(a) true,
(b) false.

6. Refer to diagram 3. The purpose of the bypass capacitor is to:

(a) connect one stage to the next,
(b) create a common emitter stage,
(c) separate one stage from the next,
(d) increase the stage gain.

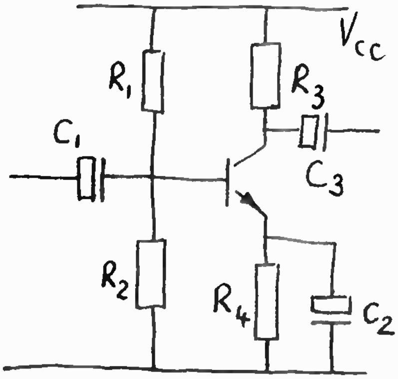


Diagram 3

7. Increasing the value of the bypass capacitor will:

(a) improve low frequency response,
(b) change the DC operating current,
(c) change the quiescent current,
(d) have no effect.

8. Refer to diagram 3. Under fault conditions $V_c = V_{cc}$. The most probable cause could be:

(a) C_2 open
(b) short circuit between base and negative rail,
(c) R_3 open,
(d) C_2 shorted.

9. Refer to diagram 3. Given V_{cc} = 12v, typical quiescent values for a correctly operating stage could be:

	V_b	V_c	V_e
(a)	2.7v	7v	.6v
(b)	2.7v	7v	2v
(c)	2v	7v	2v
(d)	2v	7v	.6v

10. Refer to diagram 4. The arrangement in diagram 4:

(a) will not work,
(b) is a voltage amplifier,
(c) is an emitter follower,
(d) is a common emitter amplifier

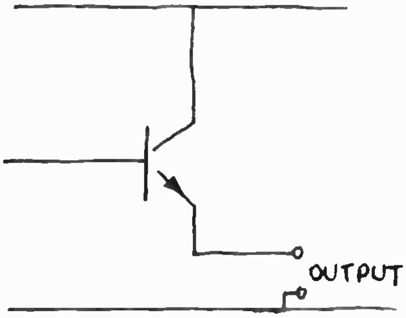


Diagram 4.

11. The approximate value of a dropper resistor for a LED operating on a 12v DC supply is:

(a) 47R
(b) 560R
(c) 4k7,
(d) 22k.

12. Refer to diagram 5.

(a) the circuit will not work because pin 7 is not connected.
(b) the circuit will work because pin 3 is always out-of-phase with pin 2.

(you can refer to
data sheets if required)

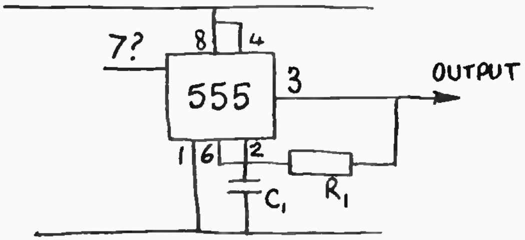


Diagram 5

13. Refer to diagram 6. What is the approximate current through the LED:

(a) 20mA,
(b) 15mA,
(c) 0mA,
(d) cannot be determined as no dropper resistor is included.

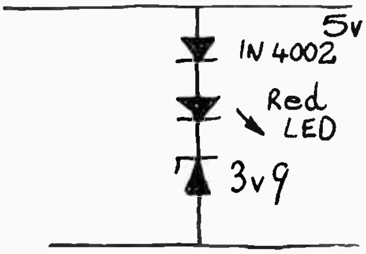


Diagram 6

14. Refer to diagram 7.. The circuit has high output ripple, possibly due to:

(a) no protection diode across the 7805,
(b) smoothing capacitor value too low.
(c) insufficient output current,
(d) insufficient input voltage.

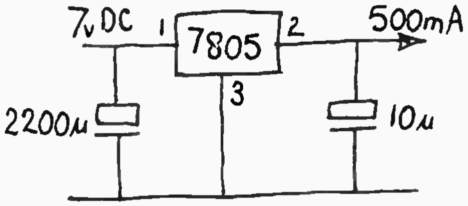


Diagram 7

15. Refer to diagram 7. If terminal 3 of the regulator goes open circuit, then:

(a) the regulator will be damaged,
(b) V_{out} will drop to zero,
(c) V_{out} will rise to nearly V_{in},
(d) V_{out} will remain constant.

16. Refer to diagram 8. In a push-pull output stage, one transistor is PNP and the other NPN.

(a) Q_5 is PNP,
(b) Q_6 is PNP.

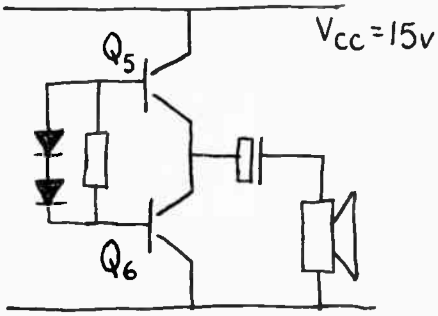


Diagram 8.

17. Refer to diagram 8. Which transistor discharges the electrolytic:

(a) Q_5,
(b) Q_6.

18. Refer to diagram 8. The purpose of the two diodes is:

(a) to provide stage separation,
(b) to reduce cross-over distortion,
(c) to provide two out-of-phase signals,
(d) to provide high quality class-A amplification.

19. Refer to diagram 9. The supply voltage and gate voltage should have the following polarities to ensure that the device will turn on:

	V_{gk}	V_{ak}
(a)	positive	positive
(b)	positive	negative
(c)	negative	positive
(d)	negative	negative

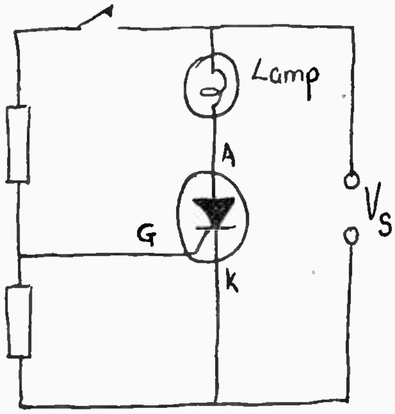


Diagram 9

20. Refer to diagram 10. When the device in diagram 10 is in the 'pinch off' region:

(a) V_{DS} is zero,
(b) V_{DS} is maximum,
(c) I_D is zero,
(d) I_D becomes constant if V_{GS} is constant.

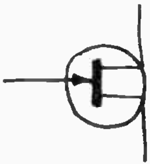


Diagram 10

21 An ideal current amplifier has the following characteristics:

	R_{in}	R_{out}	Current gain:
(a)	zero	infinite	infinite
(b)	infinite	zero	infinite
(c)	zero	infinite	zero
(d)	infinite	zero	zero

22. Refer to diagram 11. When biased to operate as a class A amplifier:

(a) V_{GS} is negative,
(b) V_{SG} is positive
(c) V_s is negative,
(d) V_{dd} is positive.

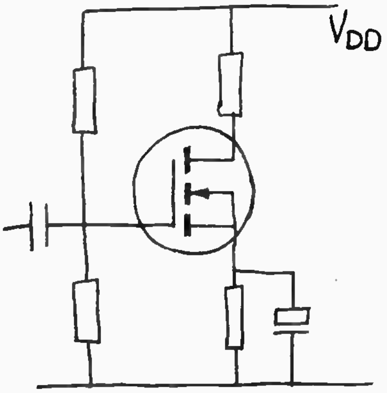


Diagram 11

23. Refer to diagram 12. The frequency of operation is usually changed by altering:

(a) R_2 and R_3,
(b) R_3 only,
(c) C_1 and R_2,
(d) C_1 and R_1.

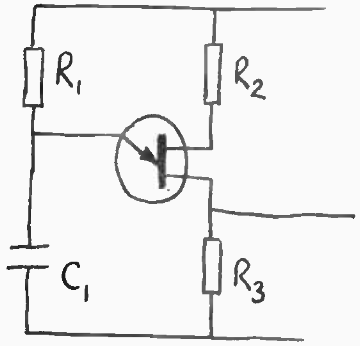


Diagram 12

24. Refer to diagram 13. If the load resistor is increased, the effect on the circuit will be:

(a) collector current of Q_1 will increase,
(b) Q_2 base voltage will decrease,
(c) Q_1 V_{CE} will increase,
(d) Q_1 base voltage will fall to 5.6v.

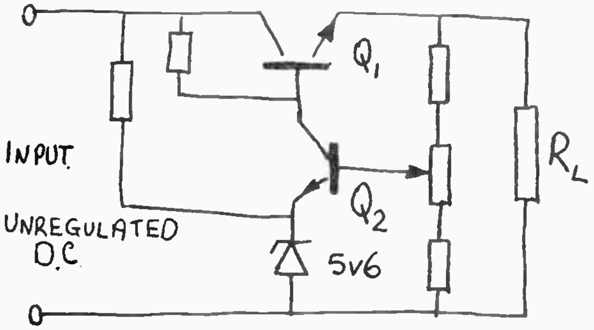


Diagram 13

25. Refer to diagram 14. If D_1 is shorted, the following will result:

(a) The output ripple frequency will increase,
(b) The circuit will operate as a half-wave rectifier,
(c) D_2 will be damaged,
(d) D_3 will be damaged.

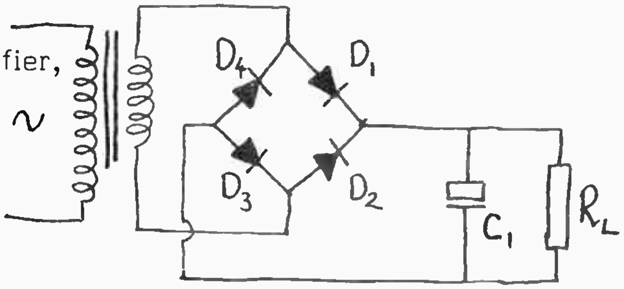


Diagram 14.

SECTION B:

Short answer section.

26. Refer to diagram 15. Given V_{BE} = .7v and $I_{R1} = 10I_B$, calculate:

(a) V_B
(b) V_{CE}
(c) A_v (voltage gain)
(d) state the effect on A_v and Zin when an emitter bypass capacitor is added.
(e) For a frequency response 100Hz to 10kHz, calculate the value of emitter bypass required for this bandwidth.

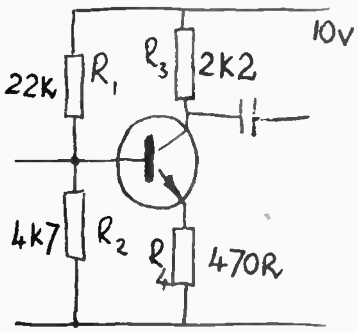


Diagram 15.

7 marks

27. Refer to diagram 15. Describe the effect on the output signal, when the input has a sinewave applied, and the following occurs:

(a) emitter shorts to negative rail,
(b) output capacitor goes short circuit,
(c) R_1 goes open circuit.

3 marks

ANSWERS ANALOGUE ELECTRONICS:

1.(c)

2.(b) WHEN TESTING EITHER PNP OR NPN TRANSISTORS, THERE ARE 6 TESTS YOU CAN MAKE WITH A MULTIMETER. 2 TESTS SHOULD BE LOW & 4 TESTS SHOULD BE HIGH. TEST SOME TRANSISTORS YOURSELF!

3(a) A HIGH GAIN TRANSISTOR NEEDS LESS CURRENT INTO THE BASE TO MAINTAIN THE SAME OPERATING POINT. TO SEE HOW THIS WORKS, ASSUME THE TRANSISTOR HAS VERY POOR GAIN & NEEDS A LOW VALUE BASE RESISTOR FOR IT TO OPERATE. —THUS A HIGH GAIN TRANSISTOR NEEDS A HIGH VALUE BASE RESISTOR.

4(b)

5(b) THE SIZE OF AN ELECTROLYTIC ALSO DEPENDS ON THE RIPPLE CURRENT IT CAN HANDLE.

6(d) THE ELECTROLYTIC (CAPACITOR) EFFECTIVELY LOWERS THE VALUE OF THE EMITTER RESISTOR & INCREASES THE GAIN OF THE STAGE AS FAR AS AC SIGNALS ARE CONCERNED.

7(a)

8(b) THE TRANSISTOR WILL BE TURNED OFF & THE COLLECTOR VOLTAGE WILL RISE TO NEARLY RAIL VOLTAGE.

9(b) THE BASE-EMITTER VOLTAGE MUST BE ABOUT ·7v.

10(c)

11(b) THE LED CURRENT SHOULD BE ABOUT 20mA MAX.

12(b)

13(c) THE COMBINED VOLTAGE DROP ACROSS THE DIODES IS MORE THAN 5v!

14(d) A 7805 NEEDS AT LEAST 3v ACROSS IT TO ACHIEVE REGULATION.

15(c)

16(b)

17(b)

18(b) THE TWO DIODES BIAS THE TRANSISTORS TO A POINT WHERE THEY ARE NEARLY STARTING TO TURN ON.

19(a)

20(C)

21(b)

22(d)

23(d) THE R,/C, COMBINATION FORMS A 'TIME-CONSTANT' ARRANGEMENT.

24(c) THIS IS A TRICKY QUESTION. WHEN THE LOAD CURRENT IS REDUCED, THE UNREGULATED INPUT VOLTAGE WILL INCREASE BY A GREATER VALUE THAN THE OUTPUT VOLTAGE. HENCE V_{CE} WILL INCREASE!

25(c) THIS IS GENERALLY WHAT HAPPENS WHEN A BRIDGE RECTIFIER FAILS. ONE DIODE TAKES THE OTHER, AS SHOWN IN THIS QUESTION.

SECTION B

26(a) THE VOLTAGE ON THE BASE IS DETERMINED BY THE VOLTAGE DIVIDER 22K/4K7 COMBINATION.

$$V_B = \frac{10}{22k+4k7} \times 4k7 = 1{\cdot}76v$$

(b) V_{CE}. THE VOLTAGE BETWEEN THE COLLECTOR & EMITTER IS DETERMINED AS FOLLOWS:
FIRSTLY WE WILL ASSUME THE EMITTER VOLTAGE WILL BE ·7v LESS THAN THE BASE. THEREFORE EMITTER VOLTAGE = 1·06v
SINCE THIS WHOLE ANSWER IS APPROX. WE CAN TAKE THE EMITTER VOLTAGE TO BE 1V.
FROM THIS WE CAN WORK OUT THE CURRENT FLOW IN THE 470R RESISTOR.

$$I = \frac{V}{R} = \frac{1}{470} \text{ AMP.}$$

WE FURTHER ASSUME THE CURRENT IN THE COLLECTOR CIRCUIT IS THE SAME AS THE EMITTER CIRCUIT.
THEREFORE THE VOLTAGE ACROSS THE 2K2 RESISTOR IS:

$$V = IR = \frac{1}{470} \times 2K2 = 4{\cdot}68v.$$

THE VOLTAGE ON THE COLLECTOR = 10 − 4·68v = 5·32v.
THEREFORE THE VOLTAGE BETWEEN COLLECTOR−EMITTER = 5·32v − 1v
= 4·32v.

(c) $A_V = \frac{2K2}{470R} = 4{\cdot}7$

(d) Av RISES. Z_{in} REDUCES.

(e) THE VALUE OF BYPASS IS CALCULATED FOR THE LOWEST FREQUENCY. AT 100Hz THE CAPACITIVE REACTANCE OF THE BYPASS CAPACITOR SHOULD BE 1/10TH OF R_4 ie. 470/10 = 47R.

$$X_c = \frac{1}{2\pi fc} = \frac{10^6}{2\pi \times 100 \times C} = 47 \qquad C = \frac{10^4}{2\pi \times 47} = 33{\cdot}8$$

THEREFORE CAPACITOR SHOULD BE 47µ OR HIGHER.

27. (a) THE TRANSISTOR WILL BE BIASED INTO SATURATION DUE TO THE R_1/R_2 NETWORK & NO OUTPUT SIGNAL WILL RESULT.
(b) DEPENDING ON WHERE THE OUTPUT CAPACITOR IS CONNECTED, THE SIGNAL MAY OR MAY NOT BECOME DISTORTED.
(c) THE TRANSISTOR WILL BE 'CUT OFF'. IT WILL LOSE ITS BIAS & THE SIGNAL WILL REDUCE (POSSIBLY TO ZERO).

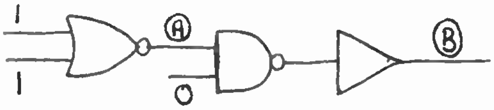
BASIC ELECTRONICS CERTIFICATE
(DIGITAL ELECTRONICS)

This paper carries 60 marks. Section A: 25 x 2 mark questions.
Section B: 10 marks as allocated.

1. Determine the operating voltage range for these three chips:

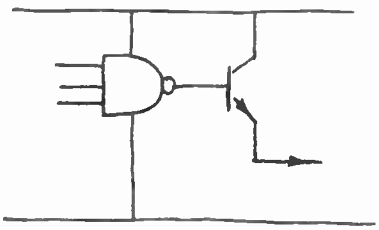
	7400	CD 4011	555
(a)	3 - 6v	3 - 15v	3 - 18v
(b)	4.5v - 5.5v	3 - 25v	12 - 15v
(c)	4.5v - 5.5v	3 - 15v	4 - 18v
(d)	3 - 15v	3 - 5v	3 - 15v

2. Determine the state of the output at A and at B.



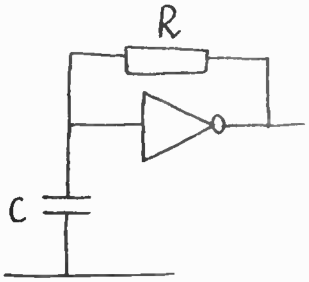
	A	B
(a)	0	0
(b)	1	0
(c)	1	1
(d)	0	1

3. Determine the correct comment:



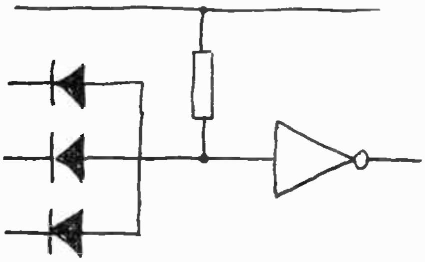
(a) The circuit needs a resistor in the base line.
(b) The transistor acts as a buffer.
(c) The transistor acts as an inverter.
(d) The transistor should be a PNP type.

4. The gate must be:



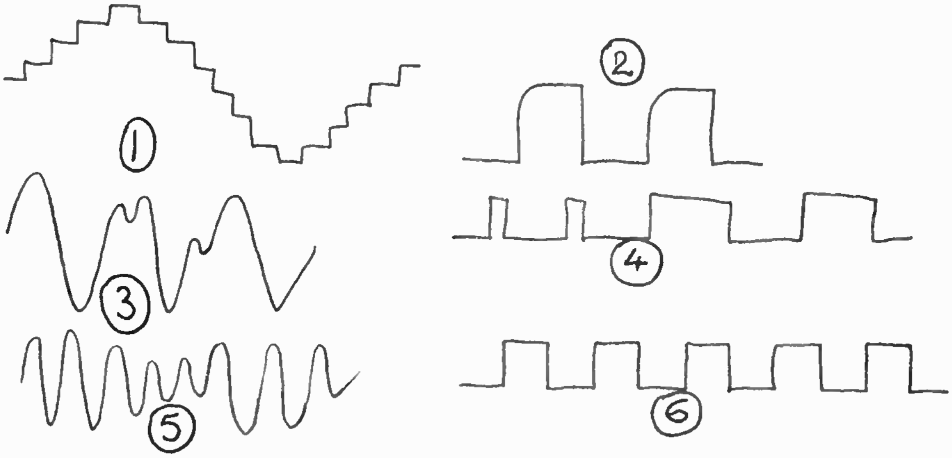
(a) a buffer,
(b) a Schmitt Trigger,
(c) an op amp,
(d) an open collector buffer.

5. Select the correct description for the diode gate (positive logic):



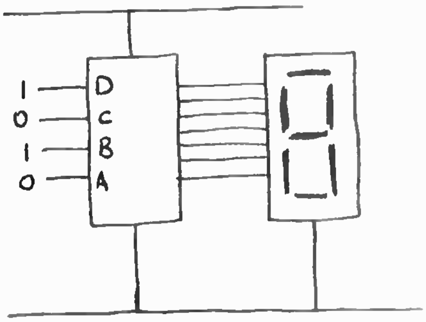
(a) diode OR gate,
(b) diode AND gate,
(c) diode buffer,
(d) the diode gate will not work.

6. Select the digital waveforms:



(a) 6 only,
(b) 1, 2, 4, and 6,
(c) 6 and 4 only,
(d) 2, 4 and 6 only.

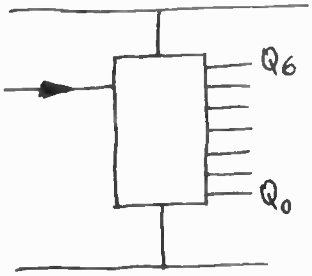
7. What digit is displayed on the 7-segment display:



(a) 6
(b) 5
(c) A
(d) C

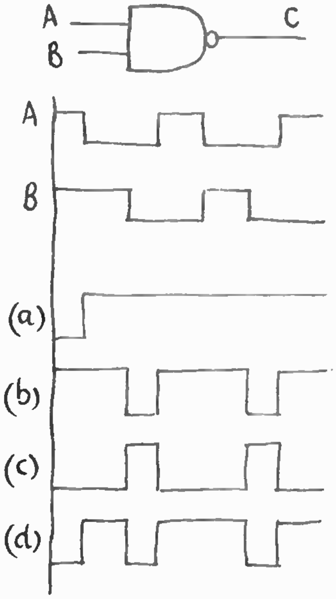
8. The device is a 7-stage binary counter/divider. What is the state of each output after 64 counts:

Assume the device is initially reset.

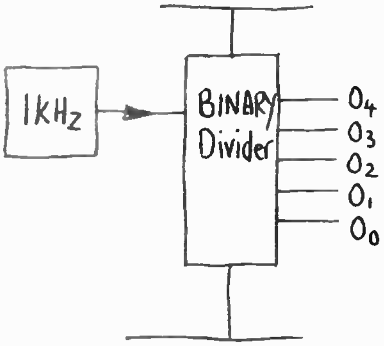


(a) All zero,
(b) only Q6 high,
(c) only Q5 high,
(d) all high.

9. Two signals, A and B are gated via the device in the diagram. Determine the output waveform:

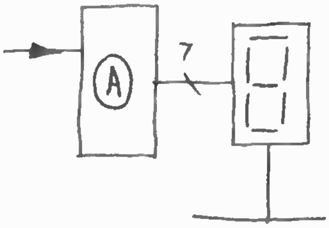


10. What is the frequency of O_4:



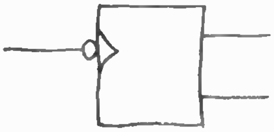
(a) 31.25Hz,
(b) 1kHz,
(c) 62.5Hz,
(c) 125Hz.

11. Device A is a Hex decoder/divider (counter). What digit will be displayed on the 7-segment display after 14_H cycles: (counter starts from zero)



(a) E
(b) 4
(c) 1
(d) Unknown

12. The input line in the diagram is:

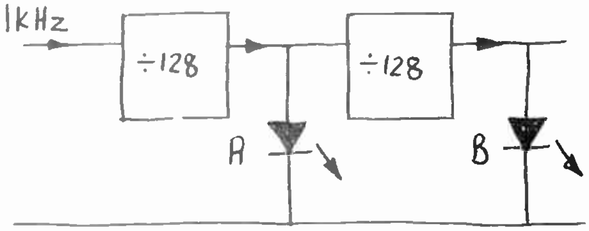


(a) active low, pulse triggered,
(b) negative level. triggered,
(c) negative edge triggered,
(d) active low, delayed.

13. Select the best description for COMBINATIONAL LOGIC, as compared to SEQUENTIAL LOGIC.

(a) distinguished by the output changing immediately,
(b) distinguished by the output being delayed.

14. The diagram below was constructed and LED B did not change state. The most probable cause is:

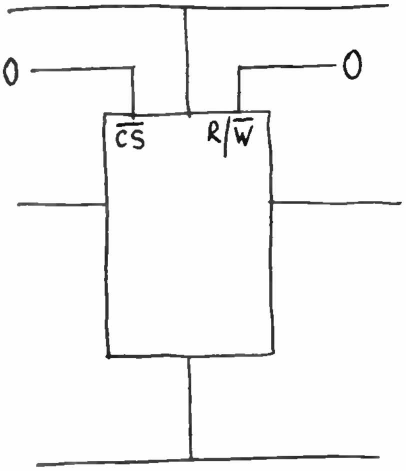


(a) Input signal frequency too low,
(b) LED B loading the output,
(c) LED A loading the data line,
(d) Dividers cannot be connected directly together.

15. In a simple microprocessor system, temporary data is stored in:

(a) the ROM only,
(b) the RAM only,
(c) the RAM and CPU registers,
(d) the EPROM.

16. The state of the RAM chip in the diagram is:

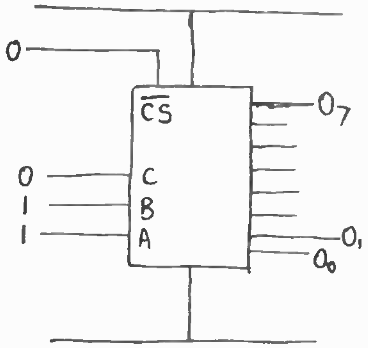


(a) not selected, in READ mode,
(b) not selected, in WRITE mode,
(c) selected, in READ mode,
(d) selected, in WRITE mode.

17. The accumulator in a microprocessor:

(a) holds the location of the present instruction,
(b) holds data for manipulation and transfer,
(c) keeps count of the number of instructions processed,
(d) increments the program counter.

18. For the 1 of 8 decoder chip A, which device(s) are activated:



(a) 0_1 & 0_2,
(b) 0_3 only,
(c) 0_2 & 0_4,
(d) 0_6 only.

19. An assembler is a program that:

(a) converts mnemonics into high level language,
(b) converts machine code into mnemonics,
(c) converts machine code into high level language,
(d) converts mnemonics into machine code.

20. $1A_H$ is added to $2B_H$ to get:

(a) $3C_H$,
(b) 45_H,
(c) 46_H,
(d) 51_H.

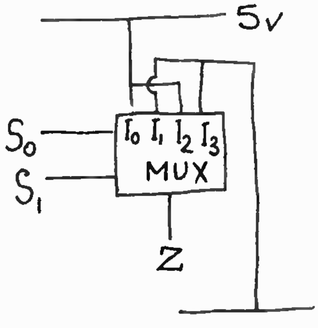
21. Convert 1100110_2 to Hex:

(a) $C6_H$,
(b) CC_H,
(c) 66_H,
(d) $C3_H$.

22. Why are some simple computers programmed in Hex in preference to binary:

(a) Hex is used by the processor itself,
(b) Hex numbers can be larger than binary,
(c) Hex is more easily recognised by humans, than binary,
(d) Hex numbers can be multiplied.

23. Select the truth table for the circuit:



S_1	S_0	Z
L	L	L
L	H	H
H	L	H
H	H	L

1.

S_1	S_0	Z
L	L	L
L	H	H
H	L	L
H	H	H

2.

S_1	S_0	Z
L	L	H
L	H	L
H	L	H
H	H	L

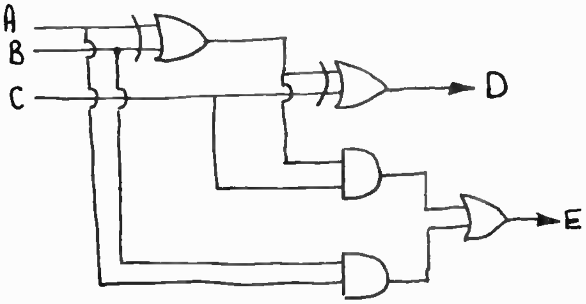
3.

S_1	S_0	Z
L	L	H
L	H	L
H	L	L
H	H	H

4.

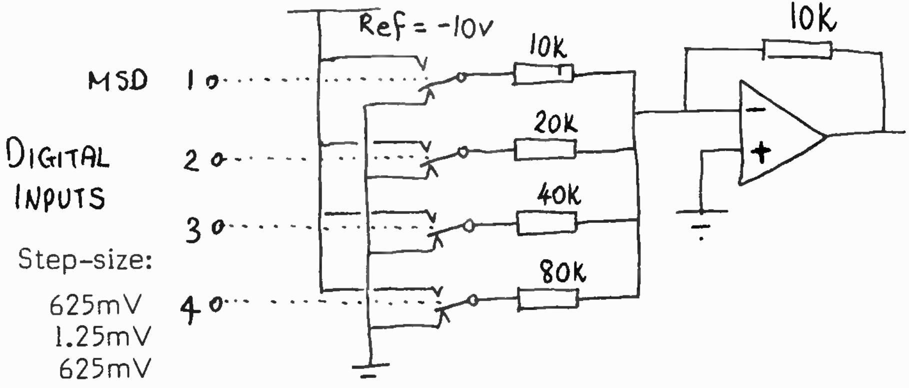
(a) 1.
(b) 2.
(c) 3.
(d) 4.

24. The circuit will carry out the logic function of a:



(a) half adder,
(b) full adder,
(c) decoder,
(d) subtracter.

25. The resolution and step size of this DAC are:

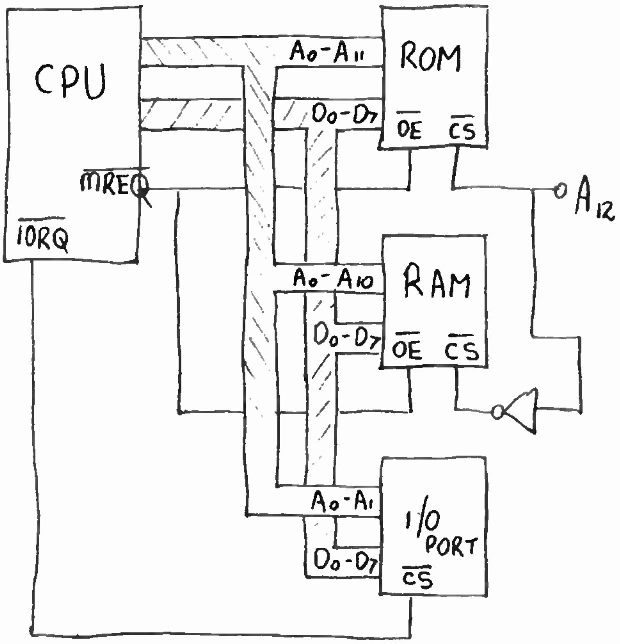


	Resolution:	Step-size:
(a)	15%	625mV
(b)	15%	1.25mV
(c)	6.25%	625mV
(d)	6.25%	1.25mV

SECTION B:

Short answer section.

26. A small microprocessor system uses the following decoding:



(a) What is the lowest address of each device.
(b) How many addressable locations in each device.

6 marks

27. (a) Referring to the system above, state the direction of the data bus and address bus for each device.

(b) What is the state of each address line, each data line and control line for the situation where 3E is placed in RAM address 142A.

4 marks

ANSWERS Digital Electronics

1. (c) 2. (d) 3. (b) 4. (b) 5. (b) 6. (d)
7. (c) 8. (b) 9. (a) 10. (a) 11. (b) 12. (c)
13. (a) 14. (c) 15. (c) 16. (d) 17. (b) 18. (b)
19. (d) 20. (b) 21. (c) 22. (c) 23. (c) 24. (b) 25. (c)

26. ROM = 0000_H RAM = 1000_H I/O PORT = 00_H

ROM = 1000_H or 4096 decimal RAM = 800_H or 2048 decimal

I/O PORT = 04_H or 4 decimal

27. (a) Address bus for all devices is unidirectional, from CPU to device. Data bus for ROM is unidirectional, from ROM to CPU. Data bus for RAM is bidirectional. Data bus for I/O port is bidirectional - from port to CPU for input and from CPU to port for output.

(b) Address bus: 1 0 1 0 0 0 0 1 0 1 0 1 0
Data bus: 0 0 1 1 1 1 1 0
$\overline{\text{MREQ}}$ is HIGH.

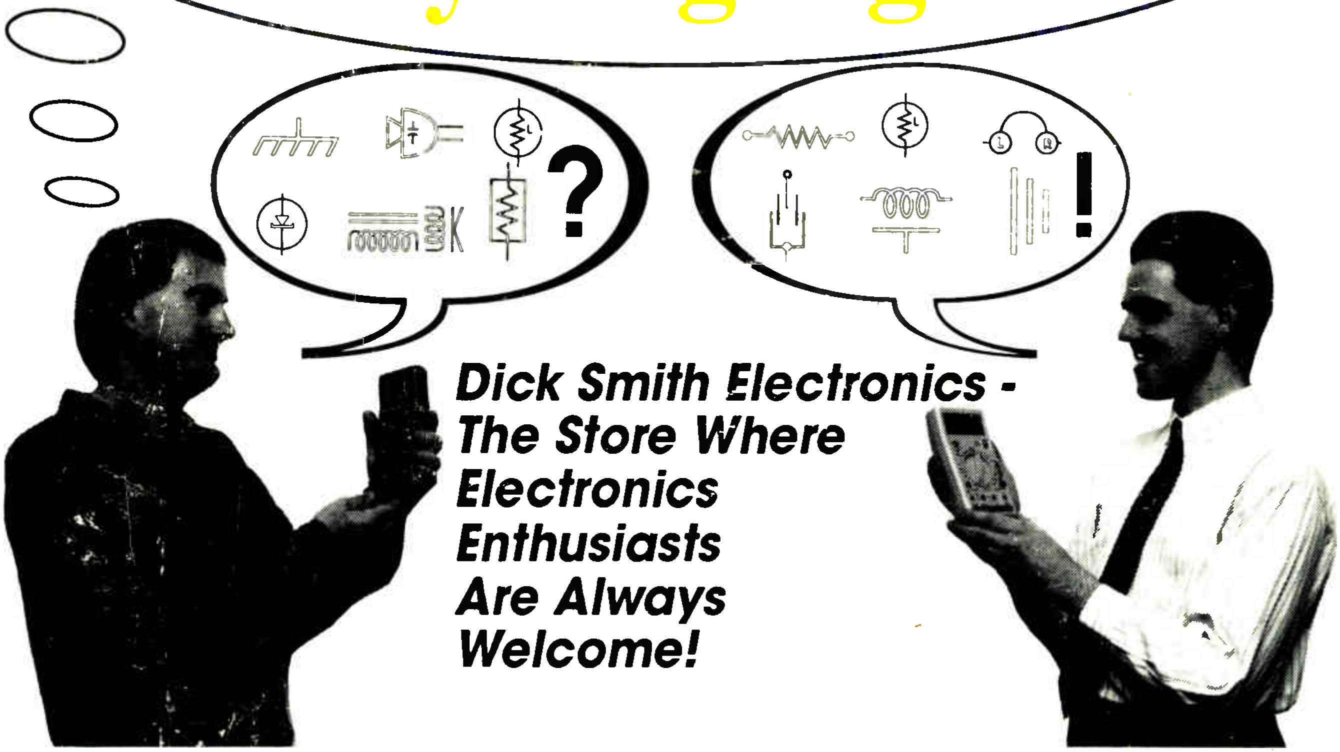
INDEX

CORRECTIONS TO NOTEBOOK 1

Page 22 & 23: The peak voltage for 230v mains is 325v. The peak for 240v mains is 340v!
Page 48: The X shift on a CRO is Horizontal Shift, not Vertical.
Page 50: The graphs show correct current increase and decay but the CRO, as connected, would read voltage. To read current, the signal must be derived across a non-inductive resistance.

A.D. Rumble, 2650.

"At Last, someone who speaks my language!"



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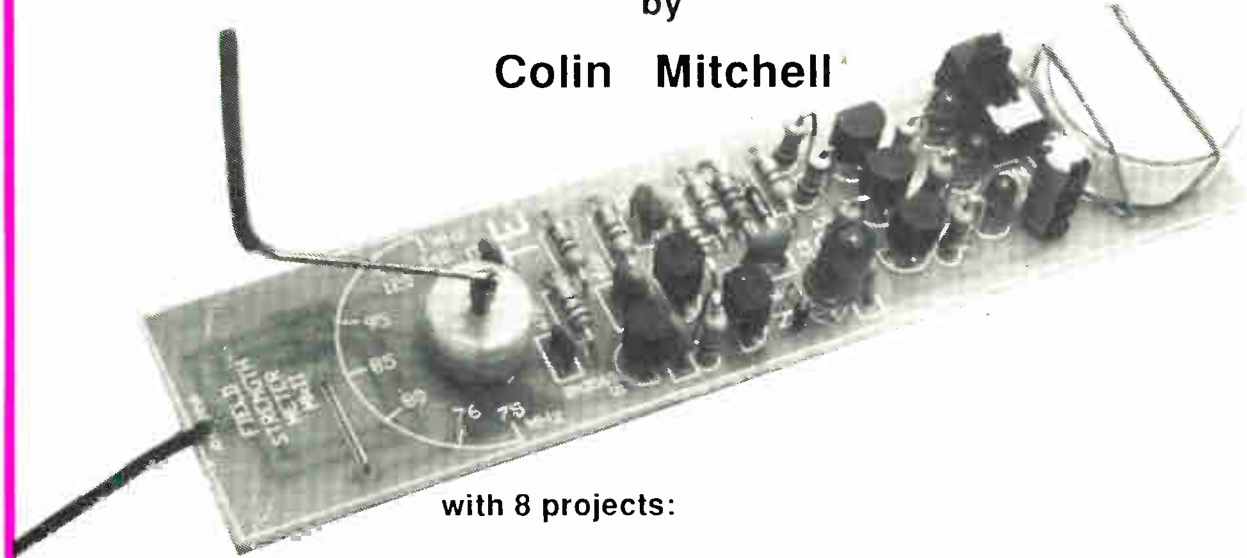
ELECTRONICS NOTEBOOK

6

by

Colin Mitchell



with 8 projects:

- → Capacitance Meter
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- → Phone Ring
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BUILD A KIT

We have added a number of projects to this Notebook to keep up your building skills. Building projects is a very big part of learning electronics. We put a lot of work into designing a project and in the process we learn a lot. We hope you learn a lot too when you put them together.

As one of my teachers said: "There are three kinds of people: Those who make things happen, those who watch things happen and those who wonder what happened!"

Make sure you are one of those who make things happen.

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(see P 11)
Parts & PC: $15.55
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Test all those capacitors before using

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Photocopy this page. Please don't cut the book!

INTRODUCTION

WHY IS IT SO?

As Professor Julius Sumner Miller so often said "Why is it so?" Why are magazines and books filled with so much padding, hype, advertisements and rubbish?

There is so much information to get across to readers in this technological age - it amazes me to see so many magazines with glossy pages of advertising and fiddly articles that don't really say anything at all.

So too with books.

You wonder how a sub-editor could pass some of the manuscripts! Quite often an entire book is nothing but drivel and regurgitated padding.

I know, I have shelves full of them. That's why they call them pulp. They're only good for pulping back into recycled paper. Many don't have a single page of valuable material.

Quite often the only thing that attracts you in the first place is the cover. Once you get the book home and look through the pages you feel like you've been duped. I've spent hundreds of dollars on these worthless dust collectors and now I'm more astute. I look through them before buying. The only reason I keep the junk ones is to stop the others falling over!

But things have now got even worse. Not only are the trashy books staying trashy, but the prices are going up. Have you seen how expensive books and magazines have become?

It seems we are locked into an ever-increasing spiral. As the cost of printing goes up, the cover price increases. This reduces sales and increases the cost of printing. So we see another increase in price.

Where it will end I don't know. Magazines that were a couple of dollars a few years ago are now twice the price and books that were less than ten dollars are now nearly thirty dollars! Some magazines from overseas are around the seven dollar mark!

I wouldn't mind paying seven dollars if the intention of the editor was to provide the reader with good articles. But the main aim is to provide a vehicle for the advertisements and allow the articles to "fill the holes."

Even some of the adverts are annoying. Some are repeated over and over again, month after month while others are so microscopically reduced in size that you need a magnifying glass to read them. How you are expected to read them, I don't know.

And what about the glossy paper. Have you ever tried to read an article under an electric light with the shine of the paper obliterating the text. It's exasperating. It's a typical example of a designer never using or testing his own product.

But the production of glossy magazines and pulp books has a broader ramification.

The natural resources consumed by them is enormous. The amount of timber required to print a run of a single book is astronomical. It's almost equal to the wood required to frame a 14 square house. If you extrapolate this into all the newspapers and books produced in a single day, you can see how many houses are being denied.

The world is consumer-oriented and advertiser driven.

I wouldn't be half as angry if it wasn't for the wastage. More than 25% of all publications are wasted. If a publication doesn't sell within an allotted time is it returned to the distributor for pulping or disposal. Most times it is sent for straight-out disposal.

Out of all the product that is sold, only a small percentage is read completely and only a tiny percentage is shared.

Take the most wasteful product ever invented. The telephone book. Not only is it 6 months out of date when you get it but the number of pages looked at by a household per year is less than ten. The other 99.9% of the book is never used!

The next biggest waster is the local paper and then the daily

CONTENTS

● PROJECT TO BUILD

All the projects in this book are available in kit form from Talking Electronics. See inside front cover for details.

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newspaper.

We have only got ourselves to blame. We laugh at Russia producing 500 copies of a newspaper and pasting them on a billboard for everyone to read. But the time is coming when we should reject the local paper, tear down our newspaper tube for junk mail, stop buying the newspaper and revert to a community attitude of reading the pages of a displayed copy.

This will not only save millions of trees but somewhat restore our global weather balance!

We at Talking Electronics have tried to regress this situation by producing books and magazines that are totally free of wasted pages and unnecessary advertising. The only problem with this is the delay between issues, as it takes a long time to produce 70 pages of concentrated information.

Anyhow we are out again with another Notebook and since all the previous issues have sold out we are convinced they are a needed resource.

In this issue we have combined theory with a number of projects so you can put your understanding into practice with construction.

You will notice we are always guiding you along the practical path in the hope you can turn your studies into a career.

We have always said that electronics is one of the most successful ventures you can enter. The world of electronics is advancing faster than any other field and you can enjoy its rewards if you follow through with at least some of the areas we are covering.

It doesn't matter if you are a designer, promoter or manufacturer of electronic devices or prefer the software side, the scope for new products is enormous.

All it takes is the capability to design the right product at the right price. In this way you can be ahead of the competition and maybe start your own business.

Julius Sumner Miller

Julius Sumner Miller is undoubtedly one of the greatest teachers of our time. Not so much for what he taught but his way of teaching. He showed that teaching and learning can be fun. He reduced the most complex mathematical concepts into simple ideas that made even me sit up and think.

It's unfortunate that he, and the Sydney School of Physics, did not get the recognition they deserve. Relegated to an early morning program on TV they had an enormous struggle to get the concept of teaching the masses Physics and Science, accepted.

If you ever get the opportunity to see an old video of Julius Sumner Miller in action you will see what I mean when I say he is one of the teachers I most admire. That's why I like his quote: "Why is it so?"

In this regard we try to help you all the way. Lots of our pages have stories and anecdotes to assist you and prevent some of the pitfalls that cripple 50% of new businesses in the first two years.

Even if you are not a whizz at electronics you may be able to excel at the marketing side. Always remember that marketing is 70% of the success of an idea.

It's no good having brilliant ideas if they aren't marketed properly. You must be able to get your idea out to the buyer quickly and cheaply.

But this needn't be an expensive exercise. In fact it must be cost-effective and means you should spend as little as possible on advertising.

Advertising is a compete waste of money. You will make absolutely nothing out of your product if you have to advertise it heavily.

This goes against everything you have been told in the past but that's because you have been fed false figures.

The only way to sell a product is to PROMOTE it. You do this by distributing leaflets and creating displays at outlets that sell your product. This will create "word of mouth" sales and a satisfied customer will tell his friends. But a dissatisfied customer will tell the world! So you have to have a quality product at a realistic price.

To prove my point, we have not spent one cent on advertising Talking Electronics in 12 years and that's the only way we can keep our prices down.

The second tip I can offer is DON'T BORROW! Never take out a loan or borrow any money at all from any loan organisation whatsoever. It's the surest way to go under.

Save up before you start your business and keep within its income. It may be slower but it's guaranteed to work in the long run.

It doesn't matter how inviting a loan may sound on paper, the fact is the lending company becomes a monkey on your back sooner than you think. It finishes up being a "ghost" worker, picking up more than you!

It's enough that credit-cards take 3% - 5% of everything you make, imagine how fast you would go under if every dollar cost you 17%! But that's what a loan costs.

And the loan companies start to dictate - ringing up at the most inconvenient time, demanding the account be pulled into line and strangling your achievements. The answer is to say NO from the start and you won't have to grovel to someone you despise.

The main secret is to keep small. The most efficient business is 3 - 4 workers! Yes, it's a fact. The most efficient business consists of only 3 or 4 workers. Once you get over 5, the return per head decreases. You need bigger premises, a secretary, sandwich boy, accountant, cleaner and the list goes on.

So, keep small but think BIG. Think of ideas that will help in the educational field, the medical field, industrial field and in fact everywhere around you. There are so many devices to be designed and improved that when they come on the market you say "why didn't I think of that!"

Be first, and think of an idea. Look around and see what YOU need. Expand the idea and see if others need it too. Then think of how many in a population of 16 million will need it. Imagine the sales potential for one billion consumers!

Remember, there's a millionaire created every 20 minutes in America. So, someone's succeeding, why can't it be you? It can, but if you are only just starting in electronics you will have to be patient. You have a lot of preliminaries to work on. I suggest you begin by building up your knowledge-base so you will be capable and able to launch a product when the time comes.

Get to it, and read as much as you can and build as many projects as possible. It's only through construction that you will really understand electronics.

TE has produced a range of more than 25 books, of which only about 10 are still available. The rest have completely sold out.

The ones to look for are the Notebook series: 1-6, bugging books such as 14 FM Bugs and Security Devices, Digital Electronics Revealed, and Smart Security Devices.

All the books contain projects and articles specifically designed to help you learn electronics and we can do nothing more than put them out at the lowest price so you can get them all.

We have already had many reports of the success of our readers and I know this will continue during these hard times. The best YOU can do is prepare yourself for the eventual demand for qualified and forward-thinking personnel. I know of three occasions where the mere mention of Talking Electronics has won the person a job and a career - don't forget to try it yourself.

This Notebook contains a lot of things I have been saving up for years and years. Many of them are so old that if I don't put them into print they will be lost forever. They have been put at the back of the book. I hope you like them.

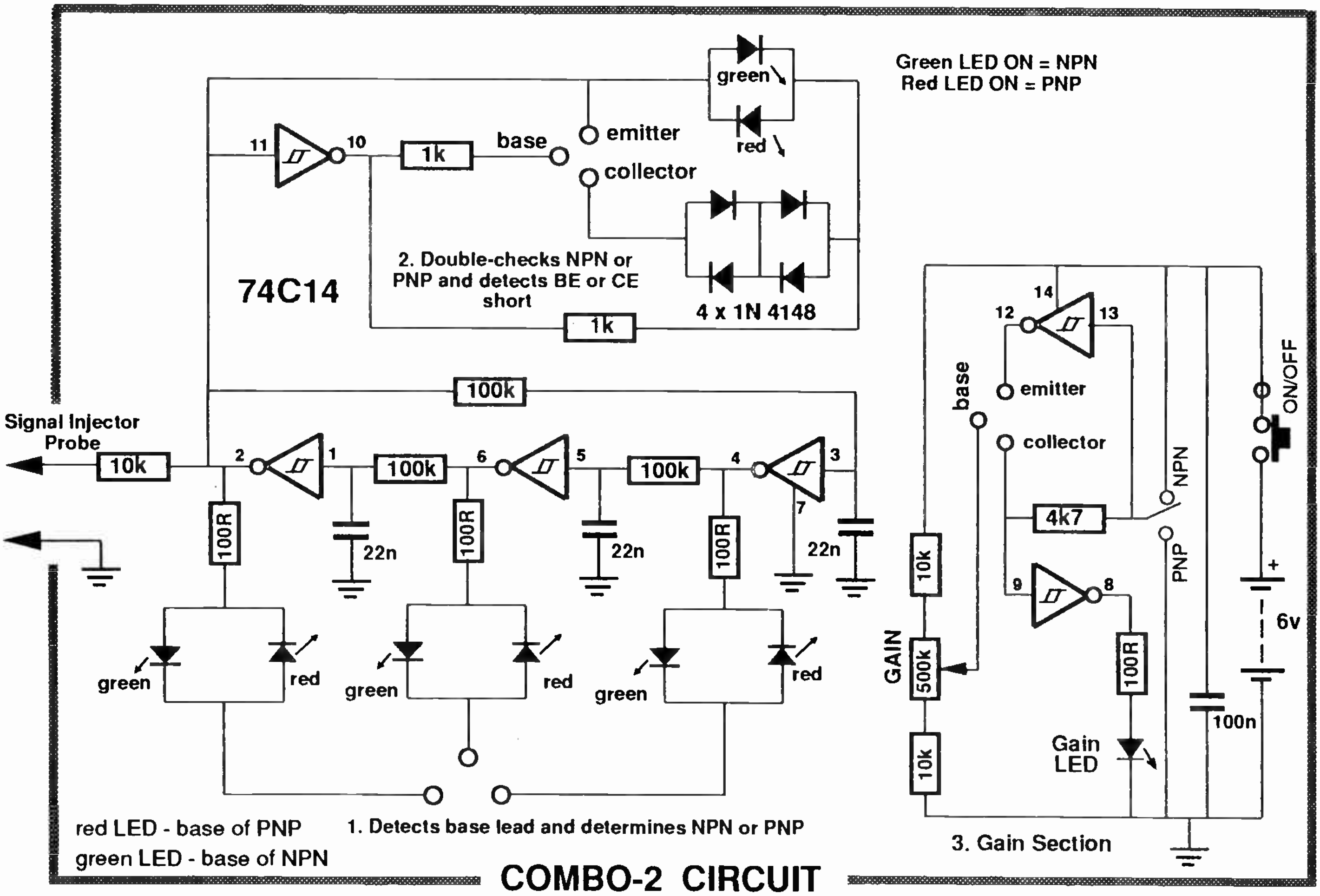
Cheers,

Colin

COMBO-2

Parts & PC: $18.00
PC board only $3.20

TRANSISTOR TESTER & SIGNAL INJECTOR



COMBO-2 CIRCUIT

There have been a lot of transistor tester circuits presented over the years in electronics magazines, but this one is different. It has more features than the others and includes a signal injector so you can test audio sections of radios and the front end of FM transmitters etc.

The major advantage with this design is its automatic operation. All you have to do is fit the three leads of the transistor to the tester in any order and the LEDs will let you know the base and if the transistor is NPN or PNP. This is section 1 at the bottom left-hand side.

The base is indicated by a single illuminated LED out of a pair.

If the LED is green, the transistor is NPN. If the LED is red, the transistor is PNP.

This saves fiddling around, swapping the leads until the base is determined. Many of the other testers do not identify any of the leads and its very frustrating if you don't know the pin-out of a transistor.

From there you go to section 2 at the top where the polarity of the transistor is further proven and a check is made to see if the transistor has a collector-emitter short or base-emitter short.

All you have to do is fit the transistor to the three leads so that the base goes to

FEATURES:

- Tests transistors - locates base lead and finds CE or BE shorts.
- Determines transistor gain
- Produces a signal for testing audio circuits

OPERATION

Use section 1 to detect the base lead and determine PNP or NPN.

Go to section 2 to determine open or shorted collector-emitter or base-emitter junction.

Go to section 3 to determine gain of transistor.

PARTS LIST

4 - 100R
2 - 1k
1 - 4k7
3 - 10k
3 - 100k
1 - 500k mini trim pot with shaft
3 - 22n ceramic
1 - 100n monoblock
4 - 1N 4148 diodes
5 - 3mm red LEDs
4 - 3mm green LEDs
1 - 74c14 Hex Schmitt trigger IC
1 - 14 pin IC socket
2 - SPDT slide switches
4 - 15cm hook-up flex
1 - black alligator clip
3 - coloured ezy clips
11 - machine pins on strip & 1 pin
1 - 2cm heatshrink to fit over socket
1 - paper clip or nail for probe
4 - AAA cells & 2cm double sided tape
1 - 10cm tinned copper wire

1 - COMBO-2 PC BOARD

the correct ezy clip and the two LEDs at section 2 will indicate if the transistor has a short in one or more of the junctions or if any are open circuit.

The transistor can then be taken to section 3 where the gain is determined.

The PNP/NPN switch is set, since you already know this fact from the previous sections.

Turn the gain knob fully clockwise then anticlockwise. If the red LED illuminates or goes out at a low gain value, the collector and emitter leads must be swapped.

You now know the pin-out for the transistor and are ready to determine the gain.

The gain is given the parameter H_{fe}. This is a value determined by measuring the base current and comparing it to the collector current.

Our tester does not provide an extremely accurate measurement as the scale is very compressed at one end but it does provide a good indication that the transistor is amplifying or if it has a low gain due to a fault.

The gain pot is rotated until the LED just goes out for a PNP transistor. The value is read from the scale around the pot.

For an NPN transistor, the reading is made when the LED just illuminates.

HOW THE CIRCUIT WORKS

The circuit consists of three sections. Section 1 is a run-of-three oscillator. Section 2 is a phase inverter and section 3 is a current gain section.

1. BASE DETECTOR

The run-of-three oscillator consists of three schmitt inverters connected in a ring with 100k and 22n components in the timing circuit.

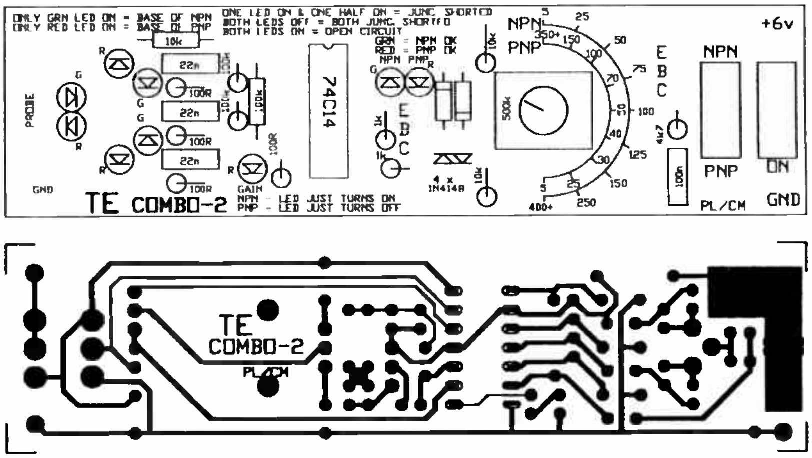
When the project is first turned on, the three 22n capacitors are not charged and the input to each inverter is LOW. This makes the outputs HIGH and causes the three 22n's to charge up at the same time via the three 100k resistors.

A race will occur and the first to charge to about 70% of rail voltage will make the input of its schmitt trigger HIGH. The output of the trigger will go LOW and the 22n on the following gate will begin to discharge via the 100k.

This LOW will cause the output of the second schmitt trigger to be HIGH and apart from charging the next 22n capacitor, it feeds into a red and green LED via a 100R resistor. We will talk about these LEDs in a moment.

When the second gate charges the 22n to 70% of rail voltage, the gate changes state and its output goes LOW.

This LOW is transferred around to the first gate where it begins to discharge the first 22n in the discussion.

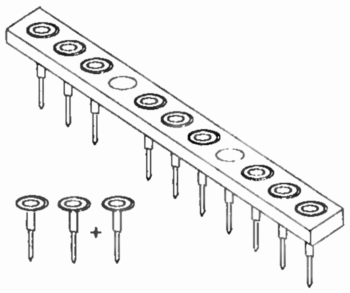


Artwork for Combo-2 Transistor Tester

The circuit runs around with one output high, then two outputs high. When an output is HIGH, a green LED is illuminated via a 100R and the current passes through a junction of a transistor placed in the set of three hollow pins. If the junction is forward biased, the current will flow through the junction and through a red LED and 100R to the negative rail. Both the green and red LEDs will turn on.

The way the circuit works is to automatically produce a voltage at every pin in turn and have each of the other two pins at zero. It then produces a voltage at TWO PINS in turn and a low at the third.

This provides all the 6 possibilities for testing the leads of a transistor and because the circuit runs around so fast, there is only one junction that will not conduct. This is the base-collector junction. You have to remember that this method of testing a transistor is not the same as testing it with a multimeter as we are "actively testing it" by suppling the base with a turn-on voltage and causing the collector-emitter junction to conduct.



The 4th and 8th hollow pins are removed from the strip and used as separate pins at the front-end of the board. The strip is then cut into 3 sections of 3 pins and the ends neatly filed.

2. THE COLLECTOR-EMITTER SECTION

This section detects shorts or open junctions between the collector-emitter leads as well as double-checking the NPN or PNP polarity of the transistor.

When an NPN transistor is fitted, only the green LED will illuminate.

The circuit is being fed a voltage that is constantly reversing. When output pin 10 of the inverter is HIGH, the NPN transistor is biased on and the voltage drop across the two lower signal diodes (1.2v) as well as the voltage across the collector-emitter junction (.3v) is too low to allow the red LED to turn ON. The green LED is presently reverse biased and does not turn on.

When the output of the Schmitt trigger goes low, the transistor is reverse biased and the green LED will illuminate.

If a PNP device is fitted, the opposite occurs and the red LED illuminates.

If a faulty device is connected, both LEDs will illuminate if the device has an open collector-emitter junction as the transistor will not be turned on during the forward part of the cycle.

If the device has a short between collector and emitter, neither LED will illuminate as only the forward voltage drop of the two diodes (1.3v) will be present and this is not enough to turn on either LED. (You need at least 1.7v).

3. THE GAIN SECTION

The gain section uses the circuit in figure 1 (in the H_{FE} article on page 9). The transistor is placed in the circuit around the correct way and the base current is adjusted via the pot until a pre-determined current flows through the 4k7 load resistor.

When this exact current flows, the voltage across the load resistor is detected by the Schmitt gate and the LED is illuminated (or extinguished) according to the polarity of the transistor.

A slide switch allows the circuit to test

THE GAIN OF A TRANSISTOR

The gain of a transistor varies enormously from one type to another and also within the same type. It also varies according to the frequency at which the transistor is operating and the circuit components surrounding it.

Putting it into a nutshell, the gain is very hard to predict as it is affected by so many factors. We will discuss some of these.

The first transistor to be invented had a very small gain and in fact it was so small the inventors were not sure if the device had a gain of not! The noise produced by the transistor was overriding the gain they were getting.

Early transistors were germanium devices. They were noisy, low gain, and with characteristics that depended on the temperature of the day! They were extremely temperature sensitive, so much so that early transistor radios could not be left in the sun without the sound distorting!

As transistors were improved, their whole structure changed.

One of the first things to change was the material from which they were made. It changed from germanium to silicon. With this came higher voltage capability, higher current and temperature of operation, better stability and higher gain values.

Let me qualify this.

The gain of a transistor (in the category in which it is placed), is very high or at least sufficient for the intended application.

For any transistor, there is a connection between gain and current handling capability. In most cases it is not possible to produce a transistor with high gain AND high current handing ability.

That's why small signal transistors have a high gain and power transistors have a low gain.

When designing a circuit you have to take this into account. All the amplification (voltage amplification) must be done in the early stages of the circuit so that the current amplification can be achieved in the final stages.

To overcome the problem of high-power, low-gain; manufacturers have introduced a special type of transistor called a Darlington. It combines two transistors in the one package so that very high amplification can be achieved as well as high current handing.

But Darlington transistors form a very small portion of the overall transistors types. The most common types are low current, medium current and high current varieties. These are available in both PNP and NPN. Each of these groups can be divided further into low frequency and high frequency.

Let's stop there before we get too involved with groupings.

CURRENT GAIN

The main element of this discussion is the gain of a transistor.

There are 4 different current gains. These are:

1. The DC current gain (as measured by the Combo-2 tester),
2. The AC current gain when the transistor is operating as an oscillator in a test circuit,
3. The gain when the transistor is placed in a normal circuit, and
4. The current gain at the maximum frequency of operation (for the transistor).

These are different values and we will see why.

1. THE DC CURRENT GAIN

This is determined by measuring the current in the collector circuit and dividing it by the current in the base circuit.

The highest result obtained from a number of determinations is selected and used as the value for the transistor. It is the value supplied in the specification sheets. This value is quite often completely different from what you get when using the transistor in practice as it is generated under ideal conditions.

It is determined under very low current conditions. When a higher current is required to be controlled by the transistor, the gain drops considerably.

For example, a transistor may be capable of handling 500mA, but the best gain factor may be determined at 10mA! The gain at 10mA may be 300 but at 500mA it may be only 70.

This applies to all transistors and that's why the gain values you will be getting on the Combo-2 are the highest the transistor will produce. When the transistor is placed in a normal circuit the gain factor will fall according to the current required by the circuit.

2. THE AC CURRENT GAIN.

The AC Current gain is the gain you get when the transistor is operating as an amplifier in oscillator mode, but again under very favourable conditions. Instead of taking static conditions as in the DC gain above, the SLOPE OF A GRAPH is measured and a value obtained. The result is less than the DC current gain but not very much less.

3. THE GAIN IN A CIRCUIT

When a transistor is placed in a circuit, things change completely. All the components around the transistor have a loading effect that reduces the gain.

The result is called STAGE GAIN and this is the MOST IMPORTANT GAIN as it is the gain you REALLY get.

For instance, a transistor with a gain of 300 may only produce a gain of 50-70 when fitted into a stage. It's the effect of all the components around the transistor that reduce the gain.

Such things as output capacitors, coils, loudspeakers and stages that follow, all require to be driven and/or have losses and when the transistor has to drive these components, its gain suffers.

There are also components called self-biasing components and negative feed-back components that reduce the gain so you can see why a transistor has to have a high gain in itself to end up providing a gain when fitted to a circuit.

4. THE FREQUENCY

The third factor is frequency. As the frequency of operation of a transistor increases, its gain decreases. This is a characteristic of the transistor itself. It is due to the way the transistor is made and the size of the chip making up the device. It is something that cannot be altered after the transistor is made. It's only by improved technology that transistor frequencies have increased from the first audio transistors to the modern gigahertz devices.

As the frequency of operation of a transistor increases, its gain decreases to unity and this point is called F_T, the cut-off point and determines the maximum frequency at which the transistor will operate. This is usually in the MHz range for small signal transistors and about 1MHz for power transistors. For high frequency transistors F_T will be 500MHz and higher. We generally do not have to worry about the maximum frequency capability unless we are designing high frequency circuits.

This leaves the question "What is the gain of a transistor?" unanswered, but you can see how complicated it is.

THE GAIN is what you get when the transistor is fitted to a circuit. If you are designing a circuit it is always a wise idea to take CRO measurements of the input and output of each stage to determine the gain as well as view the waveforms and also see if any high frequency noise is present.

both PNP and NPN transistors.

CONSTRUCTION

All the components fit on a PC board 107mm x 28mm.

Refer to the photo below to see how the machine pins are used as a 3-pin plug for the test leads so that they can be moved from section 2 to section 3.

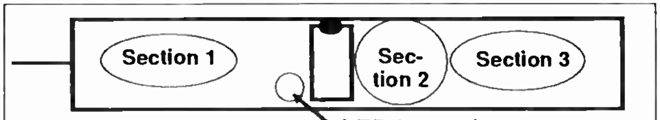
PREPARING THE 3-PIN PLUG AND TWO 3-PIN SOCKETS

Supplied in the kit is a strip of 11 machine pins to make the plug and sockets for the test leads.

From this strip three 3-pin sections are made and two individual pins are removed (plus 1 pin) for the test pins for section 1.

Remove pins 4 and 8 from the strip and cut it into three pieces making three 3-pin sections.

Two of these sections are soldered to the board as 3-pin sockets and the other is turned into a 3-pin plug for the three test leads.



The three sections on the Combo-2.

Cut three pieces of hook-up wire to equal length and solder them to the top of the three machine pins.

Place heat-shrink over both the leads and plug and shrink into place.

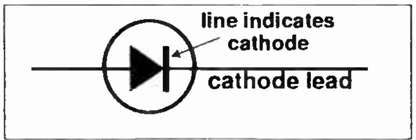
Solder 3 ezy clips to the other ends of the leads and label them collector, base and emitter with an adhesive label wrapped around the clip.

Mark one end of the 3-pin plug so that it can be fitted the correct way into the socket on the board.

Start assembling the board by fitting the IC socket and the two 3-pin sockets.

Then start at one end and fit each component as you come to it.

Each LED is identified on the board with a diode symbol and the cathode lead is the line on the symbol.



The cathode of the LED is identified by a flat on the side of the body of the LED and it is also the shorter of the two leads.

The 3 individual machine pins at the end of the board are the next to be fitted.

These are designed to take the leads of the transistor under test.

The rest of the components are easy to fit as everything is identified on the board.

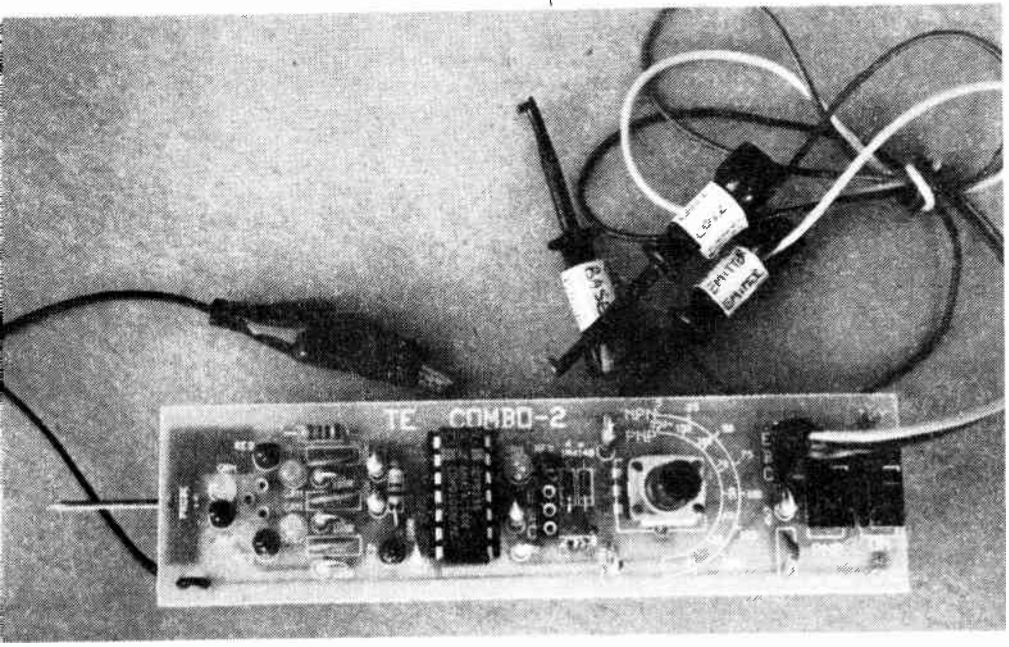
The earth lead for the signal injector is soldered to the board at the point marked GND and an alligator is fitted to the other end.

The probe is made from a nail soldered to the underside of the board at the position marked "probe."

Solder the 4 AAA cells together with short pieces of tinned copper wire and fit them under the board with double sided tape.

Don't forget to mark the ON/OFF switch with red nail polish to identify the ON position.

Fit the IC to the socket so that pin 1 is towards the top of the board and the project is ready for testing.



TESTING THE CIRCUIT

To test the Combo-2 you will need a number of good transistors, preferably both PNP and NPN types.

Section 1 finds BASE lead:	
NPN	Only green LED of pair comes on
PNP	Only red LED of pair comes on
Section 2 double-checks for PNP and NPN and checks for shorts between COLLECTOR and EMITTER leads:	
Both LEDs off, both junctions shorted	
Both LEDs on - open circuit	
Green LED ON - NPN, ok	
Red LED ON - PNP, ok	
Section 3 determines gain:	
NPN	LED just turns on
PNP	LED just turns off

Place them in the first section and make sure that only the green LED comes on for the NPN type next to the base lead.

Swap the leads around to check that all the LEDs work. Repeat with one or more PNP types.

USING THE COMBO-2

When the Combo-2 is turned on, only the two LEDs in Section 2 will come ON. This indicates power is applied to the circuit.

Place the leads of the TRANSISTOR UNDER TEST (sometimes called TUT) in the three machine pins at section 1. If the transistor is "good", five LEDs will come on. The base lead is identified by only one LED of the pair coming on.

If this LED is green, the transistor is NPN. If this LED is red, the transistor is PNP.

Sometimes, if the transistor has shorts between some of its leads, 5 LEDs will come on and so we need section 2 to determine if the transistor is "good."

Connect the transistor to section 2 via the jumper leads and read the LEDs as shown in the table above.

Take the jumper plug to section 3 and determine the gain of the transistor. Turn the gain pot and read the scale from the pointer on the shaft.

CONCLUSION

This project should solve a lot of your problems with identifying transistors, especially when using transistors with odd pin-outs. Add it to your collection of test equipment and most of all, don't loan it as you will never get it back!

Hfe

The need for measuring the gain of a transistor goes back to the early days when the gain was fairly low and to get a good device for a particular application you had to go through a whole batch and pick the best.

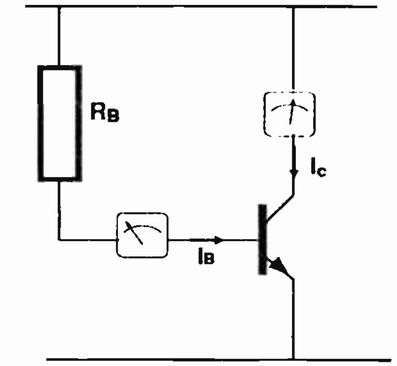


Fig: 1. Measuring the current gain of a transistor

The DC current gain H_{fe}, for a transistor is:

$$\beta = \frac{I_C}{I_B}$$

Today's transistors are much better and almost all have more gain than you need.

This means we don't really need to know the gain but it is interesting to find out the value for those transistors you have in the junk-box or for a transistor you may have damaged during soldering. For this and other reasons we have designed a tester to give you the answers.

It has been designed to give you the gain for small signal devices, medium power devices and high power devices.

We mentioned in the main article that small signal devices have a gain in the range 70 - 450, medium power devices have a gain of 50 - 200 and high power devices a gain of 10 - 110.

These are only approximate values and you could get a device with a value totally outside this range. For instance, some medium- to high-power devices are available in darlington versions and have a gain of 1,000 to 30,000 - way outside the range of our Tester.

BUT if the device is BELOW the range specified above, I would suggest the transistor is faulty and damaged in some way.

This can quite often happen due to over-heating, if you don't use a heatsink when soldering, or overheating when in use.

But this is getting away from our topic.

Let's get on with the theory.

THEORY

The gain of a transistor is a very variable thing. Even from a single batch of transistors, the gain can vary from less than 70 to more than 400.

GAIN is one of the factors used to grade transistors and is one of the reasons why we have so many thousands of different types. You may have noticed the suffix 'A,' 'B,' or 'C' after a transistor type. These letters denote the gain category and although none of the transistors are faulty, the numbering and lettering combines with other factors that mean the transistor can only be used in a certain location such as low voltage, low gain or low frequency application.

Since the gain of a transistor varies according to many things such as manufacturing technique, the voltage of the supply (in which the transistor is placed), the frequency of operation of the circuit and the current passing through it, an infinite number of values can be created from a single type, so it is quite often difficult to know which to use and what to expect.

The only way we can cover this complexity is to discuss the three values commonly quoted in specification sheets.

What happens to a transistor, and how it behaves in a particular circuit is another matter and cannot be predicted in any way so we will content ourself with values that can be determined.

The most often quoted gain for a transistor is the optimum value - the one that is determined under ideal conditions. It is called the DC gain or β_{DC} or H_{FE}.

This is obtained from a circuit such as shown in figure 1. The circuit is set up and a graph drawn for the collector current when varying base currents are applied. The maximum gain is read from the graph.

This value is generally about 20% higher than the "AC" or "working" gain (to be discussed later) and that's why it is most commonly used.

But some purists don't think the above method is realistic as a transistor is not a static device but a dynamic amplifier such as when used in an audio situation. They want an "operating" value of gain. In other words they want an AC gain value.

In this case an amplifier is set up and varying signals are applied to the base for varying rail voltages.

Once again, the best gain is picked off the graph and used as the AC value or BETA or H_{fe}.

The third value of gain is the value that applies at the upper operating frequency of the transistor and does not concern us in this discussion. It is the highest operating frequency for the transistor and occurs when the gain falls to unity.

For most requirements, the difference between h_{fe} and h_{FE} can be ignored if you are working within the limits of the transistor.

Data sheets generally supply h_{FE} or d.c. current gain and this is the value we obtain from the tester.

The current gain can be written as:

$$\beta = \frac{I_C}{I_B}$$

and this is exactly what the tester is doing, but in a reverse mode. It is reading off the base current for a particular collector current.

It does this in a very clever way. It knows that when a certain current flows through the 4k7 collector load resistor in the gain section, a voltage will be produced across this resistor to cause the detecting gate between pins 9 and 8 to change state and turn on the "gain LED."

By turning the "gain pot," the base current is increased until the transistor produces the required collector current and the value of gain is read off the scale around the pot.

In other words all the mathematics has been done by the project designer and any transistor fitted to the test socket will duplicate the values already worked out.

THE BJT

In most discussions, transistors are referred to as "transistors," but in effect the writer is referring to the first type of transistor to be invented (in simple terms), namely the bipolar junction transistor, or BJT.

They should be referred to as BJT's, but since this is such a mouthful, they are simply called "transistors."

Since the introduction of this type of transistor there have been a number of other developments such as the Field Effect transistor (the FET), the darlington transistor and others that can be lumped into the transistor group.

Unfortunately our tester is not capable of testing these devices and you will get a false reading if you try to test them, so it is advisable to know the device you are testing is actually a "common" or "garden" transistor.

Most of the devices in your junk-box will be common NPN or PNP transistors and the tester will identify the base lead and provide a value of gain as well as an indication that the transistor does not have an obvious short between any of the junctions - so you shouldn't have any problems.

STAGE GAIN

The gain we talk about in our projects, under the heading "HOW A CIRCUIT WORKS," is the OPERATING GAIN or STAGE GAIN. It is not the gain of the transistor.

For example, the first audio stage in our FM transmitters, such as the FM Bug, Ant, Amoeba, Cube of Sugar, VOX etc. has a STAGE GAIN of between 50 - 70.

This is the highest gain you will get, even if you are using a transistor with a gain (H_{FE}) of 250 to 450.

If you are using a transistor with a gain below 250, the stage gain may drop to 30 - 50.

The problem is the gain of a transistor is almost totally "killed" when it is fitted into a circuit.

Why is this so?

The reason for the drop in gain is due to biasing and coupling.

Figure 1 is a typical example. It is a self-biased stage with a 2M2 as the base bias resistor. We will see how this resistor reduces the gain of the transistor.

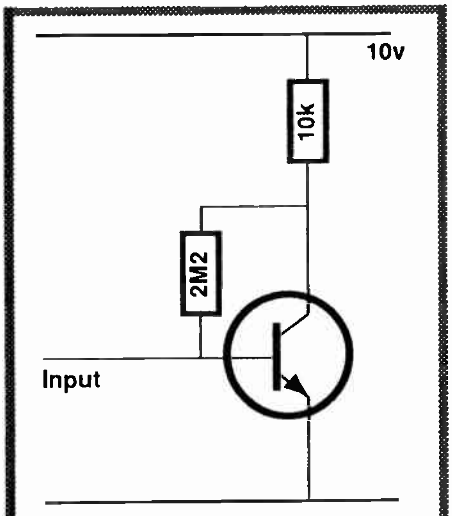


Fig.1: A self-biased transistor stage

BIASING

Let us assume the transistor has a gain of 250. When power is first applied, current flows in the 2M2 to turn the transistor ON. As the transistor turns on, the voltage across the 2M2 reduces because the voltage across it becomes less and this reduces the current to the base. A point is reached where the current through the 2M2 cannot turn the transistor ON any more. This is called the equilibrium point or quiescent point or balance point and the voltage on the collector is about 5v. The current through the 2M2 will be about 2uA.

The transistor cannot turn on any more due to the value of the 2M2 and the gain of the transistor.

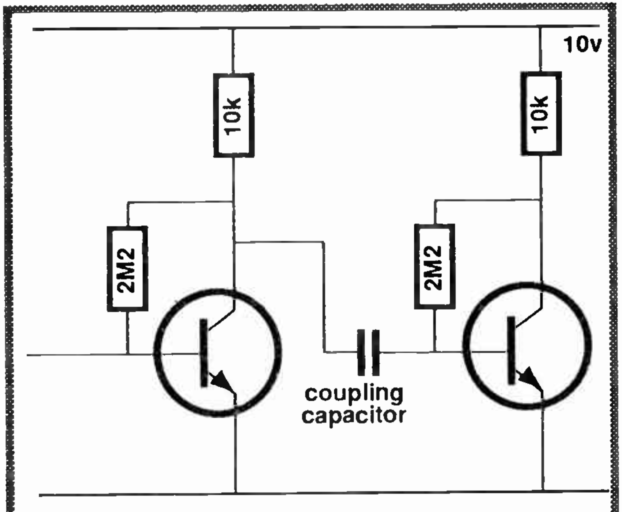


Fig.2: Two stages coupled via a capacitor

If we supply 1uA into the base of the transistor via the input line, the transistor will turn on more and produce a further 250uA in the collector circuit and drop the collector voltage another 2.5v.

But something else will happen at the same time to prevent the collector voltage dropping.

It's the current flowing through the 2M2 resistor. As the voltage on the collector drops, the current through the 2M2 will reduce and if the collector voltage drops to 2.5v, the current through the 2M2 will fall from 2uA to 1uA and so the collector will not fall to 2.5v but something between 2.5v and 5v.

The actual final voltage does not matter but you can see that the current flowing into the base is partially reduced (or cancelled) by the base bias resistor, due to the fall in collector voltage. Thus the transistor does not produce the 250 gain you expect.

In reality the gain is about 125.

Further losses are encountered by coupling capacitors between the stages.

We will see how this occurs.

COUPLING

Figure 2 shows a coupling capacitor between two stages.

When a sinewave is processed by the first stage it is passed to the second stage via the capacitor.

The second stage will amplify this to produce a larger output but we want to investigate how and why the waveform on the collector of the first stage is reduced when the second stage is added.

The best way to see this is to remove the second stage.

With the second stage removed we will assume the waveform on the collector of the first stage is 8v.

When the second stage is reconnected, the waveform will fall to about 6v.

The reason for this is the second stage puts a LOAD on the first stage. After all, the energy to drive the second stage must come from somewhere and it comes from the first stage.

The "reduced swing, or reduced amplitude, on the collector" decreases the gain of the stage even further and the gain may fall from 125 to between 50 and 70.

This brings us to our conclusion. The gain of a transistor has almost no bearing on the gain you will get when it is connected to a stage.

The only way to determine the gain of a stage is to take measurements with a CRO.

To do this you must inject the input with a low-level signal from a sinewave generator and record the amplitude. Then read the output of the stage.

Sometimes you will get quite a shock at the low gain. It can be as low as 10 - 50 for a stage you are expecting to be 100. The main reason will be due to poor design.

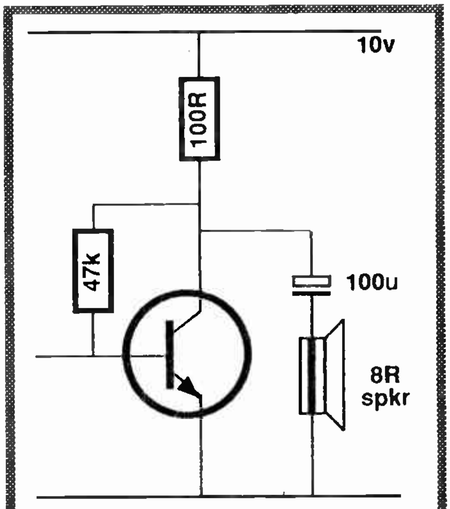


Fig.3: An output stage

Figure 3 shows a transistor driving an 8 ohm speaker. This is where the problem lies. The transistor is NOT driving the speaker. It is merely discharging the 100u during the second half of the cycle. The 100 ohm resistor is DRIVING THE SPEAKER and since this resistor is such a high value, the speaker cannot expect to be driven very hard.

It is being driven at less than 10% of full output (due to the ratio of the 100R:8R) and this means the waveform will be less than 10% of rail voltage. It will appear that the transistor is not providing a good driving force but the fault lies in the poorly designed circuit.

Build this . . . Add-on

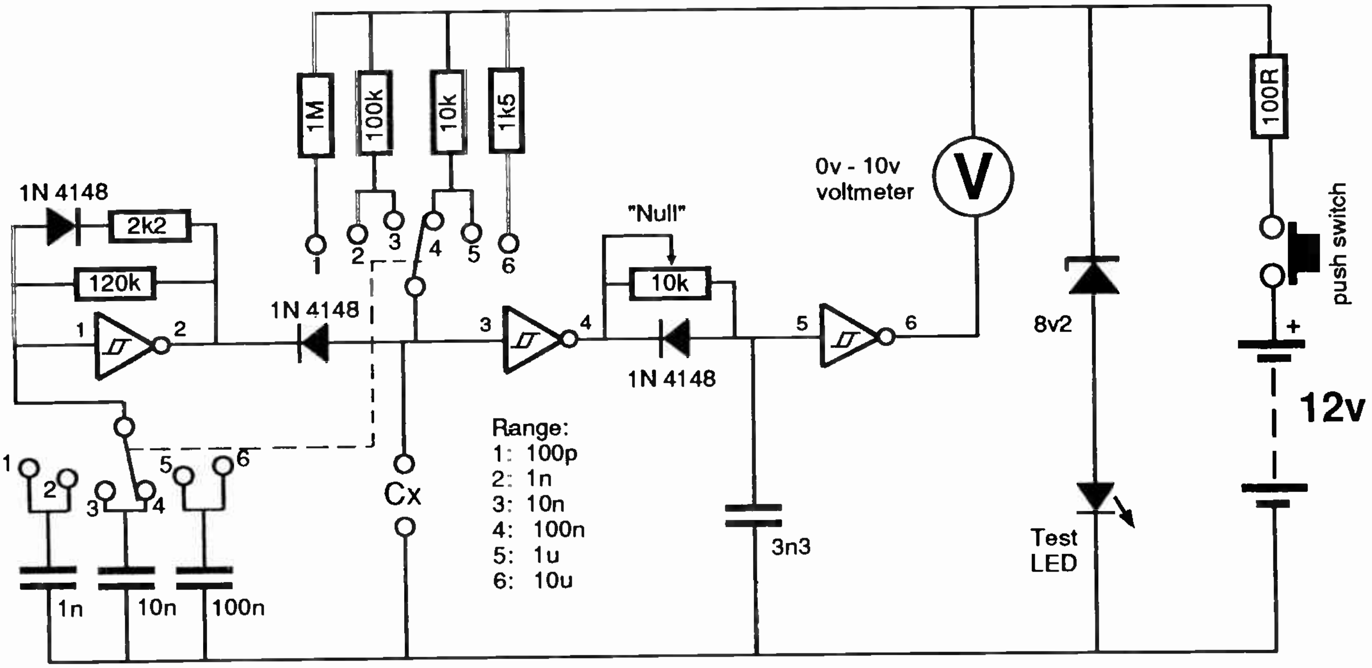
CAPACITANCE METER

PARTS & PC: $15.55

PC Board only: $4.20

You will also need a 0v - 10v meter.

Tests capacitors from 1p to 10u, in 6 ranges



Add on CAPACITANCE METER CIRCUIT

This simple add-on capacitance meter has been specially designed to help you identify capacitors from 1p to 10uF.

There has always been a problem identifying capacitors, due to the enormous variety in size, shape and coding. Most of the time it is impossible to identify a capacitor by its size due to the different forms of construction, so you have to be able to read and interpret the codes on the body. But if the numbers are missing or microscopic in size, you have a problem. The only solution is to have a piece of test equipment that will identify it for you.

This project is exactly what you need. It is simple to construct and can be connected to almost any analogue multimeter.

The scales are accurate over each range - certainly good enough to provide you with the value of any capacitor between 1p and 10u.

The actual accuracy depends on the tolerance of the components used in the design and since we have used 10% components, you can assume this accuracy for any of the reading you take. It is interesting to note that the actual value of a capacitor is not important for most applications.

Coupling capacitors can be +/-50% without affecting performance, as can bypass capacitors. About the only types that have to be accurate are tuning capacitors and those in oscillators, and then there is usually a trimmer cap or slug tuned coil that can be adjusted to set the frequency.

The reason we designed this project was a result of our need to determine the value of a couple of capacitors we were using in the front end of an RF motion detector (yet to be released). It had to be 1.8p and the capacitors I found in our parts store looked like 18p - it was difficult to read the value printed on the body. I had to borrow one of the staff's capacitor testers to prove it was 1p8.

When you are working with high frequencies such as 400MHz, capacitors have to be the correct value or the circuit will not work. Certainly an 18p will not work in place of a 1p8 in an oscillator stage at this frequency.

The tester proved so handy I thought it would be a good idea to present something similar as a project.

It's very handy when you are not sure of a value. This is especially important with surface-mount components as their value is not marked on the body and the size is no indication of capacitance. Many capacitors are made in layers to

PARTS LIST

1 - 100R
1 - 1k5
1 - 2k2
1 - 10k
1 - 100k
1 - 120k
1 - 1M

1 - 10k mini trim pot

1 - 1n greencap
1 - 3n3 greencap
1 - 10n greencap
1 - 100n monoblock

3 - 1N 4148 diodes
1 - 8v2 zener
1 - 5mm red LED
1 - 74c14 Hex Schmitt trigger IC
1 - 14 pin IC socket
1 - 2 pole 6 position rotary switch
1 - knob to suit
1 - push button
1 - 12v lighter battery
3 - machine pins for test socket
1 - 20cm red hook-up flex
1 - 20cm black hook-up flex
2 - paper clip for multimeter
1 - CAPACITANCE METER PC BOARD

reduce their size and this is certainly the case with surface-mount. We have instances where 10p is physically larger than 22n! - this is because the 22n is made up of many layers.

Ceramic capacitors can sometimes be a problem too. Their size is also dependent on the layer principle and a 22n can be the same size as a 10p or even smaller! There is also a problem with the markings. Sometimes 100p is marked as "100" and sometimes "101." You have to think every time you pick up a component and remember the coding being used - if you don't want to make a mistake.

On page 14 we have included an article on the coding of capacitors and this will help you identify some of the more-difficult values.

If you make a mistake and put 102 or 103 in a circuit in place of 100p, you may be creating a fault that you will never locate as 102 is 1n and 103 is 10n. We have also had the case of a 1n capacitor being marked 1n0. The numbers were so small that the constructor thought it was 100, and used it as a 100p!

It's even more difficult to decipher 5.6p from 56p on tiny ceramic capacitors as the decimal point is so small that a magnifying glass can hardly pick it up.

Another trap is the marking of capacitors such as 47000 instead of 47n or .0022 instead of 2n2.

When we are making up the kits, we know a component is 5p6 because it comes from a box labelled 5p6 or marked on the bag as 5p6, but when you pick up some oddments from a junk box, you can't be quite so certain.

When you are experimenting with high frequency circuits such as RF stages in transmitters, you will very soon realise the importance of pF values. The difference of only a few pF will change the frequency many MHz, depending on where it is situated in the circuit. The wrong value will even prevent a stage from oscillating.

So there we have it, some capacitors are critical and some can be almost any value.

Going back to the old radio days and the introduction of transistor radios, some of the ceramic capacitors had a tolerance of 50% to 80%. This wasn't a problem as they were used in bypass situations and for coupling where a value could be increased by as much as 100% without any affect in performance.

Tolerance has improved with modern components and the normal tolerance is now about 10% to 20% but we need not be concerned with the accuracy of a capacitor, or the tester, but rather the need to determine if the value marked on the body is the same as it appears to a circuit.

By double checking with a tester, you will prevent silly mistakes such as using a 10n capacitor in place of a 1n or 56p in place of 5p6.

Now to the technical part.

Measuring from 1p to 10u is a factor of 10 million. To cover this we need 6 ranges. Each range is divided into 100 parts, making it easy to read values on a 0-10v scale.

For each range we need to switch some of the components into circuit to create the necessary test frequencies and charging values. This is the function of the rotary switch.

All you have to do is fit the unknown capacitor to the test socket and press the button.

If you don't know the value of the capacitor at all, you can start on any range. When on an incorrect range, the needle will swing full scale or not move at all. Only when it's on the correct range will deflect to the appropriate value.

The only other time when the needle will swing full-scale is when the value is equal to full scale deflection. This may sound a bit complex but you'll see what we mean in a moment.

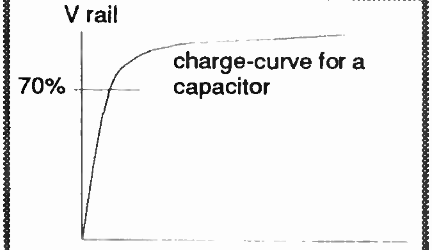
HOW THE CIRCUIT WORKS

This circuit reads the value of a capacitor and displays it on an analogue meter.

Designing a circuit to do this is considerably more difficult than you think as the only way to read a capacitor is to charge it and measure how long it takes to charge.

As you may be aware, the charging of a capacitor is a non linear function and so we must create a circuit that by-passes the non linear problems and works on a linear arrangement.

We have done this by charging the capacitor to a specified voltage level and this level is detected by a gate.

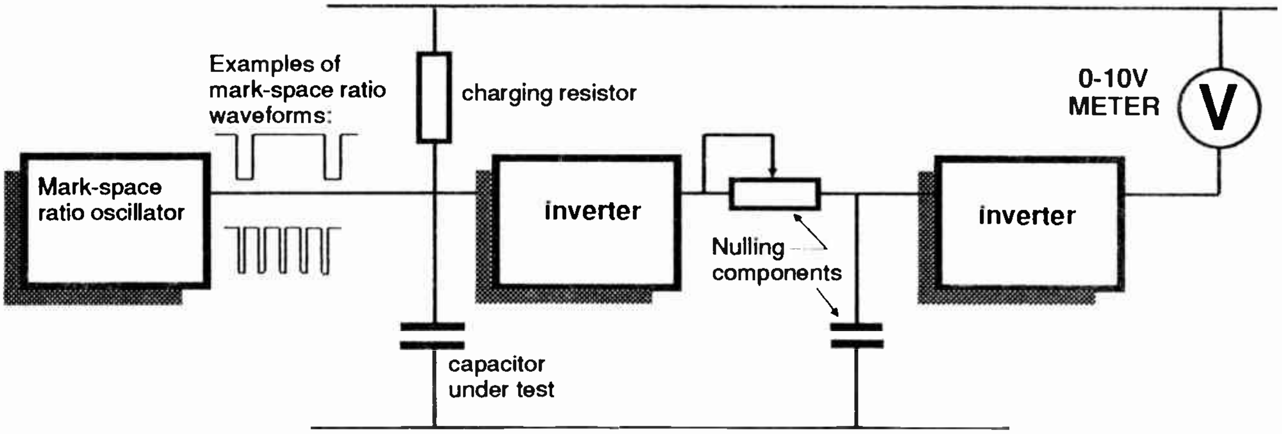


The input of the 74c14 detects the voltage on the capacitor at the 70% position on the curve and up to this point the charging is quite linear.

We wanted to use our favourite chip, the 74c14 hex Schmitt Trigger in this project. It operates by detecting 2/3 of the rail voltage to change the state of the output. At first it seemed that this could not be used to create a linear output. But where there's a will, there's a way.

Not only does the circuit produce very good linearity, but it is simpler and better than anything else we have seen.

The circuit works on a timing principle. The first oscillator, between pins 1 and 2



BLOCK DIAGRAM OF CAPACITANCE METER

has a high time of 100 units and a low of 1 unit.

The HIGH is created by the 120k resistor and the capacitor selected by the rotary switch and the low is created by the 2k2 and diode.

This gives us our starting point where we can divide a scale into 100 parts.

The next section of the circuit charges the test capacitor via a resistor selected by the rotary switch.

The requirement of this section is to charge the largest capacitor (in the range) in exactly 100 units of time.

This means a 100p capacitor will take 100 units of time to charge and it will not quite get to the point where the gate detects a HIGH before the output of the timing oscillator goes low and discharges it, ready for the next cycle.

This means the output pin 4 will not go low so that the 3n3 capacitor will remain fully charged.

The third gate inverts this result so that output pin 6 remains low and thus the meter gives a full range reading of 10v. This is read as "100" to give a value of 100p.

If a 99p capacitor is tested, it will charge in 99 units of time and the output pin 4 of the Schmitt gate will go low for one unit of time and discharge the 3n3 capacitor. This will make output pin 6 of the third Schmitt trigger HIGH for one unit of time and thus the meter will be turned off for one unit of time out of 100.

Now, here comes the clever part.

Since the circuit is operating at a fairly high frequency, the needle of the meter does not have time to swing back to zero during this one unit of time but it does drop a small amount and the result is it sits on 9.9v or "99" on the scale.

At the other end of the scale, if a 1p is fitted, the capacitor will charge in one unit of time and output pin 4 will go low for 99 units of time. The inverter between pins 5 and 6 will produce a one-unit pulse to the meter and thus the needle will rise .1v and this will be read as "1" or 1p.

Now we come to the nulling circuit made up of the 10k pot and 3n3.

If no capacitor is fitted to the test terminals, the mark-space ratio oscillator will produce a high for 100 parts, and a low for one part of the time and this will go directly through the inverter between pins 3 and 4.

If the nulling components were not present, output pin 6 would be high for 100 parts and low for one part.

This means it would put a small "set" of about one part on the meter and cause a unit deflection. In other words the meter would not zero and when measuring the low values in any of the ranges, such as 1p, 1n etc, the needle would add one to the result to get "2" etc. This may not be important at 100p, but at 2p2 the value will be 3p3 and it would be annoying to have to take 1p off the readings.

Another solution is to re-zero the meter but the best solution is to provide a nulling circuit.

The 3n3 and 10k trim pot are designed to create a timing circuit that takes one unit of time to charge and thus the first one unit of time is not registered on the output.

The other features of the circuit are a voltage stabilised section made up of a zener diode and 100R resistor as well as a LED to indicate the battery voltage is above the 10v required to drive the circuit and a test button so that power is only applied for the brief moment when you want to make a test.

A 12v lighter battery has very little capacity and cannot be expected to supply a circuit for any more than a few moments at a time.

CONSTRUCTION

All the components fit on a compact PC board with the 12v lighter battery soldered on the board too.

The range switch is a PC mount type so that no wires are needed between the switch and board. This makes the project very neat and tidy.

The first item to fit is the IC socket, making sure the cut-out at the end of the socket goes over the mark on the PC board. This will help you fit the chip around the correct way at the completion of construction.

Next fit the small components such as the resistors, diodes, capacitors and zener, along with the LED, slide-switch and trim pot.

The machine pins for the test capacitor are from an IC socket and these are added to the board to complete the small components. All that's left is the fitting of the rotary switch and the tinned copper wire for the 12v lighter battery.

Solder red and black leads to the 2 paper clips and solder the leads to the PC board. Bend the paper clips to fit the + & — sockets of the multimeter. Fit the knob to the switch and add the IC to the socket to complete construction.

Press the push switch and see the LED come on. It should now be ready for setting up and testing.

THE NULL CIRCUIT

Before the Capacitance Meter can be used for the first time, the output must be nulled so that it produces a zero reading when no capacitor is fitted.

To do this, connect the paper clips to a multimeter set to 10 volts and press the button. Turn the 10k mini trim pot until the needle just reaches the zero mark. It is now ready for use.

USING THE CAPACITANCE METER

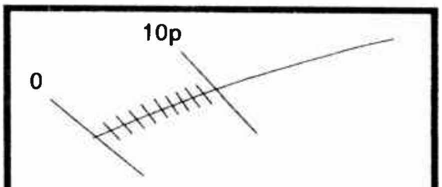
The capacitance meter is very simple to use. Simply connect the two leads to a multimeter and insert a capacitor in the test pins.

The 10v scale is divided into 100 parts and this makes it easy to read the 1p to 100p range. The other ranges need a little bit of assistance and we have provided a diagram below to help you read each of the scales. Some of the scales overlap slightly and it is always best to get a reading on the largest scale.

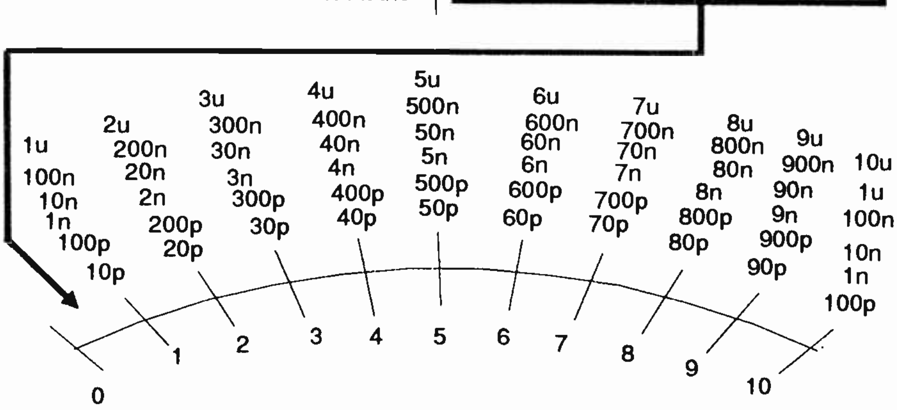
IF IT DOESN'T WORK

There's nothing worse than a piece of test equipment failing to work or being inaccurate. After all, we use it at the most desperate of times and it has to be reliable.

That's why we have made this project compact, with its own supply. Simply by pressing the button you can see if the



The 0 - 10p on the scale can be divided into 10 parts: 1p, 2p, 3p etc.



The 6 ranges for the CAPACITANCE METER

CAPACITOR CODES

Identifying capacitors has always been a problem, mainly due to the wide variety of shapes and sizes on which the numbers must be printed.
But very soon this should be at an end.
A universal 3-digit code has been developed to cover the entire range from .1pF to 1 Farad and this code is very easy to follow.
The main reason why a compact code is needed is due to the size of some capacitors - such as monoblocks (monolythic), ceramics and chips, they are very small. There is not enough room for more than three digits and this is why the code is so good.
In the past, capacitors have been marked in a variety of ways and have included the disastrous decimal point and sometimes lots of zeros.
If you have ever tried to decide if a mark on a capacitor is a decimal point or a spot of dirt, you know what I mean. It is absurd to use a decimal point in such a vital place.
The 3-digit code does away with the decimal point and uses either a number or letter instead.
There are two forms of the 3-digit code.
One uses three digits and the other uses two digits and a letter. An example of this is a 5p6 capacitor or 10p or 47p.
You will see how the first type is written by reading through the table in the next column, they are all pF values.
At the moment only about half the manufacturers are using this code and a couple of conflicts exist. Take for instance a 100pF ceramic. It can be marked "100" or "101" whereas "100" on a chip capacitor is 10pF. So be careful.
If you are working with some of the older style equipment, you will find values such as .0022 or 2200 on mica capacitors and 4700 or 47000 on polyester capacitors, making it a logistic nightmare to work out the actual value. All our circuit diagrams and discussions use the easy to understand code and it corresponds to the coding on the latest micro-components.
If you want to know where to start when memorising the table, start with 102 = 1n, 103 = 10n and 104 = 100n. All the other values fit into these three ranges, or a range lower or higher.
The most essential thing is to put a capacitor into the correct range. For instance, 222 must be put into the "n" range and then you say "it's 2n2."

We don't have trouble with capacitor codes because we take them from large bins that have clear identification. But when it comes to a bundle of capacitors in a kit, I know the problems many constructors will be having. We have them ringing us all the time!

VALUE:	VALUE WRITTEN ON THE COMPONENT:
0.1p	0p1
0.22p	p22
0.47p	p47
1.0p	1p0
2.2p	2p2
4.7p	4p7
5.6p	5p6
8.2p	8p2
10p	10 or 10p, 100 on chip caps
22p	22 or 22p, 220 on chip caps
47p	47 or 47p, 470 on chip caps
56p	56 or 56p, 560 on chip caps
100p	100 or 101, 101 on chip cap
220p	220 or 221, 221 on chip cap
470p	470 or 471, 471 on chip cap
560p	560 or 561, 561 on chip cap
820p	820 or 821, 821 on chip cap
1,000p (1n)	102 on ceramic and chip cap
2200p (2n2)	222 " " " " "
4700p (4n7)	472 " " " " "
8200p (8n2)	822 " " " " "
10n	103 " " " " "
22n	223 " " " " "
47n	473 " " " " "
100n	104 " " " " "
220n	224 " " " " "
470n	474 " " " " "
1uF	105 " " " " "
2.2uF	
4.7uF	These elelctros
10uF	usually have
22uF	their value marked
47uF	in uF (on the body), and are
100uF	quite easy to identify.
220uF	
470uF	
1,000uF . . . . .100,000uF and higher!	

If you are having trouble reading capacitor values, build the CAPACITANCE METER project, that's why we designed it.

Finally, mF values

Some magazines use millifarads for the value of large capacitors such as electrolytics. I don't like to use millifarad values because no capacitors are marked in millifarads and it only confuses the issue.
1mF = 1,000uF. If you saw 1mF in a circuit you may confuse it with 1uF. Similarly 100mF is equal to 100,000uF and a mistake could easily be made. Stick to uF, (microfarads) even when it comes to a 100,000uF electrolytic. This way you can't make a mistake.

battery has sufficient voltage to power the project.

But if it fails to work after construction, here is the process to follow:

First press the button and make sure the LED comes on.

If it doesn't, measure the voltage of the battery and the track-work around the switch and 100R resistor for shorts or broken tracks. Measure the voltage before the 100R and after it. If it is 12v after the resistor, the LED or zener is faulty or around the wrong way. The voltage on the chip should be very close to 10v.

The next step is to short between the two terminals of the test socket. This will cause full deflection of the meter. If this does not happen, the fault will lie in the second and third inverters or the meter. If the LED goes out when you short the terminals on the 10u scale, the battery will be getting very weak.

If it goes out on any of the other scales, the fault will lie in the value of the charging resistors on pin 3 or the placement of the diode on pin 3.

You must get full scale deflection of the meter, or at least near full scale deflection before proceeding further.

To check the inverter between pins 3 and 4, short the test pins with a jumper lead and place another jumper between pin 5 and the positive rail.

This should provide full scale reading, but if it doesn't, place a third jumper between pin 6 and the negative rail.

This has to work as we are placing the meter directly across the power rails and if it is not deflecting, the leads are faulty or the multimeter is on the wrong scale.

We can now start to work backwards, firstly removing the jumper on pin 6. Each time you take a measurement, press the button for only a second so that you don't use up too much of the battery.

Output pin 6 should be low, but if it is not, the inverter may be damaged or the chip may not be getting its voltage from the supply.

A damaged inverter can be replaced by one of the other 3 inverters in the chip and this simply means wiring up one of them to the meter.

Now remove the jumper on pin 5 and place it on pin 4. Turn the pot to minimum resistance and the meter should provide full scale deflection. If it doesn't, the mini trim pot is faulty.

Remove the jumper on pin 4 and we are back to where we started.

If the meter doesn't give a reading, the inverter between pins 3 and 4 will be faulty and can be replaced with one of the spare inverters in the chip.

We have now checked about half the circuit.

The only section remaining is the mark-space ratio oscillator. This is designed to produce a very short low and a long HIGH. When the output is HIGH the diode between pins 2 and 4 does not have any effect of the second section where the test capacitor is charging.

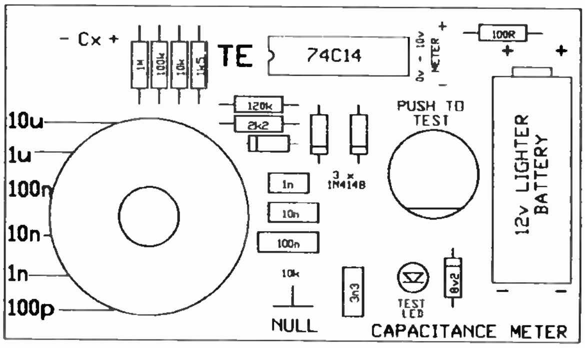
However when the output goes LOW, the diode discharges the test capacitor.

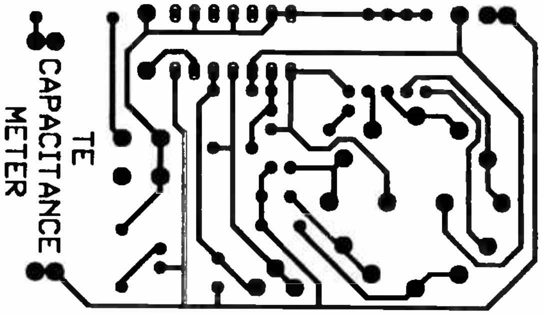
This section is very difficult to test as it is operating at a high frequency and is classified as a high impedance stage. This means you cannot put any load on the components otherwise the circuit will stop operating.

The only thing you can do is connect a LED from the bottom of the 1k5 resistor to pin 3 of the chip and change the range switch from 100p to 1n or 10n and note the very slight glow from the LED. It is responding to the 1% of the time when the output is low. If the LED is bright, there will be a short or leak from pin 3 to the earth rail.

This could be a short under the board or the fact that the mark-space ratio oscillator is operating on a 50% duty cycle.

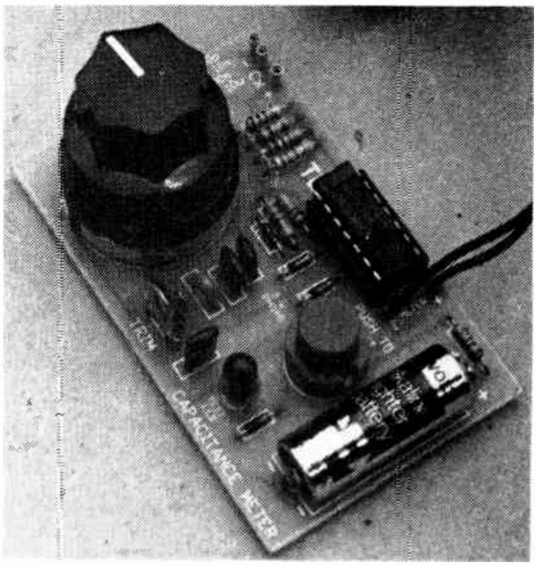
This could be due to the absence of the diode in series with the 2k2 resistor.





Artwork for Capacitance Meter

If the 1n capacitor is shorted with a jumper lead when the range switch is on the low capacitor range, the LED will go out.



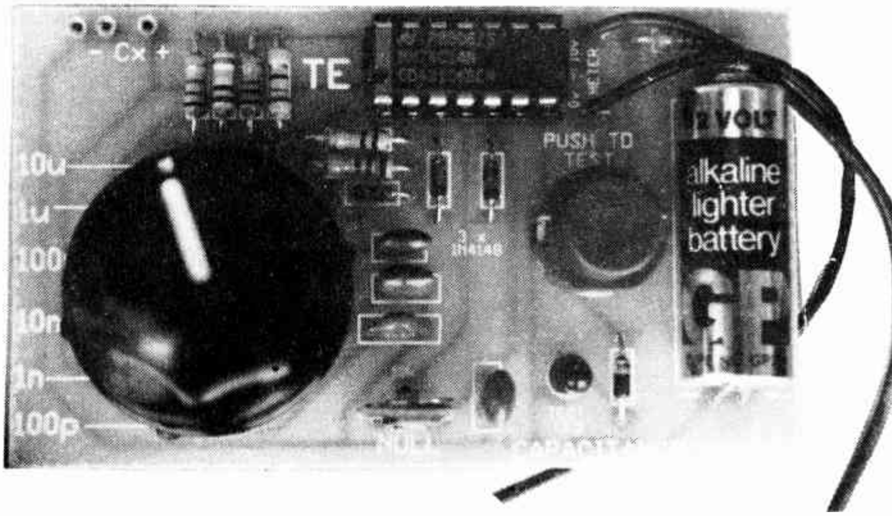
Completed Capacitance Meter

This is the best we can do with simple equipment to show the oscillator is working. Further tests can be made with a CRO or audio amplifier to see or hear the effects of the oscillator.

CONCLUSION

The Capacitance Meter can be used as is or fitted into a small jiffy box and added to your other test equipment.

I am sure you will find it handy for those times when you need to know a value of capacitance.



COMPONENTS IN PARALLEL AND SERIES

Too much time is taken up in electronics courses, learning about connecting resistors and capacitors in parallel and series.

In my 15 years of servicing television sets (26,000 sets) I have only had to connect resistors or capacitors in series or parallel about 10 - 15 times. This has been mainly due to not having the correct component or components in the tool kit or maybe needing to have a higher voltage capacitor or a higher wattage resistor.

In 10 years of designing at Talking Electronics I have only needed to use parallel connection of resistors 3 times!

Here comes the amazing part. In all the instances I did not use mathematics to work out the value of the components. I either used the approach I going to tell you about in a moment or guessed the value and changed it slightly until the desired result was achieved.

Even though I know the mathematical equations for working out the values, I refuse to use them as a challenge to and in support of what I am suggesting.

For the number of times when a parallel or series connection is needed, far too much time is taken up in electronics courses, learning about how to work it out mathematically.

Much of this time could be spent on more important issues so that more topics could be covered.

My solution to parallel and series connection is simple. You only have to remember a couple of examples and these provide you with the rules.

Once you know these you can interpolate (guess) the values in-between or even measure the result with a multimeter and change it until you are satisfied.

When it comes to measuring the value of capacitors in series or parallel, a multimeter doesn't give you the answer. You need a CAPACITANCE METER similar to the one described in the previous article.

It will give you the result without having to go through any of the mathematics.

So, here are the simple rules:

In all cases we use 2, 3 or 4 components of the same value. I know this doesn't correspond to many of the mathematical problems you have to solve but in most instances where components are paced in series or parallel there are two situations:

Situation 1 is where resistors are used in series or parallel so that the overall dissipation is increased. In this case the resistors are generally of EQUAL VALUE.

Situation 2 is where a resistor or capacitor is "trimmed" with another to achieve an exact value. This exact value usually cannot be obtained via the standard range of resistors or capacitors.

Examples of this is where a very small capacitor is placed across a larger value so that the result is altered only very slightly.

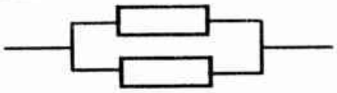
In the case of resistors, a very high value is placed across one of a smaller value to alter the result a very small amount.

You can carry out all the above operations without any mathematics once you understand how the principle of parallel and series works.

THE EXAMPLES

The 4 examples to remember are:

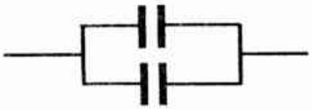
1. Two equal value resistors in series create a value of double.



2. Two equal value resistors in parallel create a value of half.

The opposite rules apply to capacitors:

3. Two equal value capacitors in series create a value of half.



4. Two equal value capacitors in parallel create a value of double.

These rules are obvious when you think about them.

They can be extended to three resistors, such as:

3 resistors in series create a value of three times the value of one.

3 resistors in parallel create a value of one-third.

For three capacitors:

3 capacitors in series create a value of one-third.

3 capacitors in parallel create a value of three times the value of one.

Now we come to a little bit of interpolation - the art of guessing or gaining an approximate value by experimentation.

TRIMMING

If we wish to trim a resistor we know that an equal value in parallel with it will reduce the result by 50%. If the trim resistor is twice the value of the resistor we wish to adjust, the result will be a reduction of 33%, if the trim resistor is 4 times, the reduction will be 25%, If the trim resistor is 5 times, the reduction will be 20%, if the trim resistor is 10 times the reduction will be 10%. If it is 20 times, the reduction will be 5%.

What more can I say, you can see the pattern. The reduction is the reciprocal in percentage.

Most often the parallel trim resistor will be 10 to 20 times to value of the resistor to be trimmed. This means if we want to trim a 1k resistor, we need a 10k to 20k across it.

Resistors can also be increased in value by adding a resistor in series. The result is simply the addition of the two values.

Capacitors can also be trimmed. This is done by placing a capacitor of about 1/10th the value, across the one to be trimmed. This result will be the addition of the two.

Capacitors are rarely placed in series to be trimmed.

SUMMARY

Trimming of resistors is usually done by placing a high value resistor (10 to 20 times) across another resistor - the result is LESS than either resistor.

Trimming of capacitors is usually done with a low-value air trimmer across a larger value capacitor - the result is the ADDITION of the two values of capacitance.

THE TIME HAS COME

With apologies to Lewis Carroll

The time has come to talk about Talking Electronics and all the things it has to offer. TE has produced a complete range of magazines and kits, starting with projects for the beginner, through to the advanced hobbyist.

Many new readers are writing to us, wondering what books and projects they can buy and how they can learn electronics at the least cost.

To answer this fully I will have to go back to the beginning and tell you how Talking Electronics started.

THE HISTORY OF TE

Talking Electronics didn't just happen. It was the inspiration of Colin Mitchell, a Teacher, TV serviceman and design engineer.

He had a vision of producing an electronics magazine for experimenters; one that included explanations of how things worked, with projects backed by the availability of kits.

It started in 1981, when Colin was asked to prepare some technical notes and design a piece of equipment for a client.

He was surprised to find that simple technical information was very difficult to find. Most books looked impressive at first glance, but when he wanted various pieces of information, they couldn't be found. The only solution was to sit down and write the notes himself.

After spending many weeks on the project, he decided there was an enormous need for basic electronic instruction and he decided to do something about it.

Fortunately he had all the skills to do it but firstly he needed $120,000 to buy a typesetting machine, typewriters, drafting equipment, parts for prototypes, test equipment and most important of all, an extension to his house in which to produce the magazine.

Next he needed to think of a name for the venture.

It came suddenly one day, just as all good things do.

The name: TALKING ELECTRONICS. It was perfect. It was a play on words and Colin liked the hidden meaning. Hobbyists are always "talking electronics" and the name fitted in perfectly with the way he intended to present his ideas.

To his amazement he found no-one had registered the name before. So, armed with this dynamic title he started preparing the articles for the first issue.

All the start-up costs for nearly six months had to come from his thriving TV service business and fitting them both in meant 18-hour days.

After about 6 months the first issue was ready to go to press.

After another 10 days the magazine hit the streets and orders started coming in. The first week was slow but the second week saw interstate orders and very soon half the day was taken up processing the orders.

The magazine has continued like this for the past 12 years of its existence and more than 25 books and magazines have been produced.

Unfortunately many of the early issues have sold out however some have been reprinted and it is now possible to offer a set of books that start with very simple circuits and take you through more than 150 kits to a single-board Z-80 computer.

In a moment I will give a list of the books and the order in which they should be purchased, but first a short digression.

Each book has a number of low-cost projects with a full explanation on how the circuit works and how to get it to work if something goes wrong.

This is the major advantage of Talking Electronics. Each project is available as a kit and prices are less than if the parts were bought individually. All the books cost $5.00 or less (plus the cost of postage) so you should have no trouble saving up for them.

We have seen many readers buy kit after kit and some have written to say the skills and knowledge learnt from Talking Electronics has enabled them to get the job they have always wanted.

The same could happen to you. There is no reason why you could not advance to the top after working through our series of kits. Talking Electronics is designed to be a learning medium and teach electronics at the lowest cost.

When you get the complete range of books you will find you have a miniature encyclopaedia and I am quite sure you will find it an invaluable reference source. The main thing is never to lend any of the publications. You will never get them back and some titles will be out of print in the future.

To gain the maximum from these books you must carry out a "building program" by putting together as many of the kits as possible. A fair requirement is one kit a week.

There are over 150 kits to choose from and a complete list of kits comes with your first order.

You cannot hope to learn everything from reading alone. It's only by building that you will gain the finer points of seeing how a circuit works. By involving yourself in soldering, measuring voltages, modifying circuits, finding faults etc, will you pick up the finer points of electronics.

All the equipment you need to start construction can be purchased from us or your local electronics store. These are: a soldering iron, solder, cutters, a multimeter, and a few screwdrivers etc.

Now for the list of titles:

The first book to get is **LEARNING ELECTRONICS BOOK 1 - $3.50**

It starts at the very beginning with batteries, wires, switches, LEDs, resistors, and goes through to transistors, chips and gates. It covers more than 20 simple projects that can be purchased individually or as a complete package for $130 plus $8.00 post. One of the kits is the TTL Trainer as needed for Starting in TTL (in Electronics Notebook 1).

Then: **Electronics Notebook 1 - with Starting in TTL - $5.00** You will learn about TTL chips and how gates work as well as lots more theory.

Digital Electronics REVEALED - $5.00 This book covers more theory in a hand-written format similar to a blackboard style.

Then you can advance to: **LEARNING ELECTRONICS Book 2 $3.60** This book contains more theory and 10 projects.

Electronics Notebook 2 - $5.00
Electronics Notebook 3 - $5.00
Electronics Notebook 4 - $5.00
Electronics Notebook 5 - $5.00

You already have Electronics Notebook 6 and in the back you will find a complete index for the 6 Electronics Notebooks as well as Revealed.

Once you get these you will start to see things coming together and you can try some of our other books, these are:

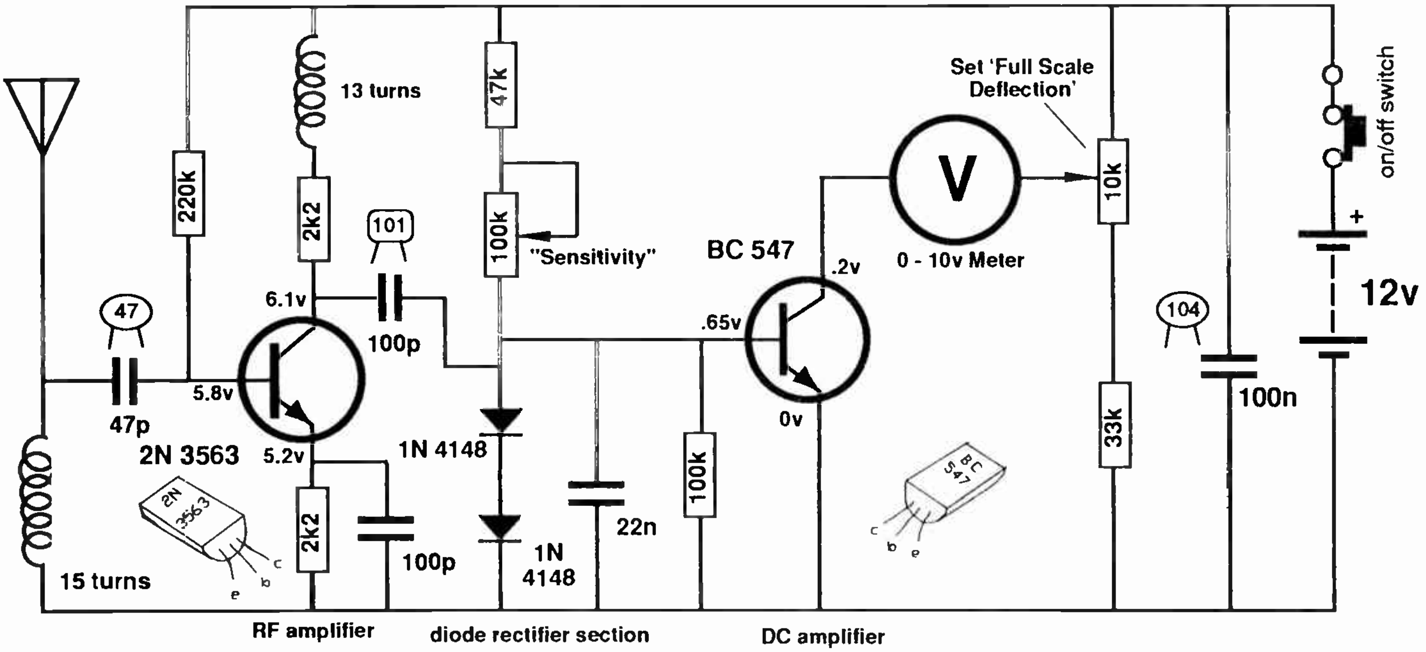
Security Devices - $3.60
14 FM Bugs to Build $3.50 and
Smart Security Devices Book 1 $3.60

You can send a Money Order to Talking Electronics for any of the books and include postage at $2.50 for the first book and 70¢ for each additional book. The address is on the inside front cover. Don't forget to use the order form.

THE FIELD STRENGTH METER MkI

Parts & PC $8.70
PC Board (only) $2.50

Essential for checking the output of our FM transmitters.



FIELD STRENGTH METER MkI CIRCUIT

This Field Strength Meter has been specially designed for our FM bugs. It is capable of detecting very low power transmitters and will assist enormously in peaking the Amoeba, Ultima, Vox IV & V and checking the output of the other bugs too.

Up to now, field strength meters have only been able to detect transmitters with an output of 100 milliwatts or higher, and for an output such as this, a simple circuit such as a meter and a coil is sufficient. But when it comes to a low power device, a simple circuit, with no amplification, is not suitable.

We spent more than 5 days building all the circuits we could find, that purported to be suitable for low-power transmitters, hoping that one of them would work.

Unfortunately none came anywhere near good enough so we had to design our own.

The circuit we came up with is shown above and it incorporates an RF amplifier, diode rectification, and a DC amplifier so that a movement from a multimeter (a movement is the 'meter' part of a multimeter) could be used as the readout. The heart of the design is a pair of diodes that are partially turned on via a resistor (the 100k sensitivity control) and this overcomes some of the .6v threshold of a diode.

You may not think .6v is very much but when you are talking in millivolt terms, it is 600 millivolts. The signal we are attempting to pick up produces one or two milli-volts on the receiving antenna and if you need 600 millivolts to turn a diode ON, the field strength meter becomes very insensitive.

Our design overcomes this problem and produces a reading up to 10cm from a bug. This means you can adjust and peak a bug with the antenna fitted and get an accurate indication of the power it is producing.

Up to now you have had to rely on the "LED Power Meter" as described in the Amoeba and Ultima articles and although it gives a good indication of the RF energy, it does not take into account the loading effect of the antenna.

The antenna loads the output stage of any transmitter and when you have a low power device such as ours, the antenna tends to detune the frequency slightly so that a slight re-peaking is necessary if you want to get maximum performance. The field strength meter will allow you to do this and get back the extra performance you may have lost.

PARTS LIST
2 - 2k2
1 - 33k
1 - 47k
1 - 100k
1 - 220k

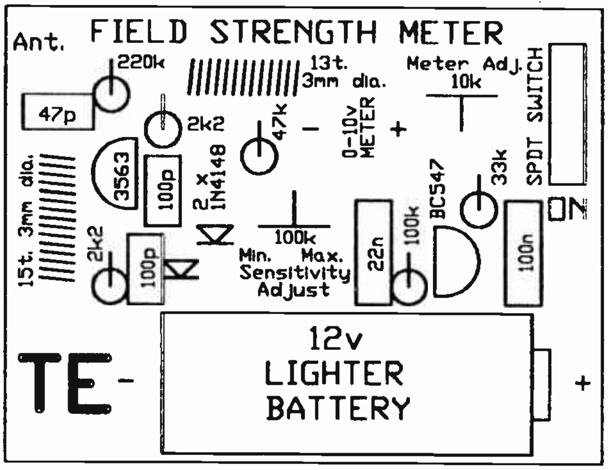
1 - 47p ceramic
2 - 100p ceramics (101)
1 - 22n ceramic (223)
1 - 100n ceramic (104)

1 - 10k mini trim pot
1 - 100k mini trim pot
1 - BC 547 transistor
1 - 2N 3563 RF transistor
2 - 1N 4148 diodes
1 - 13t enamelled wire 3mm dia coil
1 - 15t enamelled wire 3mm dia coil
1 - 12v lighter battery
1 - 25cm enamelled wire
1 - SPDT mini slide switch
2 - paper clips

1 - FIELD STRENGTH METER PC BOARD
1 - multimeter (0-10v range)

HOW THE CIRCUIT WORKS

The circuit consists basically of an RF amplifier, diode rectifier and a DC amplifier. The first feature that may be



The new CAD board shown 200% larger than normal.

new to you is the inductor in the antenna circuit. You may think it produces a short-circuit between the antenna and earth but the inductance of the 15 turn coil creates a voltage across it when the antenna picks up a signal. This voltage is fed to the base of the first transistor via a 47p capacitor and since the transistor is turned on via a 220k resistor, any signal from the 47p will be amplified by the transistor.

The RF amplifier has been designed to only have a gain at high frequencies. In our case this is at about 100MHz to 300MHz. The 300MHz is the upper limit due to the response of the RF transistor and the lower frequency is governed by the 100p bypass capacitor on the emitter.

It's impedance at 100MHz is 16 ohms and this gives the stage a gain of about 12. At 10MHz the reactance of the capacitor is 160 ohms and the gain of the stage drops to about 2.

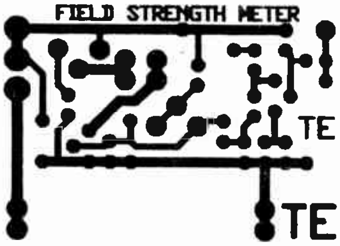
This prevents low frequencies from being amplified and up-setting the reading.

By increasing the value of the emitter bypass capacitor, the gain of the stage will be increased but this is not desirable as it may cause excessive gain in which the front end self-oscillates.

The inductor in the collector circuit separates the output signal from the power rail and increases the output amplitude slightly.

The low value coupling capacitor (100p) between the RF stage and diode pair is sufficient to transfer the energy as, don't forget, we are dealing with very high frequencies. The two diodes in the diode stage simply work as a rectifier and are partially forward biased via a 47k and 100k 'sensitivity' control from the positive rail. But they are not turned on fully due to the base emitter junction of the DC amplifier transistor only allowing .6v to appear across them.

When a signal is passed into the diode pair, the negative excursions reduce the voltage across them and this begins to turn off the DC amplifier transistor and thus the needle on the meter drops. It requires about 300mV signal to start the process and with a gain of about 12 on the RF transistor, we need about 30 millivolts developed on the antenna circuit to start the detecting process.



FSM artwork

This makes the Field Strength Meter only sensitive to nearby signals and prevents weaker signals from upsetting the reading.

The 10k pot connected to one end of the voltmeter sets the full-scale deflection for a 0-10v range on the multimeter.

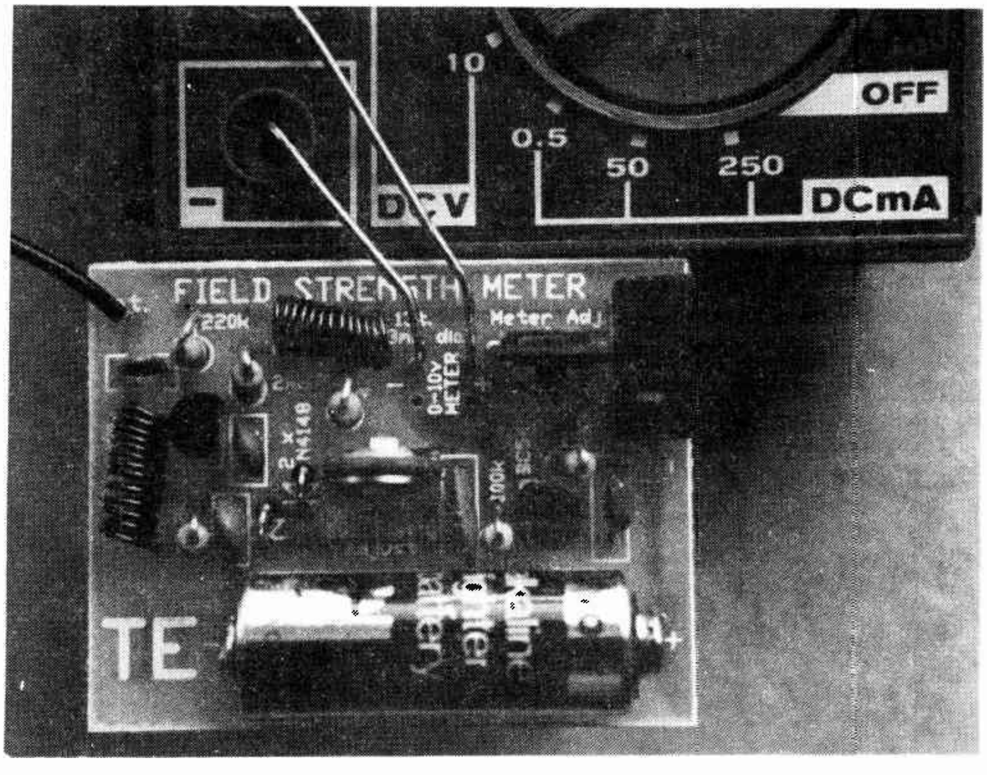
The circuit consumes about 3.5mA and with a lighter battery (50mAHr cells) the circuit will operate for more than 12 hours. A switch is provided to conserve the battery when not required and the board attaches to any multimeter via leads and paper clips that have been bent to suit the banana sockets on the meter.

Any old meter will do and it can have a sensitivity from 1k ohms per volt to 50k ohms per volt. The range we used in our prototype is 10v DC on a 30k ohms per volt meter however 12v, 15v or even 25v scale will be ok and the 25v range simply means the needle will not deflect as much, for the same RF detected.

You can even use an old, broken, multimeter providing the movement is not damaged. We have about 5 of these field strength meters at work, one for each worker, as everyone needs one to peak the devices we are making.

We turned 5 broken multimeters into active service. It's one good way of using up damaged equipment. It's amazing how the staff can blow up things, with the ohms range not working and the milliamp range burnt out.

I remember one firm had the same problem. They made all the staff spend



every Friday afternoon repairing the test equipment - but with the tight economics of today, we couldn't afford the luxury of providing half a day's holiday like this each week.

CONSTRUCTION

All the components, including the 12volt lighter battery and switch, mount on the PC board. The legend on the board shows where each part is placed and we have found it important to avoid over-heating the diodes and transistors as they lose their peak performance and cause the circuit to become very insensitive. Follow the overlay on the PC board to see where everything is placed. The coils are pre-wound in the kit and are wound on a 3mm diameter Philips screwdriver (if you are making your own) and the wire size is not critical as they simply form a broad-band trap.

The new artwork for the project is a CAD board and is shown on the previous page. As soon as the old-style boards have been used up we will be supplying the new board.

The antenna wire is enamelled to prevent it touching the active components of the bug you are testing.

We needn't say any more about construction as you will obviously know how to put the kit together.

SETTING UP

Solder the paper clips to the board as shown in the photo and bend them to suit the sockets on the multimeter. Turn the "sensitivity" control (100k pot) to minimum resistance and switch the circuit ON. Turn the "Set full scale deflection" pot (10k) to give full deflection on the meter. Now turn the sensitivity pot until the needle just starts to "dip."

At this point the circuit is the most sensitive as the DC amplifier transistor is just turned on and any signal appearing on the diodes will reduce the voltage appearing on the top of them and turn the transistor off - the needle on the meter will begin to drop. The Field Strength Meter is now ready for use.

USING THE FIELD STRENGTH METER

This project will help you get the best out of any transmitter. It will give an accurate readout because it does not connect to the transmitter but registers the strength of the field AT A DISTANCE.

The way it is used is to set up the antenna of the Field Strength Meter in the same plane as the transmitting antenna (to get the best pick-up) and at a distance that just causes the needle on the meter to deflect.

The meter is wired as a "DIP" meter and the needle deflects towards zero as the field strength increases. Place the bug to be peaked on the test bench, with the antenna out-stretched and bring the receiving antenna so that the needle just starts to dip.

Peak the circuit a small amount and take your hands away so that they don't upset the reading, and watch the needle. As the output increases, the needle dips further. By maintaining the exact same distance between bug and meter, you can compare one bug with another.

It's the fastest way of determining the output without doing a "field test."

IF IT DOESN'T WORK

As with all our projects, they work because we have actually built them and checked their performance. If yours doesn't work, the first thing to do is check the value of the components against the overlay on the board.

Two components in the wrong place can make a huge difference and a circuit like this is fairly critical as the biasing must be correct.

Secondly, make sure all the parts are fitted and nothing has been missed. Also make sure all the parts have been soldered neatly and cleanly.

We still get projects sent to us for repair where one or more leads have not been soldered and obviously the project could never work.

Next you can make a few voltage readings. Although they don't tell you too much, it is a fast way of determining if a stage has the correct DC conditions. The voltages are:

RF Stage:
  Collector: 6.1v
  Base: 5.8v
  Emitter: 5.2v
DC stage:
  Collector: .2v
  Base: .65v
  Emitter: 0v

If these check out ok, you should make a few further DC tests. If the meter swings full scale at power-up, you should short between base and emitter of the BC 547 to see the needle falls to zero. This will show the transistor is working ok. If not, the transistor may be shorted.

Next remove the 47k on the diode pair. This will also cause the needle to move down-scale and show the biasing network is working. It is more difficult to test the RF stage and merely probing around the stage with a meter or CRO, will pick up hum and cause the needle to deflect.

Of course we have assumed you have bought a kit and PC board for the project. The frequency of operation of this circuit makes it important that it is built on the correct PC board.

We cannot guarantee "breadboard" jobs or circuits made with your own components as so many variables creep in. Things like different markings on capacitors, different RF transistors or signal diodes could make the difference between success and failure.

If you know what you are doing, that's fine - you can use your own components. But if you intend to learn from our projects, don't take any chances. It's cheaper in the long run to get all the projects in kit form and build them exactly as specified.

If you get really stuck, don't hesitate to buy another kit and start again. You can come back to the faulty one later. This project is so important that we don't want you to miss out. With a field strength meter you can carry out experiments that would take a chapter of a book to explain. Here's one:

EXPERIMENTING

Take the Voyager project and connect 30cm of tinned copper wire to the antenna point on the PC board. Hold the Field Strength Meter in your hand (keep away from the actual circuit by holding the multimeter) and bring the receiving antenna near the Voyager antenna, without touching it. As you move up and down the Voyager antenna, watch the needle.

It will show that energy is not radiated uniformly from the antenna but has a maximum and minimum value. It is for you to see where these occur. Measure the length of the antenna and plot the results. Cut 2cm off the antenna and repeat the tests. Fit a 175cm antenna to the bug and repeat the tests.

This will give you a good understanding of the phenomenon of electromagnetic radiation.

There are lots of other things you can test with this project including our latest Pen Bug with its active antenna and I am sure you will find it essential for RF work in general.

The Field Strength Meter MkII is presented in the next article and has the advantage of a tuned front end and 3-LED readout. This will enable you to not only peak transmitters but also find the frequency on which they are operating.

It detects in the range 75MHz to 140MHz enabling you to design and build transmitters capable of transmitting off the normal broadcast band.

But don't put off building this project as you will need both of them as they have different capabilities. And you also need the LED Power Meter (see "14 FM Bugs to Build").

Test equipment is very important when working with RF so don't put it off any longer, start now and build up your range of gear. We will have more for you in the future so start now and keep it at the ready.

GETTING INTO BUGGING

GETTING INTO BUGGING simply means building some of our FM transmitters.

FM transmitters are generally called "BUGS." This is one of those colloquial terms that has been handed down over the ages. Its origin is unknown but maybe it came about due the small size of electronic listening devices. As electronics became smaller and more miniaturised, the average person thought they would end up the size of an insect. Thus the name 'BUG'.

And it's a great name to use.

Over the past few years, Talking Electronics has designed a number of FM transmitters or "Bugs" and presented them in a series of books called Security Devices, FM Bugs, More FM bugs and others. Many of these books are now out of print and the best of the projects have been squeezed into a title called 14 FM BUGS TO BUILD.

This book has just recently been reprinted and is available from the same store you purchased this book. Once you get into transmitter building you will find a whole new world of electronics will open up.

Building an FM transmitter is very rewarding as it requires relatively few components to achieve a very effective project.

It is quite easy to build something capable of transmitting 100 metres or more with a quality that is crystal clear and super-sensitive to sounds as soft as a whisper.

These type of transmitters can be used for many different applications including security, baby minding, nature study and bird-life monitoring as well as the favourite STAGE MICROPHONE.

The book has step-by-step plans to build a simple transmitter such as the 'ANT' or 'GNAT' or 'FM BUG' and after building these you will want to advance to more complex models such as the 'AMOEBA', 'ULTIMA', 'VOX MK IV' and MkV.

These circuits need a little more skill as they have two tuned circuits and you will need a couple of pieces of test equipment to get the best performance from them.

This is why we have designed the Field Strength Meter MkI and MkII.

In this issue you will find the two Field Strength Meter projects. Each is slightly different and you will need both if you intend to work on low power RF circuits.

We have also designed another piece of test equipment called the LED Power Meter (you will find it described in the Ultima article in "14 FM Bugs to Build").

It is designed to connect to a multimeter and indicate when energy is being produced by an RF circuit.

These pieces of equipment are called "Test Gear" and you only need one of each, no matter how many transmitters you are building.

Many readers think they need to buy one for each bug, thinking they will be "used up," but this is not so. Test equipment lasts a life-time.

The aim of this article is to show you how to get into FM transmitter building; where to start and how to follow through.

WHERE TO START

The place to start is to get the book "14 FM BUGS To Build."

Read through all the projects as they will all help you to learn about transmitters. When you get a fairly good idea of what's in store, you can send for a kit.

If you are a beginner at soldering, get the FM BUG. It is constructed on a fairly large PC board and is very easy to put together.

After this you can go to either the ANT or GNAT, where the parts are more closely packed with some of them standing on end and others lying down.

The ANT is a very compact transmitter that can be carried around, such as a stage microphone. This is the only transmitter stable enough to carry around like this.

All the others are highly active and should be placed on a shelf and left in position. The reason for this is the oscillator and output stages are producing a very high waveform and operating at the maximum level so that any stray capacitance such as from your hand or body will alter the frequency of transmission.

The output of the FM Bug, Ant and Gnat can be determined with the LED Power Meter. Although the reading will not be very high, it will prove the existence of RF and show the circuit is working.

After you have built any of these, the learning doesn't stop. You can change the frequency of transmission by adjusting the spacing of the oscillator coil, experiment with different types of antenna, work out the best placement for the antenna and try to get the best range possible.

Once you consider you have one of these models giving the best range, you can go to the next level and put together the AMOEBA or ULTIMA.

These have two tuned circuits and require test equipment such as the Field Strength Meter MkI and/or MkII to get the best performance.

The FSM MkI is the first to buy and is connected to a multimeter. It has a broad-band and will indicate the presence of energy but it won't tell you the frequency at which the bug is transmitting. If you find you cannot pick up the transmission on a radio, you will need the Field Strength Meter MkII. It has a tuned input and will detect frequencies from 75MHz to 140MHz and will help find the frequency of a bug that is outside the broadcast band.

After completing the second level of models, we have a more advanced level with the VOX MkIV and MkV. These have additional components for voice activation and beep sections. The VOX MkV is a surface-mount version and should be left to last.

If you have not built a surface-mount device before, we have three simpler models. The easiest model is the Voyager. It uses 5 surface mount resistors. The next is the Spy Bug. It uses surface-mount resistors, capacitors and a surface-mount transistor.

The most complex model is VOX MkV. It is nearly fully surface-mount and includes a surface-mount chip.

The aim of all our projects is to teach you electronics and all the circuits have been tried and tested by thousands of constructors and are graded from beginners level to advanced.

Building FM transmitters combines many facets of electronics including audio amplification, RF oscillators, tuned circuits, RF transmission, as well as stability, frequency control, regulation, PC board layout, inductance etc, and the list goes on.

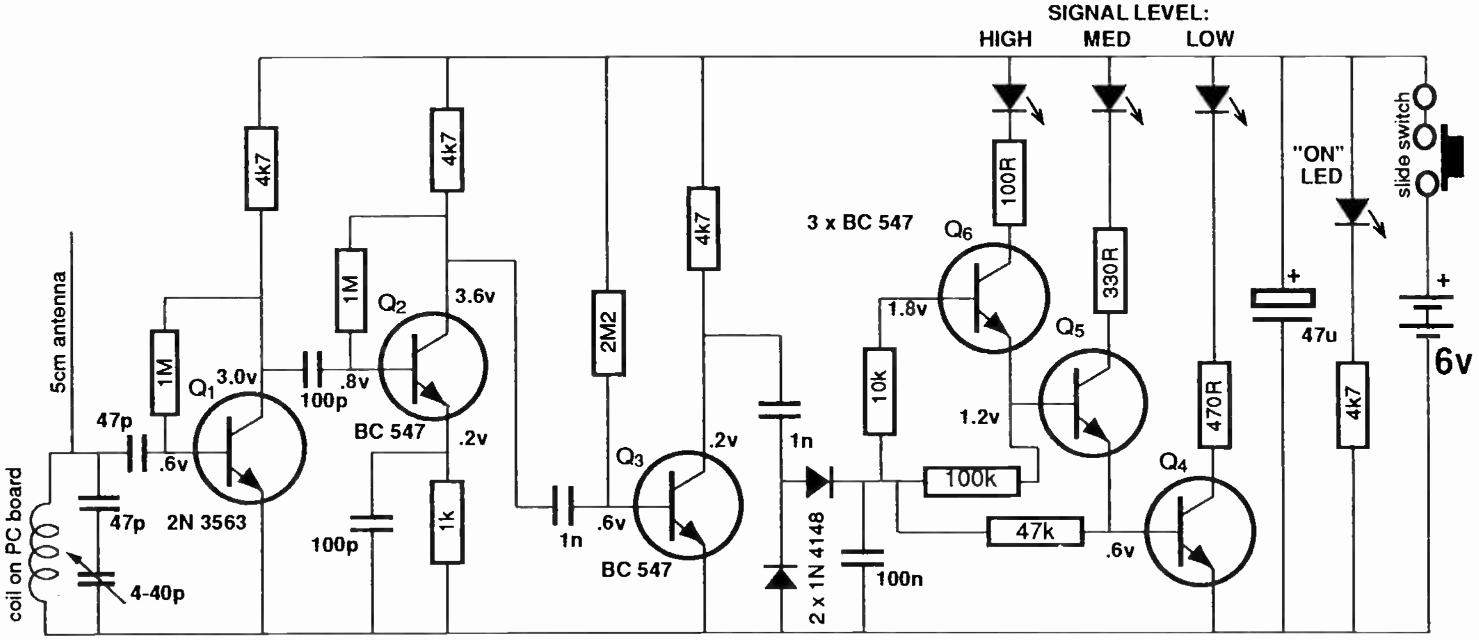
At all stages we encourage you to carry out your own diagnosis, testing and peaking of these devices rather than send them in to us for service. Although we provide a repair section for our projects, too many constructors are simply sending things in without carrying out the simplest sequence of tests.

If you buy the right kit for your level of knowledge you will not have any problems getting it to work.

With this, I hope to see you sending for a kit soon.

FIELD STRENGTH METER Mk II

Parts & PC: $13.60
PC board only: $3.00



FIELD STRENGTH METER MkII

This project has 3 features. It's ① a Field Strength Meter, ② a Frequency Meter and ③ an aid for testing detuned transmitters.

Its uses will become clear in a moment but firstly let's go over the background of a Field Strength Meter.

A Field Strength Meter is essential when designing and building transmitters. It provides signal strength values and allows us to compare and estimate the efficiency of a transmitter and its expected range.

Obviously the most accurate way of getting these results is to make a field test but this sometimes requires travelling long distances, so the next best thing is to get results on the bench by using a piece of test equipment such as an RF POWER METER.

An RF power meter is similar to a field strength meter, however the two are used slightly differently.

An RF Power Meter is generally connected directly to the antenna of a transmitter whereas a Field Strength Meter is placed NEAR the antenna without physically touching it.

When you only have 5 - 50 milliwatts available, it is very difficult to place a measuring device (such as a Power Meter) in the antenna circuit without it absorbing and upsetting the energy being radiated.

When you are dealing with frequencies in the 100MHz range, the signal flows over and through any device you place in the antenna circuit. Some of the signal is absorbed in the measuring device so that the reading may not be a true indication of the output. At the same time the performance of the transmitter is reduced so you don't know how to interpret the results.

A much more accurate way of detecting the energy is to place a device NEAR the radiating source (the antenna) so that it does not interfere with the transmission.

SUMMARY

- **Checks the output of low-power transmitters**
- **3 LED readout**
- **Detects from 75MHz to 140MHz**

This is the advantage of our FSM. It is placed near the radiating source and detects the energy AT A DISTANCE so that the output is not upset.

This project differs from the first FSM described on page 18 in that it is a stand-alone unit and does not require connection to a multimeter.

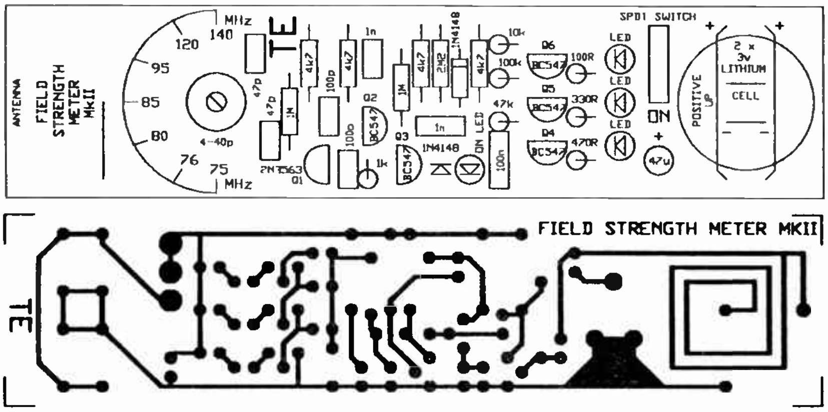
It contains a set of 3 LEDs, wired in a staircase arrangement, so that they light up progressively as the strength of the signal increases.

A trimmer capacitor at the front end tunes the exact frequency of the trans-

Voltages on Q1, Q2 and Q3 measured with no input signal. Voltages on Q4, Q5 and Q6 measured with full input signal.

PARTS LIST

1 - 100R
1 - 330R
1 - 470R
1 - 1k
4 - 4k7
1 - 10k
1 - 47k
1 - 100k
2 - 1M
1 - 2M2
2 - 47p ceramics
2 - 100p ceramics
2 - 1n ceramics
1 - 100n monoblock capacitor
1 - 4 - 40p air trimmer
1 - 47u 16v PC mount electrolytic
2 - 1N 4148 diodes
5 - BC 547 transistors
1 - 2N 3563 transistor
4 - 3mm red LEDs
1 - spdt slide switch
1 - paper clip for pointer on trimmer
1 - 5cm enamelled wire for antenna
1 - 10cm tinned wire for batteries
2 - 3v lithium cells
1 - FSM MkII PC board



Full-size artwork for Field Strength Meter MkII

mission and as the FSM is brought closer to the antenna of the transmitter, more LEDs will turn on.

We have already commented on the effectiveness of FM transmission in our many transmitter articles and shown that the range is a result of good design. The efficiency of a transmitter has a lot to do with the design of the output stage and this can be improved by adding features such as a TANK CIRCUIT and a RADIO FREQUENCY CHOKE. These are truly amazing additions as they increase the range of the transmitter without consuming any more current because they concentrate the signal into a narrow band.

One of the most-often asked questions is "How much power is a particular transmitter producing?" This is very difficult to answer but a simple rule of thumb is to allow 30% of consumption from the supply as the output power.

Thus the Amoeba at 7mA and 3v has an output of about 7 milliwatts. The Ant has the same consumption and yet the range is only one-quarter, so you can see that efficiency plays a big part in getting the range.

The Ant would be down to 1 milliwatt or less and this is shown by the fact that the output of the Ant is barely detectable on the LEDs.

The difference between the Ant and some of our other transmitters is more than 100:1 and this has made it difficult for us to produce a project that will cover the whole range.

To measure the output of the Ant you will have to wind up the antenna and push the probe into the centre of the coil.

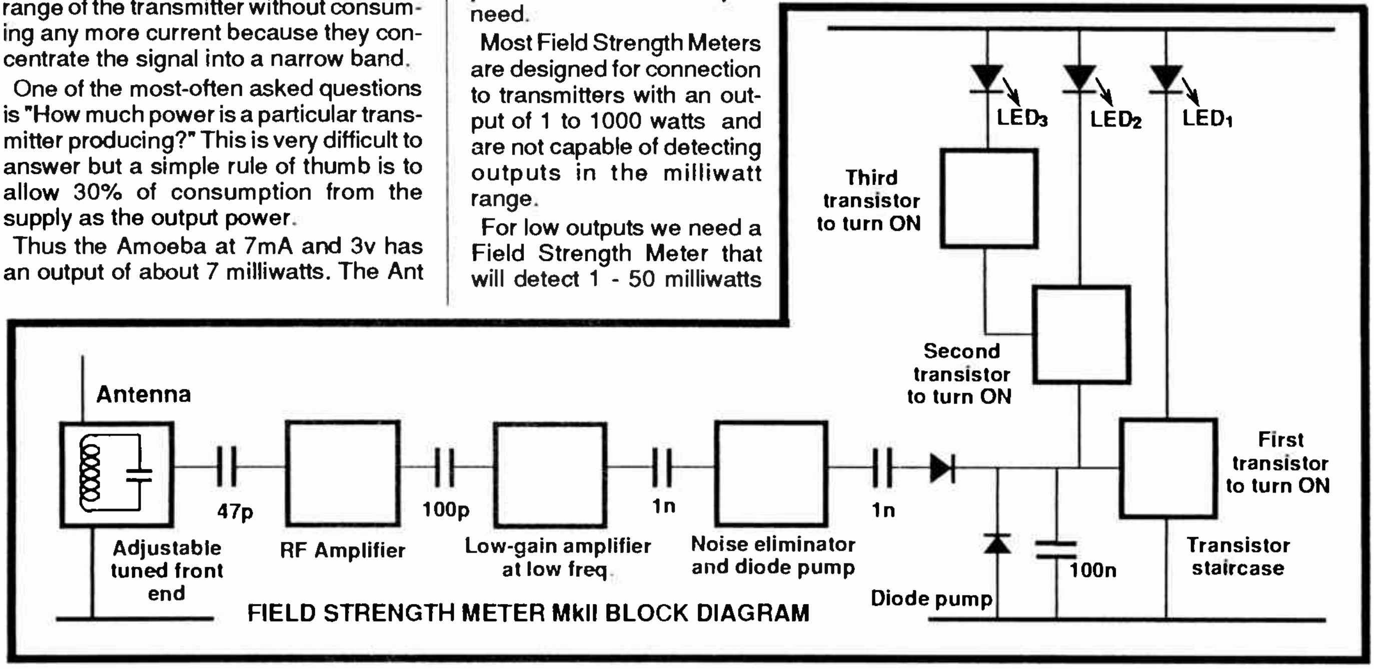
All the other transmitters have sufficient output to detect the radiation when the antenna is outstretched.

With some of the transmitters, such as the Amoeba and Ultima, the tank circuit must be adjusted so that the output is a maximum.

If you have a radio with a signal strength meter, you won't need this project, but if you don't, it's what you need.

Most Field Strength Meters are designed for connection to transmitters with an output of 1 to 1000 watts and are not capable of detecting outputs in the milliwatt range.

For low outputs we need a Field Strength Meter that will detect 1 - 50 milliwatts and that's why we designed this project.



FIELD STRENGTH METER MkII BLOCK DIAGRAM

As we have said, it is an adaption of the one we described on P.18 and in place of the meter in the output we have used a series of 3 LEDs. This makes it self-contained and "frees-up" your multimeter for other uses.

The third feature mentioned in the introduction enables you to determine the frequency of detuned transmitters. The FSM is able to detects frequencies as low as 75MHz.

This is very handy when designing transmitters for operation below the 88MHz band.

When working with a transmitter in this range it is important to keep the frequency just below 88MHz as many radios can only be detuned a few MHz before the stations at the top of the dial start to appear at the bottom.

If a bug is below this limit it will be impossible to find, even on a detuned radio.

There are two methods of detuning a radio.

One is to move the turns of the air coil near the tuning gang and see if the stations move up or down the dial.

To produce a space at the bottom of the band, the stations must be moved up and if you squash the turns too much, the top stations will wrap around and appear at the bottom.

The other method is to adjust the trimmers on the back of the tuning gang. This has proven to be the easiest and best method. Simply turn the trimmers until a space is created at the bottom of the dial and your transmitter can be fitted into the space thus created.

When you try to pick up the transmitter on a normal radio, it will be invisible!

HOW THE CIRCUIT WORKS

The circuit consists of a tuned front end, an RF amplifier, two further stages of amplification, a diode pump and a transistor staircase.

The circuit picks up RF energy on its 5cm antenna and passes it to a tuned circuit where all the frequencies EX-

CEPT ONE are lost in the coil:capacitor combination. The only frequency to appear at the output (the top) of the tuned circuit is the one that is equal to the natural resonant frequency of the tuned circuit.

This signal is passed to the RF amplifier stage where it is amplified.

The coil for the tuned circuit has been etched on the PC board so that it is a known and fixed value of inductance. This allows us to use a trimmer capacitor and put a scale around it on the PC board so that you can read the frequency.

Even though the coil does not have a very good "Q" factor it will be ok in this case as the Q is not important.

In other words the tuning will be fairly broad and you will have to find the "centre spot" to get the exact frequency. Even then, the frequency will not be exact as the scale has not been individually calibrated. It's only designed to give you an approximate value.

Back to the tuned circuit:

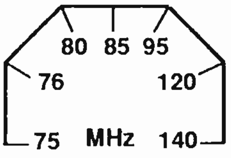
The way in which the tuned circuit works is quite amazing. All the signals from radio stations, taxis, bugs, TV stations, cellular phones etc are picked up by the antenna and passed to the tuned circuit where they try to set it into operation.

It's a bit like hundreds of people trying to push a person on a swing - most of them will get in the way of each other. For example, a signal at 150MHz will try to push the swing when it is coming towards the pusher and the energy will be applied at the wrong time.

All the other signals will be pushing at the wrong time too and the only signal that pushes at exactly the correct instant will be the one marked on the scale. Its energy will not be lost in the tuned circuit but appear on the output. This signal is passed to the RF stage via a 47p capacitor for amplification.

The RF stage is able to amplify signals in the 100MHz range as we have used a high frequency transistor and the output appears at the collector.

Two further stages of amplification are needed to increase the signal so that it is large enough to be fed into a diode pump. Q_2 is biased in a standard self-bias configuration while Q_3 is biased in an unusual way. It is biased ON so that small signals on the input do not appear at the collector. This means the noise generated by the first two stages is prevented from appearing on the diode pump. Only signals above a certain threshold on the base of Q_3 appear on the collector. This signal is rectified by a signal diode and fed into a 100n reservoir capacitor.



The scale for FSM MkII

The other diode (between the 1n capacitor and negative rail) removes the negative portions of the waveform and thus discharges the 1n capacitor so that it can supply positive pulses for the charging process.

The first transistor in the staircase (Q_4) starts to turn on when .6v is present on the reservoir capacitor. As the voltage rises to .65v the LED connected to the collector of Q_4 gets brighter and brighter. Due to the slight voltage drop across the 47k base bias resistor, the voltage on the reservoir capacitor needs to be slightly higher than .65v and once the first transistor in the staircase is turned on fully, the next transistor (Q_5) will begin to turn on as the voltage on the reservoir capacitor (100n) rises slightly above 1.3v (.65v + .65v).

This process continues with the middle LED getting brighter and brighter until it is fully turned on.

As the voltage on the reservoir capacitor increases, the top LED will come ON and illuminate fully.

The 3 LEDs will give plenty of range as you can read values such as a LED fully turned on or partially turned on.

It is important to know that the lower transistor (Q_4), turns on FIRST and as the voltage on the reservoir capacitor increases, Q_5 then Q_6 turns on. Without this, you will not be able to understand how the circuit works.

CONSTRUCTION

All the components fit on the board, with the two lithium cells at the end.

The overlay shows where the parts are placed and it's a simple matter to fit everything close to the board. If the leads of any of the components are left too long, the circuit will give a different gain to our prototype and not work properly, so keep everything neat.

The transistors, diodes and LEDs must be placed around the correct way and not overheated, otherwise the transistors will lose their gain and the LEDs will lose their brightness.

Bend the paper clip into an "L" shape. Do not cut it with side cutters as the metal is very hard and will damage your cutters.

To position the pointer correctly, fully engage the vanes of the trimmer and tin the top with solder, very quickly. If you take too long the plastic between the vanes will melt and the trimmer will be destroyed.

Now tin the end of the paper clip and solder it on to the top of the trimmer very quickly so that the pointer is over the 75MHz mark. The pointer is now in the correct position.

Don't forget the link at the front, near the etched coil.

Mark the ON position for the switch with nail polish and place electricians tape around the two lithium cells before fitting them to the board, with straps of tinned copper wire.

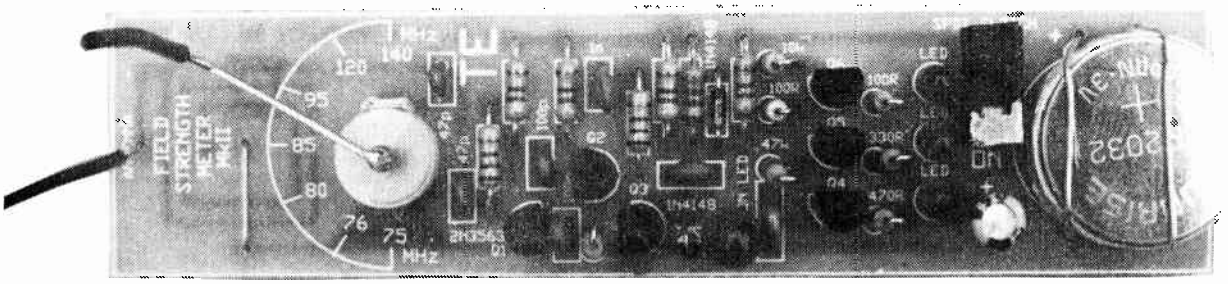
The rest of the assembly should be straight-forward.

USING THE FIELD STRENGTH METER

We are assuming the project works correctly and has been checked as per the "If it Doesn't Work Section."

To check the output of an FM transmitter, place it on the work-bench with the antenna in a horizontal plane, away from any metal objects.

Switch it on and place the antenna of the Field Strength Meter about 20cm away, with both antennas in the same plane.



Completed Field Strength Meter MkII

Gradually turn the trimmer by moving the paper clip with your finger, while keeping away from the coil on the underside of the board until the maximum readout is detected on the LEDs.

The pointer will then give you the frequency at which the transmitter is operating.

As you move the FSM away, the LEDs will dim and as it is brought closer, more LEDs will come on.

If you wish to compare one transmitter with another, simply put the second in exactly the same place on the bench with the antenna at the same distance. You may have to re-tune the FSM to pick up the frequency, however you should get the same reading on the LEDs if both have the same output.

When working with detuned transmitters, you can use the scale around the trimmer to give readings from 75MHz.

If you have a transmitter tuned to a band above 108MHz, the FSM will detect frequencies up to 140MHz.

When using the FSM, it is important to keep your hands away from the board, especially the front end, as the loading of your body may affect the readings slightly.

IF IT DOESN'T WORK

The first thing to do is check the components against the overlay on the board.

All the parts must be around the right way and as close to the board as possible so that everything will be the same as our prototype.

Check the underside of the board for any leads that are bent over and touching other tracks.

Don't forget to check the soldering for shorts and make sure the tracks are not damaged in any way.

Next check the current by measuring across the switch. In the quiescent state, when only the power LED is illuminated, the circuit should consume about 3mA. When 1 LED is illuminated, the circuit should consume about 10mA, for 2 LEDs the circuit should take about 18mA and when the 3 LEDs are illuminated it should be about 26mA.

If this is not the case, and the LEDs don't come on correctly, you will need to look into the circuit more thoroughly.

The circuit can be separated into two sections at the point where the 1n capacitor meets the two diodes.

The left half the diagram is classified as AC coupled and the right half is DC coupled.

The letters AC stand for "Alternating Current" however we really mean each stage is CAPACITOR COUPLED so that the DC voltages on one stage are not transferred to the next - a capacitor separates the stages.

The only thing that passes from one stage to the next in an AC coupled circuit is the AC waveform and although you may think this can be called an ALTERNATING CURRENT waveform, we do not use this term. We only say "AC coupled."

I know this is confusing however you have to learn the correct terminology if you want to discuss electronics.

To repeat myself, we say the left-hand half of the circuit is AC coupled. We don't say Alternating Current coupled. We just say "it's AC coupled" and only the AC voltages are passed from one stage to the next.

In other words, each stage is self-contained and the biasing comes from within the stage itself. If we view the waveforms on a CRO we call them AC waveforms and yet they are really alternating voltage waveforms.

The right-hand half of the circuit is much easier to explain as it is DC coupled (yes, Direct Current coupled). You can also say "Directly Coupled."

The easiest half to work on is the DC coupled section so we will start with it and this means covering transistors Q_4, Q_5, Q_6, and their associated components.

The quickest way to check if this section is working is to take a jumper lead from the join of the two diodes to the positive rail.

This will put full rail voltage on the reservoir capacitor and make all the LEDs come on.

If this doesn't work, take the jumper lead from the collector of Q_4 (the bottom of the 470R) to the negative rail. This will turn on the lower LED. If not, the LED may be around the wrong way.

Next, connect the bottom of the 330R to the negative rail (for the middle LED) and finally the bottom of the 100R for the top LED.

This proves the 3 LEDs (and current limiting resistors) are working.

Shorting between the collector and emitter of the middle transistor (Q_5) will turn on the two lower LEDs and show that the lower transistor is functioning. Shorting between the collector and emitter of the top transistor (Q_6) will turn on the 3 LEDs and show that the middle transistor is operating.

This is the extent of the simple DC tests for the staircase and the only other thing you can do is take voltage readings on the base of each transistor when the reservoir capacitor is fully charged. These values are shown on the circuit diagram.

The 3 RF stages are much more difficult to test and the only thing you can do is measure the voltage on the collector of each transistor and assume it is biased correctly and the coupling capacitors are passing a waveform (the AC). If you have a CRO you can see the amplitude of the waveform increase as it passes from one stage to the next and by bringing a bug such as a Voyager near the antenna, the LEDs will gradually light up.

If you have a working model of the FSM you can use it to test a non-working model. Use the antenna of the good unit as a probe to see if a signal is being amplified through each stage of the non-working model. If you don't have a FSM you will need something like a 100MHz CRO - but these cost between $2,000 - $4,000!

Now you can see why a FSM is so valuable. It's a very low-cost way of measuring the characteristics of transmitters in the 100MHz range.

If you are building our transmitters, a Field Strength Meter is an essential piece of equipment. Buy a kit with your next order and you'll find how valuable it is.

QUESTIONS FOR ADVANCED CONSTRUCTORS:

1. What is the purpose of the 47p in series with the 4-40p trimmer?
2. Why is the coil etched on the PC board?
3. What is the purpose of the 100p and 1k in the emitter of Q_2?
4. Why is Q_3 biased fully ON?
5. For the diode pump, does the transistor or the 4k7 collector resistor charge the 100n?

ANSWERS:

1. The 47p in series with the trimmer adjusts the effective value of the trimmer to 3.5 - 20p. The easy way to remember this is: two equal-value capacitors in series produces a value of half the smaller value. Thus 40p and 40p produces 20p. For the smaller value, the ratio is about 10:1 or 4p:47p. We use the same reasoning and see that the 47p will alter the 4p very little. This is the way to see things without using mathematics.
2. The coil is etched or fixed on the board so that we can generate a scale around the trimmer that will be the same for all models.
3. For low frequencies, (1MHz etc) the 100p will have a high reactance and thus the gain of the stage will be the ratio of the 4k7 to 1k or about 5. Thus the stage will not amplify all the hash and noise of the low frequencies.
4. Q_4 is biased fully ON to further reduce the noise and hash produced by a self-biased stage and also to give the diode pump full voltage swing.
5. The charging current for the diode pump is supplied by the 4k7. The transistor merely pulls the 1n low to discharge it through the lower diode.

SUBSTITUTING TRANSISTORS

I am going to make a bold statement.

"Almost all the transistors in the world can be replaced by a handful of different types."

I know this isn't entirely true but I want to change your attitude to transistors and come to the realisation that there are basically very few different types.

So why do they make so many?

Believe me, if I knew, I would be an oracle! But the main reason seems to be due to batching. There are so many parameters such as gain, maximum voltage, current etc that out of a production run, the manufacturer can create more than a dozen different types.

When transistors are tested, the maximum ratings are determined and good devices are sold at a profit while "failures" are sold at a reduced price.

Manufacturers also try to copy the parameters of their rivals and this produces more "near misses."

Add to this the list of "special" types bearing a code name or number and you have the biggest disaster in the history of electronics.

No-one has produced a complete list of every type of transistor and even the most comprehensive guide is quite useless. The trouble starts when you come to repair a product that uses one of these "oddball" devices.

Your first reaction is to replace it with the same type. But most likely the transistor will not be listed in even a 200 page substitution manual - and you are left on your own.

That's when you will come to realise there are thousands of uncategorised transistors and you will have to tackle the problem from a different standpoint.

This is the sort of headache I have had on hundreds of occasions while repairing Australian, European and Japanese TV's and the only way to tackle it is to start from the beginning.

STARTING FROM BASICS

To work out the essential characteristics of the device you intend to replace, there are 3 features you have to match.

Firstly you have to work out if the transistor is PNP or NPN. This can be done from either the circuit diagram or by tracing out the circuit from the board. If one lead goes to the negative rail you can generally assume the transistor is NPN and the lead is the emitter. From there you can work out the base and collector.

The second most critical factor is the voltage rating. If the circuit operates from batteries, almost any transistor will be suitable as the rail voltage will only be about 10v - 15 volts.

The next higher voltage range is around 50v - 60v and then we go to transistors rated at about 100v - 250v.

For each of these groups, there are different transistors and you must make sure the transistor you are fitting is suitably rated. Low voltage transistors have a rating of about 25 - 35v, the medium range is 50 - 90v and the higher range is 100 - 250v. Don't forget, we are talking about SMALL SIGNAL transistors. Power transistors go much higher but I'm not going into this range in this discussion, as you need to be very skilled to replace a medium-to-high power, high voltage, transistor.

MOST TRANSISTORS CAN BE SUBSTITUTED WITH A CHEAPER EQUIVALENT. THIS ARTICLE EXPLAINS HOW

REMEMBER THIS:

The voltage rating of a transistor is very important. If the rail voltage is 60v, you cannot use a 35v transistor as it will Zener and start to leak when the voltage goes over about 45v.

But you CAN put a 60v transistor in a circuit with a rail voltage of 25v.

The voltage rating of the transistor is the maximum it can withstand before it starts to breakdown. It is a measure of the collector-emitter capability and you should always select a transistor with the highest rating possible to be on the safe side.

Next you should try to work out the current passing through the transistor or its dissipation, by looking at the size of the transistor, the tab or flange on the case and the size of the heatsink (if one is fitted). If it has a heatsink, it must be put back exactly as before as it is very important. Some charts will tell you the dissipation rating of the transistor according to the case style (with and without a heatsink) and this must be adhered to with the substitute.

In a nutshell, this is all you have to do. You don't have to worry about the gain of the transistor or its maximum cut-off frequency (unless it is in a very high frequency circuit) as most transistors are more than adequate.

To pick out a suitable transistor, refer to a specification sheet and choose one with the highest voltage rating (V_{CE}) and an equivalent current and wattage rating. Check the pin-out to make sure you will be fitting it correctly.

If any of the resistors around the transistor have burnt out or if the transistor is in a directly-coupled configuration, you have additional factors to consider.

Resistors must be replaced with ones of the correct wattage and resistance and surrounding transistors must be checked for shorts. Normally, all transistors in a direct-coupled arrangement are replaced at the one time as they will re-damage each other if replaced individually.

Once the faulty transistor or transistors have been substituted, you should carry out three tests:

Firstly check the voltage on the collector. It should be somewhere near mid-rail and if it is zero or full rail potential, you should look into the reason why. This will be a topic for a later discussion.

Secondly check for over-heating. To do this, turn the circuit on and off very quickly while placing a finger on the transistor. If it does not heat up, turn the circuit on for a longer period of time and monitor the temperature rise. It should not rise quickly, however a transistor fitted to a heatsink can get hot enough to nearly boil water!

Lastly you should check your substitution by listening to or monitoring the circuit to see if it is as good as before the failure.

If it is, you have been successful. If not you should try another substitute.

My approach to substituting transistors was born out of sheer desperation.

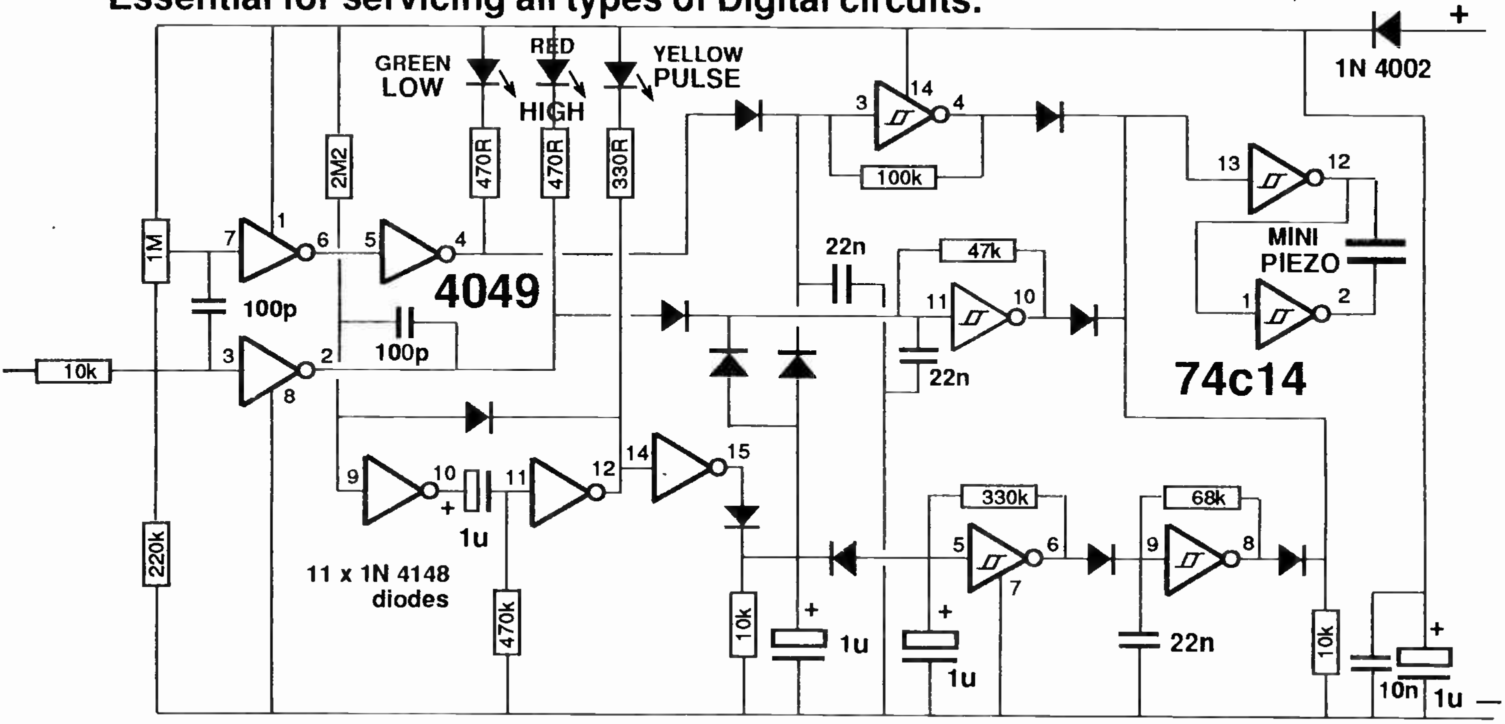
While on the road one day I ran out of an exotic transistor for a Rank Arena colour TV. It was a rather large metal-cased transistor in the vertical oscillator.

Since I did not have one in my kit, I tried a cheap Philips substitute. To my surprise, it worked perfectly. From that day I became rather blazé about fitting identical types and started to build up a list of cheap substitutes to replace the expensive imports. This has saved me a lot of money over the years and that's why I have passed the "good oil" on so that you will be more knowledgeable the next time you have an oddball transistor to replace.

LOGIC PROBE Mk IIB

Parts & PC: $16.30
PC board only: $3.00

Essential for servicing all types of Digital circuits.



LOGIC PROBE CIRCUIT

A Logic Probe is one of the most important pieces of test equipment for the digital designer.

Digital circuits will be covered in some of our later books and their testing involves a completely different approach to anything else. It requires special test gear to pick up very fast pulses to let you know if the circuit is operating correctly.

The most important piece of gear to do this is the Logic Probe. It lets you know if the lines of a particular device are HIGH or LOW or if a very brief pulse is present.

The Logic Probe is the digital technicians equivalent to the audio man's CRO (Cathode Ray Oscilloscope), and is specially designed for the job.

The reason why it is better than a CRO is due to the speed of a digital circuit.

You may be looking for a pulse that is appearing only once every second and its width may be a millionth of a second wide!

It would be very difficult to pick this up on a CRO but a logic probe catches the pulse and displays it on a Pulse LED so you can see it, as well as giving an audible beep from a piezo.

A logic probe is much easier to use than a CRO as it is capable of picking up all types of pulses including glitches and spikes that may be false triggering the project under test.

If you view some of the output lines of a digital circuit with a CRO, you may see "bips and bumps" and the waveforms produced on the screen will be very hard to interpret.

The Logic Probe does all the interpretation for you. It is very easy to use as it has 3 LEDs to indicate the state of the line while the piezo gives an audible indication that a waveform or pulse is present.

It is designed to respond to only those pulses that digital chips pick up, so you don't have to make any complex decisions.

A digital circuit may have a lot of noise on the lines that run between the chips and unless they are of sufficient amplitude to clock the chips, they will be ignored by both the circuit and the probe.

One point to remember, the tone from the piezo is not the frequency of the pulses on the line. These tones are generated by the probe and don't come from the circuit you are testing.

The tones allow you to keep your eyes on the probe tip while testing each pin of a chip.

It is essential not to allow the probe to slip between two pins of a chip as it may

PARTS LIST

1 - 330R
2 - 470R
3 - 10k
1 - 47k
1 - 68k
1 - 100k
1 - 220k
1 - 330k
1 - 470k
1 - 2M2
1 - 1M mini trim pot
2 - 100p ceramic
1 - 10n ceramic
3 - 22n ceramic
4 - 1u 16v PC mount electrolytics
11 - 1N 4148 signal diodes
1 - 1N 4002 power diode
1 - 4049 hex inverter IC
1 - 74c14 or 40106 hex Schmitt IC
1 - 3mm red LED
1 - 3mm yellow LED
1 - 3mm green LED
1 - mini piezo
1 - 14 pin IC socket
1 - 16 pin IC socket
1 - red E-Z clip
1 - black E-Z clip
1 - 40cm red hook-up wire
1 - 40 cm black hook-up wire
1 - paper clip for probe
1 - LOGIC PROBE PC board

(Buy a soft toothbrush case from the chemist to house the probe).

HOW THE CIRCUIT WORKS

The probe uses 2 IC's and a handful of components to indicate the state of the input on 3 LEDs while the piezo gives an audible indication of the state of the line.

The input is connected to two inverters in the 4049 IC. The top one is held above mid-rail via the 1M trim pot while the bottom one is held below mid rail by the 1M/220k voltage divider.

The object is to keep these two inverters in a stable state so that they will change state when an input waveform is detected.

The output of the top inverter passes through another stage of inversion so that the result is equivalent to that of a buffer.

The pulse circuit is taken from the lower inverter and passed through a pulse stretcher made up of two inverters in a monostable mode, to illuminate the pulse LED.

The 3 indicator LEDs (HIGH, LOW, PULSE) must not be illuminated when no signal is present. To achieve this, the output of the 3 driving circuits must be high, and go low when the appropriate LED is to be turned ON.

The 1M trim pot on the input line sets the voltage on pin 7 of the top inverter so that the LOW LED is illuminated when the probe detects a LOW.

The inverter between pins 3 and 2 turns on the HIGH LED when the probe detects a HIGH.

The 100p capacitor (between pins 3&7 of the inputs of these two blocks) acts as a speed-up capacitor.

The pulse stretcher is taken from the output of the HIGH inverter via a 100p capacitor and the input of this monostable is high due to the presence of the 2M2 resistor. This makes the output pin 12 low. The 1u electrolytic sits in an uncharged condition and the output is high so that the pulse LED is not illuminated.

The circuit is triggered into operation via the 100p on input pin 9, when output pin 2 goes low. This causes pin 12 to go high and takes pin 14 high with it.

Pin 15 goes low and the latching feature is provided by the diode between pins 12&9. When pin 12 goes low, pin 9 is pulled low and the circuit latches into this state.

The time-delay for the circuit is controlled by the charging of the capacitor, via the 470k resistor.

The voltage on pin 11 gradually falls and at about 40% of rail voltage the inverter changes state and pin 12 goes HIGH. The pulse LED will go out and the low on pin 9 (provided by the diode) will be removed.

The inverter between pins 9&10 will change state and the charge on the 1u will be removed fairly rapidly due to the presence of diodes on the input line (pin 11) of the second inverter.

The remainder of the logic probe is handled by the Schmitt trigger IC.

When a LOW is detected, the low LED turns on and the line also passes to a tone oscillator between pins 3&4 of the 74c14 to produce a low tone. The output of this oscillator is buffered by a pair of inverters to drive a piezo. These fantastic little devices are effectively a crystal that changes shape (sideways mode) when a voltage is present between its two electrodes.

By wiring it as shown, it sees a voltage that is double rail voltage and this accounts for its loudness (see notebook 4, P 55 for a detailed explanation).

When a HIGH is detected, the high tone comes into operation and the piezo is pulsed with a square wave to give the characteristic piezo sound.

The diodes between input and output of the tone circuits are gating diodes to allow pulses from different blocks to feed into the one circuit.

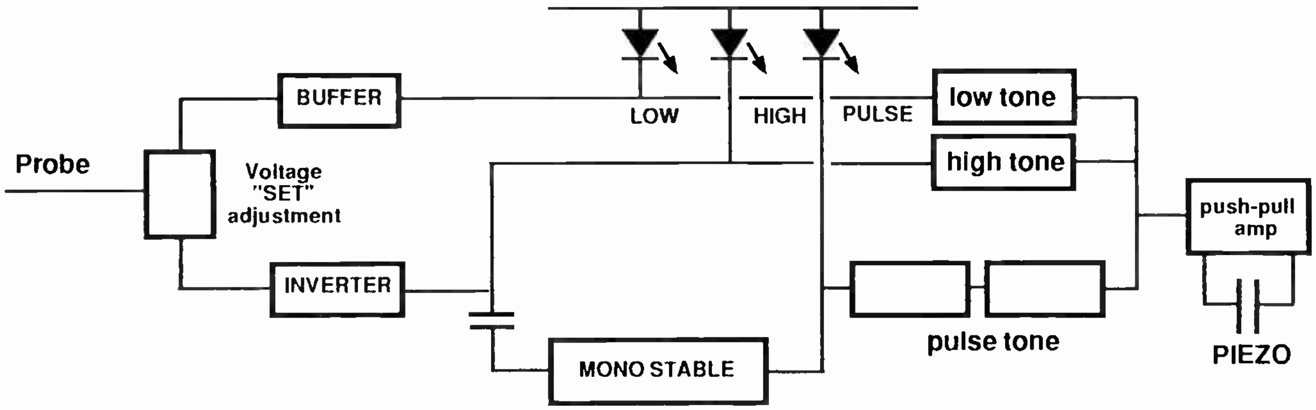
The diode between pins 6&9 turns on the Schmitt oscillator between pins 9&8 when the anode of the diode is low. This allows the 22n to discharge via the 68k resistor and the circuit will start to produce a tone. When the anode is high the 22n remains charged and the oscillator is prevented from operating. This is a simple way of "gating" or turning the oscillator on and off.

The output from the pulse stretcher circuit is taken from an inverter between pins 14 &15 and passed to a pulsed-tone circuit made up of a Schmitt inverter between pins 5 & 6 and 9 & 8. At the same time both high and low tone sections are disabled.

A power diode is provided in the positive rail to prevent damaging the probe with reverse voltage if connected to the power around the wrong way.

The 1u and 10n capacitor across the rails help remove spikes from the power rails and prevent false triggering. The 10k input resistor prevents the circuit being tested, from overload or damage.

BLOCK DIAGRAM

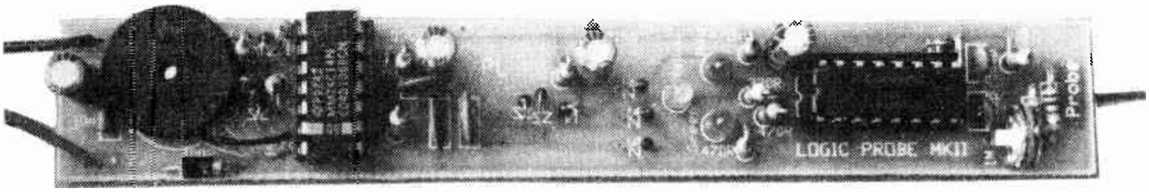


The input block is a "voltage set" control to turn the HIGH/LOW indicator LEDs off when no input is present.

The incoming signal is passed through a non-inverting buffer (two inverting buffers in series) and also one inverting buffer. The output of these gives the HIGH/LOW indication.

A pulse-stretcher circuit provides an indication of a pulse as short as 1 microsecond. The outputs of the HIGH/LOW drivers are passed to tone circuits to drive a piezo. The pulse circuit is fed to a pulse-tone pair of oscillators to provide a beep tone for the piezo.

The result is 3 different tones to make it easy to differentiate between HIGH, LOW and PULSE.



create a short. The tones allow you to keep your eyes on the job and prevent a disaster.

The second most important piece of test gear for digital repairs is a CONTINUITY TESTER. This simple piece of test equipment measures continuity between two points on a circuit and produces a beep.

You could use a multimeter but it is much slower. Sometimes you have to measure between all the pins of a 24 pin chip and this could involve over a 1,000 tests! The continuity tester will do this in a matter of moments and will be described in the next article.

You will also need a multimeter for voltage checks but best of all, you don't need a CRO for digital work and that will save a lot of money.

CONSTRUCTION

Before starting construction, the first item you must organize is the case.

The best type is made of soft plastic as it will withstand knocks and scratches without cracking.

It is made by a process called vacuum forming and is similar in appearance to plastic drinking cups and you know how strong they are.

Once you have the case you can lay the kit of components on the bench and identify all the values. Fit the board into the case so that you can see how much headroom you have. This is why all the parts must be fitted close to the board and some need to be pushed over slightly to allow the board to slide into the case.

All the parts supplied in the kit are the right size and if you are buying parts separately, you must check to see that they are small enough.

The first two items to be fitted are the two IC sockets. A small identification mark is located at the end of each socket and this fits over pin 1 so that when the IC's are to be fitted, you know which way they go.

Next fit the resistors. The overlay on the board and the photos will show that some of the resistors stand up while others lay down. Keep them close to the board when soldering and make sure the board will still slip into the case.

The signal diodes and power diode are next. If you keep one finger on or near the diode when soldering you will not get it too hot and if you solder very quickly there will be no chance of damaging anything. The line on the diode represents the cathode end and this is shown on the board by a diode symbol.

The electrolytics are next and these must be placed around the correct way for them to function correctly. The positive hole is marked on the board and this corresponds to the long lead of the electro.

The small capacitors are next and can be fitted either way around.

The three LEDs are the most delicate components as they will lose their brightness if heated up too much. Don't spread the leads apart as this will damage them but fit them down the correct holes so that the short lead goes down the hole identified with a line on the overlay. Make sure the top of the LED is low enough for the board to slip into the case. Solder quickly and cleanly.

The probe tip is made from a paper clip. This is very hard springy steel so don't try to cut it with pliers as the steel will damage the cutters. Use a hax saw or file or bend it sharply a couple of times and it will fracture. Bend it back on itself to form a "U" shape to make the joint stronger and solder it to the board.

The power leads for the probe should be as long as possible as you need plenty of length when you are moving the probe around a project such as tracing a fault on the top and bottom of a board.

The last two items to be soldered are the alligator clips. The leads have to be fitted through two holes in the end of the case and then the clips can be connected.

Fit the two IC's so that pin 1 covers the dot on the overlay. This is most important as they will be damaged it fitted around the wrong way. Before the board is slipped into the case, connect the leads to a 9-12v supply and touch the tip to the negative terminal of the supply. Adjust the mini trim pot until the LOW LED is just illuminated. The probe is now ready. Slip it into the case and tape the two halves of the case together.

IF IT DOESN'T WORK

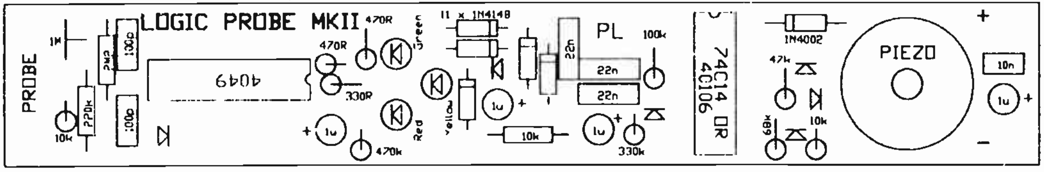
If none of the LEDs come on when the probe is connected to the positive or negative rails, the most likely cause is a faulty 4049 or the LEDs have been fitted around the wrong way.

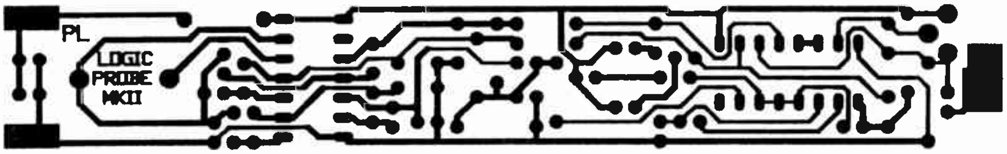
Remove the 4049 and connect the power leads of the probe to a 9-12v source. Take a jumper lead and short between pin 4 of the 4049 and ground. The green LED should come on. If not, the LED has been fitted incorrectly or damaged during soldering.

Replace it and try again. Short between pin 2 and negative for the red LED to come on and pin 12 and ground for the yellow LED.

Once you know they all work, the IC can be put back and the probe tested again. If the pulse LED doesn't work when the probe is taken to the positive line, take a jumper from pin 11 to the positive rail and it should illuminate. If not, something is preventing pin 12 from going low. It could be the inverter between pins 11 & 12 or a fault in the trackwork or even a short across the 2M2, keeping pin 9 & 12 high.

Take a jumper from pin 9 to negative. If this doesn't turn on the pulse LED for a short period of time, the fault may lie in the 1u between pins 10 & 11 not working or not connected to the board. Try short-





ing between pins 10 & 11 with one jumper lead and take pin 11 low again with another lead.

The only other component affecting the pulse line is a 100p capacitor. Try shorting across it and take the probe tip high.

The 3 tones are produced separately and if no tone is emitted, remove the two diodes on pin 3 of the 74c14 and the low tone should be produced.

If not, the Schmitt trigger between pins 3 & 4 is faulty or the 22n or 100k are not fitted correctly.

If still no tone, remove the diode on pin 10 and on pin 8. To test the inverters between pins 13 & 12 and 1 & 2, connect a piezo between pin 4 and negative rail. This will prove the oscillator between pins 3 & 4 is functioning.

Short between pins 4 & 13 to prove the diode has been fitted correctly and the piezo should be working by now.

If the high tone is not produced, the inverter between 11 & 10 will be faulty or the 22n, 47k will be at fault.

You can also remove the two diodes on pin 11 to produce the high tone and if it is still not being produced, you can connect a piezo between pin 10 and negative rail to detect the tone.

The pulse frequency is a little more complex however we know the piezo drivers are working so removing the diode between pins 6 & 9 will produce a constant tone. If not, the oscillator between pins 9 & 8 will be faulty or the 22n, 68k or gating diode on pin 8 will be the fault.

Once the middle tone is produced, replace the diode between pins 6 & 9 and remove the diode on pin 5. This will give a pulsed tone and if not, the low frequency oscillator between pins 5 & 6 will be faulty or the 1u or the 330k on pin 5.

Your probe should be working by now.

Make sure all the components are soldered back on the board and it is ready to give years of useful service.

USING THE PROBE

The power for the probe is obtained from the project you are testing. This way the voltage is automatically adjusted to match the project.

Connect the positive lead to any positive rail on the project you wish to test and the black lead to ground.

Start by using the probe on a known project so that you can identify the HIGH/LOW tones. Always refer to a circuit diagram when checking a circuit and ask yourself "Will it be HIGH, LOW or give a PULSE?" before using the probe.

The tones will confirm your reasoning and show what is occurring.

You will find this project essential for digital work and equal to anything on the market. Let us know how you find it.

ABOUT THE TEC-1C COMPUTER

We have mentioned the TEC computer a number of times in recent books but not explained how it works or how important it is to learning computer fundamentals.

Once you have built the Logic Probe and Continuity Tester, you will be asking for a project to use them on. The computer is ideal. We had a call today from a school who bought the TEC-1C and built it as a class project. Fortunately it didn't work and now they will start to learn something about computers by checking it with the Continuity Tester and tracing through the circuit with the Probe.

TEC-1C stands for Talking Electronics Computer 1C and it is a single-board computer consisting of 9 IC's, a set of push buttons, six 7-segment displays and a speaker.

This is all you need to learn how a micro computer works and since it is a learning aid, it is nothing like the computers you buy at your local computer shop.

All the parts fit on a single PC board so that you can see what is necessary to become familiar with the type of chips and components required to make it "tick."

The computer is programmed with a set of keys marked in Hexadecimal - this simply means the keys are marked 0-9 and A-F and all the programming is done with these keys.

A short program is needed to start it up so that it detects the keys and the displays show the appropriate letters and numbers.

This program is stored in a chip called the EPROM and is supplied in the kit. This is called the MONITOR program or "MON" for short.

When the computer is turned on it runs through this program and sets everything up.

The TEC is similar to a blank book with the first 10 pages filled with information. The EPROM occupies the first few pages of memory.

You can then write your own program on the blank pages and these are catered for by a chip called the RAM. This stands for Random Access Memory and is volatile memory, meaning the memory is only maintained while the power is applied. When the computer is turned off the data is lost. The data can also be written over at any time and this is what you do when you carry out the exercises in issues 10 - 15 of Talking Electronics.

The other chips are support chips to drive the display, interpret the keyboard and generally connect everything together.

The computer comes as a kit and can be assembled in an evening. It should work when first turned on but if not, you will need the Logic Probe, Continuity Tester and a multimeter.

Fault finding is covered in the notes so you should not have any trouble in getting it to go.

When it's up and running you can start on the exercises. They start at a very simple level and take you through programming steps to create flashing effects, movement on the displays, and tones and tunes from the speaker.

When you complete all the exercises you can go on to building some of the add-ons. There are over 10 additional projects that can be added to the computer to expand its capabilities and increase your programming skills.

All the programming is done in machine code as this is the language that is directly understood by the microprocessor. With the simple hex keypad you can create programs for almost any application. Projects like burglar alarms, controllers for moulding machines, drilling machines, watering systems, etc are all possible.

The main aim of this computer is to get you started in micro design so that you can show your prospective employer that you have created your own computer, understood how it works and feel comfortable with the technology.

Micro-control is a very challenging field and is very similar to writing a story or a book. When you start to write a program the possibilities are limitless. All you have to do is learn the codes necessary to instruct the processor to carry out specific operations.

For instance, if you want to turn a segment of a display on and off, you must load the working register (the accumulator) of the microprocessor with a value, output it to a port and latch it for a number of cycles so that it can be observed. You then clear the accumulator, output to the same port and display for a number of cycles. You then loop the program to repeat the effect. The length of the loops give the frequency of the flashing. Everything is made with simple instructions like this and once you start writing your own programs you will be hooked. It's like creating projects by writing about them.

With micro-processor design, what ever you want to do, can be done with a program.

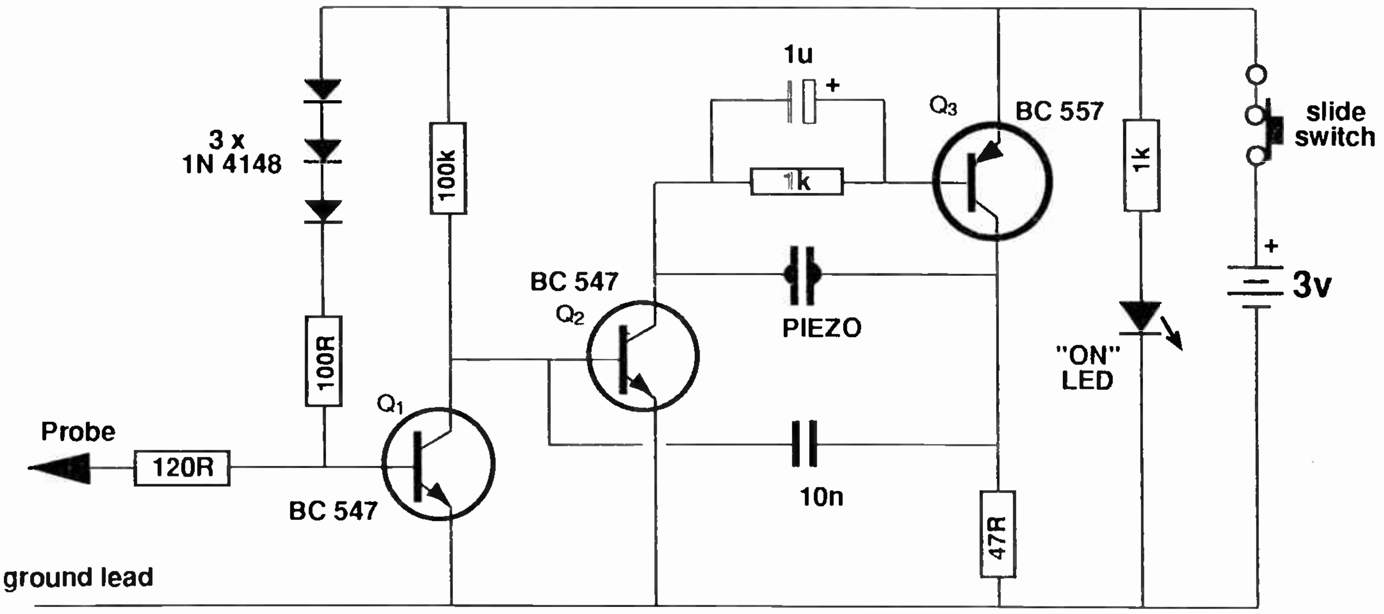
It opens up a whole new world of ideas and brings you into the forefront of technology. And who doesn't want to be at the leading edge?

CONTINUITY TESTER

ESSENTIAL FOR SERVICING DIGITAL PROJECTS

Parts & PC: $10.95
PC board only: $2.40

You will also need to buy a toothbrush case from your local Chemist shop to house the project.



CONTINUITY TESTER CIRCUIT

This is the second piece of test equipment for use in digital work. A Continuity Tester looks to be a fairly unimportant device and hardly seems worthwhile constructing, but after you have used it, you will realize how important it is.

A multimeter can be used but it takes much longer to do the same job.

Our Continuity Tester has been specially designed and has three very interesting features.

Firstly it gives an audible indication so that you can keep your eyes on the probe tip. Secondly its response-time is very short so that you can make lots of tests very quickly while listening for the beep.

And thirdly it only responds to a definite short circuit or one that has a resistance of 50 ohms or less. It will not respond to values above 80 ohms or the voltage drop across a diode.

This is where the multimeter falls down. When you are measuring the resistance between pins of a chip on a digital circuit, a protection diode is often present inside the chip and if you measure with a multimeter, it will be difficult to determine if the meter is detecting the presence of a diode or a low resistance.

The Continuity Tester eliminates this problem. We have found it invaluable for diagnosing some of the computers that come in for repair. Most of the problems have been poor soldering but some have been shorts between lands and cracks in the tracks.

To find a short between two pins of say a 24 pin chip, requires 24 x 24 tests and this would take quite a while.

With the Continuity Tester we place the negative lead on the end pin of the chip and quickly wipe the probe down the other pins of the same side then the 12 pins on the other side. The only time you will hear a beep is if a short is present or if the two probes touch.

When you hear a beep, you should examine the trackwork carefully to see if a fault is present or if the pins are joined by a track, or some other component.

Continue this procedure with pins 2, 3, 4 etc. until all the possible combinations have been covered.

This is repeated with all the chips in the project and any other connections you can find on the board. This is the only way to locate a hidden short and even though it involves thousands of tests, it will be much quicker than using a multimeter.

HOW THE CIRCUIT WORKS

As we have mentioned, the circuit detects resistance values of 50 ohms or less between the probes and allows an oscillator to turn ON and produce a tone

PARTS LIST

1 - 47R
1 - 100R
1 - 120R
2 - 1k
1 - 100k

1 - 82R
1 - 1N 4148
for test purposes.

1 - 10n greencap
1 - 1u 16v PC mount electrolytic

3 - 1N 4148 diodes
2 - BC 547 transistors
1 - BC 557 transistor
1 - 5mm red LED
1 - mini piezo diaphragm

1 - SPDT slide switch
2 - AAA cells

1 - paper clip (to be cut in half)
10cm tinned copper wire
50cm hook-up flex

1 - CONTINUITY TESTER PC BOARD

from the piezo.

A LED is also included on the board to indicate when the unit is ON as the circuit consumes about 2-4mA and the battery would eventually go flat if left on for long periods.

Actually the circuit doesn't detect resistance at all. It detects a threshold voltage across the base-emitter junction of the first transistor. When the tester is in the "rest" state, the first transistor is turned ON and this inhibits the oscillator.

It gets its turn-on voltage from the 100R resistor. The 3v supply is taken through 3 diodes and these drop a total of about 1.9v, leaving about 1.1v for the base bias.

When the transistor is turned on, the base-emitter voltage (the junction-voltage) is .7v and thus .4v is dropped across the 100R resistor. This means we have only .4v leeway for the batteries to fall and when they drop to below 2.6v, the tester will fail to work. That's why we have to conserve energy as much as possible by putting an indicator LED on the board to prevent it being left on.

0.4v across the 100R delivers about 4mA into the base of the gating transistor and this keeps the oscillator OFF. When a resistance of 50R or less is placed between base and emitter, the voltage on the base falls sufficiently to turn the transistor off.

This allows the 2-transistor feedback oscillator to come into operation and produce a tone.

A diode placed between base and emitter of the first transistor will have no effect on the circuit as it will allow .6v to .7v to be appear across the probes and this will not change the state of the circuit. The voltage must drop to .5v or less and this requires a resistance of about 50 ohms or less.

The 2-transistor feedback oscillator is set into operation by the 100k base bias resistor. This turns on the middle transistor and thus its collector voltage falls. The collector is connected to the base of the third transistor and this is also turned on.

The result of this action is to raise the voltage on the collector of the BC 557, to which a 47R is connected. Also connected to the collector is a 10n capacitor and it has presently been charged to about .6v.

As the voltage on the collector rises, it pulls the capacitor up with it and pushes the charge into the base of the middle transistor. This causes the transistor to turn on even harder and very soon we have a situation where both transistors are SATURATED.

The base does not rise above .65v while the other end of the capacitor has been pulled high by the BC 557. This causes it to charge in the opposite direction and after a short period of time its charging current cannot hold the middle transistor ON as hard. The result is the BC 547 turns off slightly and this action is passed to the BC 557 via the 1k & 1u, and the voltage on its collector falls. This action is passed back to the base of the BC 547 via the 10n capacitor and it gets turned off even further.

Both transistors are now completely off and the cycle starts again by the 100k charging the 10n and turning on the BC 547.

An invaluable tester for digital work

The 1k and 1u electrolytic couple the two transistors and the purpose of these has been discussed in the theory sections.

The two leads of the piezo see an AC voltage that is slightly higher than 3v.

Each time the circuit changes state, a click is produced in the piezo and since these clicks are produced in rapid succession, the result is a tone.

CONSTRUCTING THE TESTER

All the components are mounted on a small PC board that is designed to fit into a toothbrush case. There are a number of suitable cases and even a small one will fit the board. At first we thought the soft type would not be suitable but after we tried it, we found it was the best. The soft plastic is more durable and will not fracture if dropped or bumped. The rigid styrene case tends to crack very easily and one of ours was crushed under foot when it fell on the floor!

The case is the first item to purchase as it is needed to give you a guide as to the maximum height available for the components. If some of the parts are too high, they can be bent over during assembly and its important to know this before you start.

Next you need to make sure the slide switch is the right size for the board. The switch supplied in the kit fits exactly into the holes and any mounting flanges must be cut off so that the board will slide neatly into the case. Make sure you do not take too long to solder it or the operation of the contacts will become faulty due to flux running down the lead. Once this is done, the rest of the components can be fitted.

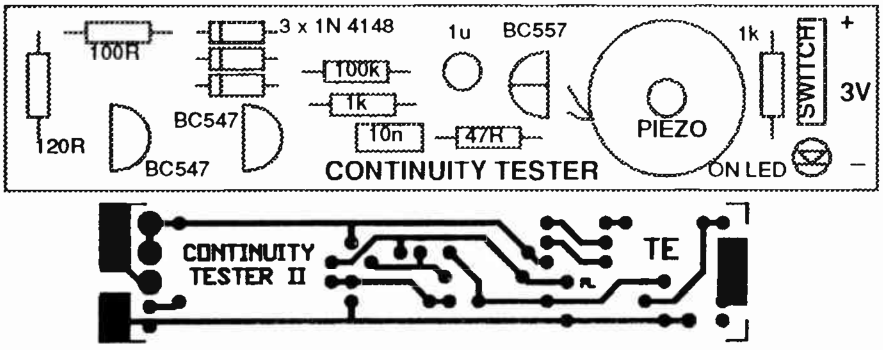
Start assembly at one end of the board and fit each component as you come to it. The LED, transistors, diodes and electrolytic must be fitted around the correct way and the layout on the board will assist you. If you are not sure, refer to the photos for placement or get someone to assist you, but don't guess!

The probe tip is made from a paper clip that has been straightened and one end bent into a hook for soldering to the board. The two cells are soldered to the board with short lengths of tinned copper wire, provided in the kit.

The wander lead can have either an alligator clip or E-Z clip attached and this allows it to be connected to one point of the project under test so that the probe can go over the board in a hunt for the fault.

The kit contains a paper clip that is cut in half, one half for the probe and one half for the wander lead. Don't cut the paper clip with side cutters as it is very hard steel and the cutters will be damaged. Use a pair of long nose pliers. Bend the clip back and forth a few times and it will break.

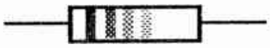
When everything has been soldered in place, slide the switch ON and the LED will illuminate. Touch the two probes together and the oscillator will emit a tone.



Overlay and trackwork for the Continuity Tester.

MOD'S TO OLD PC's

If you have an old Continuity Tester PC or have already built the older model, you can modify the board quite easily by desoldering the probe end of the 100R and taking it directly to the base of the first transistor. Refer to the diagram below. Cut the track between the base of the same transistor and the probe. Solder a 120R between the base and the probe, either on the underside of the board or on top, so that it looks neat and the mod's done.



82 ohm resistor

1N 4148 signal diode

TESTING THE UNIT

You will require a diode, and an 82R resistor.

Place the probes across the diode, firstly in one direction then the other. The tone should not be heard. Place the probes across the 82R resistor and once again the tone should not be emitted. You may find the tester will operate on a resistor which is one value higher or lower than this. The actual value will depend on the battery voltage. But don't worry too much about the actual turn-on and turn-off values as most digital projects have resistors of about 470R in their lines and the tester will not detect them.

IF IT DOESN'T WORK

If the tester does not emit a tone when the two leads are touched together, follow these steps:

Check the voltage of the cells. They should give at least .1v drop across the 100R resistor. If there is no voltage drop, check the voltage-dropping diodes. They should each drop .65v. Also check the supply voltage. It should be higher than 2.6v.

Remove the gating transistor (the first transistor) and turn the unit ON. This will allow the tone circuit to operate. If not, check the value of the 1k and 100k resistors and also their positions. Next check the 10n capacitor and also the BC 547 and BC 557 transistors, they will not work if swapped over or if fitted the wrong way around.

You can determine if the oscillator is jammed in the ON mode or OFF mode by taking a current reading across the switch. If the current is more than 20mA, it is jammed in the ON mode and this means the BC 547 in the oscillator is conducting.

The transistor could be shorted between collector and emitter or the 10n feedback capacitor is open circuit.

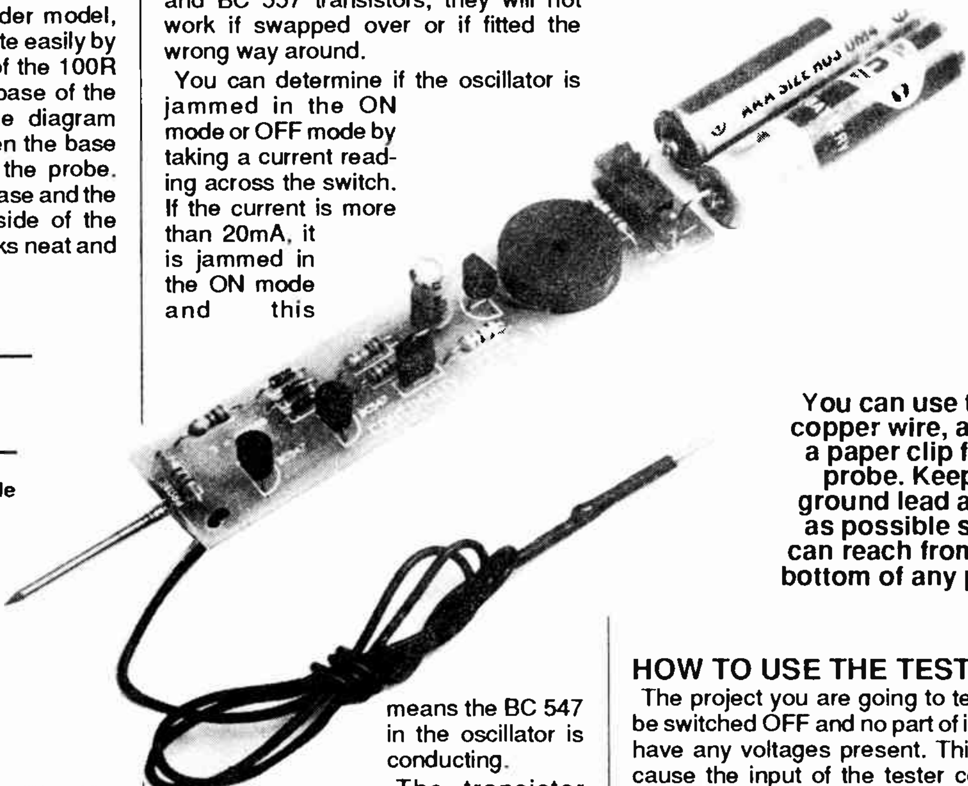
Create a short between base and emitter of the BC 547 to bump the circuit into oscillation or replace the 10n.

If the circuit is jammed in the OFF mode, either of the transistors in the oscillator may be open circuit or incorrectly fitted. Try new transistors. If the circuit remains in the OFF state, remove the 10n feedback capacitor and the circuit should turn ON. If it does, the fault will lie in the capacitor being shorted or open circuit.

Once the tone circuit operates, the only other stage to be checked is the gating transistor. If it fails to turn the tone off, the fault will lie in the base bias.

If the gating transistor still fails to turn the tone off, replace it. You may have damaged the base-emitter junction.

This should be sufficient to get the tester working. If not, ask another hobbyist to help you.



You can use tinned copper wire, a nail or a paper clip for the probe. Keep the ground lead as long as possible so you can reach from top to bottom of any project.

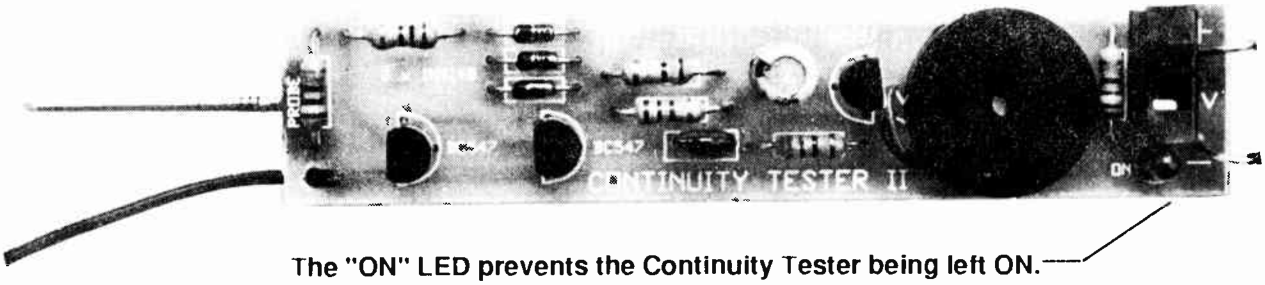
HOW TO USE THE TESTER

The project you are going to test must be switched OFF and no part of it should have any voltages present. This is because the input of the tester connects the base of the gating transistor to the probe via a very small value resistor and high voltages (greater than 6v) will destroy the junction by allowing high currents to flow.

Switch the tester ON and the indicator LED will illuminate. Touch the two probes together and the tone will be produced. This is the tone you will be listening for during the tests.

It is important to have a set plan of approach as lots of tests will be required for even the simplest circuit and a logical diagnosis will prevent you going over the same area twice or missing a test.

Once you have used it on a digital project such as Talking Electronics Computer (TEC-1B or 1C) you will realize how important it is to be able to quickly test all the lines for continuity and shorts. We have used it many times for computer repairs and it has found cracks and dry joints that the eye missed. It has helped us fix more than 10 TEC's in the past 2 months! I am sure you will find it invaluable too.



The "ON" LED prevents the Continuity Tester being left ON.

A SHEEP IN WOLF'S CLOTHING ... or something like that.

LOOKING AT A TWO-TRANSISTOR DIRECTLY-COUPLED STAGE

Quite often we look at a circuit and ask "why did the designer choose that particular arrangement?"

This discussion considers such a situation. It's a two-transistor direct-coupled stage that's becoming quite popular in circuit designs.

It seems to have a number of features but it's not until you put it under the microscope and see what happens at different rail voltages, with different configurations, that its dangers emerge.

Some of the designers claim the arrangement is relatively stable due to the 100k feedback resistor maintaining the overall gain of the circuit, even when components and conditions are changed. But although the 100k provides negative feedback as far as the signal is concerned, there is a hidden **positive feedback** for high frequencies and that's what we are going to uncover.

I have hunted through lots of books looking for circuits that use this arrangement and found it comes in four different arrangements. The capacitor on the base of the first transistor can be present or omitted as can the electrolytic on the emitter of the second transistor.

But it's not until you build it up and put it under the scrutiny of a CRO that you see how the circuit behaves.

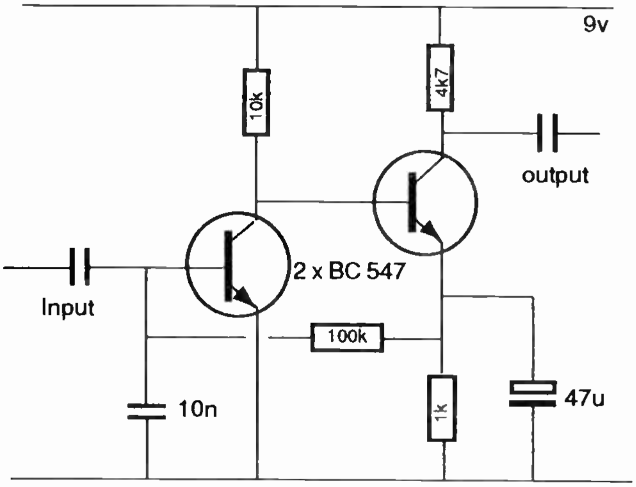
Without the 47u, and capacitor on the base of the first transistor, the gain of the circuit is very small, about 10, as we found. I have to admit the output is very clean, but that's no great achievement when you are using 2 transistors and lots of feedback.

The reason for the low gain is due to the feedback. Q2 is operating with a very low gain of about 4 or 5 (as determined by the value of the collector resistor divided by the value of the emitter resistor) and the large change in voltage on its emitter is fed back to the base of the first transistor to give it very little gain too.

When the 47u is fitted, both transistors effectively become common emitter amplifiers and if each transistor has a gain of 100, the overall amplification is enormous.

And this is where the problem lies. The circuit has so much gain that it self-oscillates.

This is very dangerous as the last thing we want a stage to do is break into oscillation. The reason why is the fact that if it is self-oscillating, it is fully occupied generating the waveform within itself and cannot accurately amplify any audio presented to it.



This is the circuit under review. It looks to be quite innocent but under the guise of negative feedback lies a mound of instability.

Secondly, when a transistor or transistors are self-oscillating they draw more current than in quiescent mode and may even heat up and become damaged. That's why self-oscillation is to be avoided at all costs.

So, how do we stop it?

So, how does the stage break into self-oscillation?

The fault is entirely due to the enormous gain.

If we assume the gain of each transistor is 100, the total gain of the stage is 100 x 100 = 10,000. This means 1mV of noise on the base of the first transistor will create a 100mV signal on its collector. This will be passed to the second transistor to produce a 10v waveform on the output. And a 10v (or 9v) waveform is the largest you can get from a 9v supply.

The base of the first transistor may not see 1mV of noise at the beginning of a demonstration (however turning the circuit ON will certainly spike it with a fairly decent pulse) but let's say it sees 1/100th of a mV. This will be amplified by the two transistors to produce an output of 100mV. Some of this signal will appear on the emitter of the second transistor and even though it has an electrolytic across the emitter resistor, the voltage will not be absolutely rigid. It only takes 1mV of noise to set the whole circuit into oscillation and when you look at it on a CRO, that's exactly what happens. Some of the output signal is passed to the front to ASSIST in creating a beautiful, clean, 9v waveform. **And since it ADDS to the instability, it's called positive feedback.**

The only way to prevent this from occurring is to put a capacitor on the base of the first transistor as shown in the diagram. In one of the circuits I looked at, the capacitor was 1n, but this value is not sufficient to prevent oscillation, so the designer of the circuit obviously never looked at the output with a CRO. On two other circuits the 10n was missing and so the circuits would be capable of oscillating at about 100kHz. This is higher than the ear can hear and so I suppose the designers thought that since they could not hear any noise, they surmised that everything was working ok. That's why this circuit is so dangerous.

CONCLUSION

Personally, I would not use this arrangement unless you know where it is going and what you are doing. After spending some 20 hours studying it with a CRO and seeing how it behaves under different conditions, I would say it's a wolf in sheep's clothing. It's unpredictable. The voltage of the supply has an effect on the gain and some of the effects of instability are not noticeable at low voltage.

But it's the effectiveness of negative feedback I want to emphasise.

You would think that negative feedback would work at all frequencies to produce a completely stable circuit. But this is not so. Positive feedback can work right through negative feedback at high frequencies and produce an effect called HIGH FREQUENCY INSTABILITY. It's very easy to be fooled by negative feedback. You must prove its effectiveness by looking at the circuit with a CRO.

All this leads to one conclusion. Beware of DC coupling and make sure noise is not getting in.

THE POSITIVE APPROACH

While on the topic of the two-transistor amplifier circuit on the previous page, I have a letter from a reader who thinks the biasing of the first transistor comes from the negative rail via the 100k resistor.

This problem is really about the direction in which current flows and I can see how some readers can be confused.

For this discussion we are going to use conventional current flow, in which the current flows from positive to negative.

I know there is enormous confusion between conventional current flow, electron flow and whether you describe the operation of a transistor by current flow or voltage levels. Conventional current is the most convenient way and after this discussion it will be a lot clearer.

To explain the direction of flow through the 100k resistor we will take a bridge circuit as shown in figure 2.

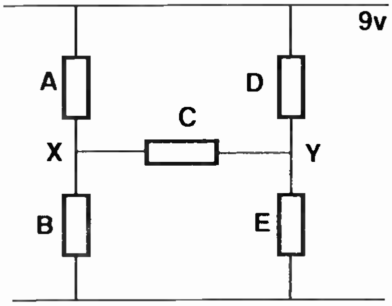


Fig: 2. A bridge circuit

Current can flow from left to right or right to left, depending on the values of A, B, D and E.

To find out, disconnect C. We now have two paths: A, B and D, E as shown in figure 3. The current must flow DOWN as it flows from positive to negative.

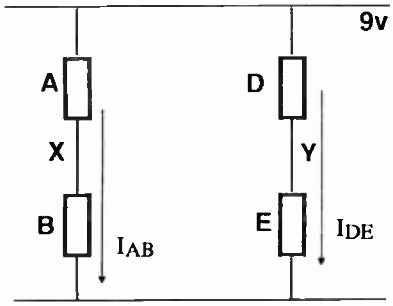


Fig: 3. Two current paths

When a current flows through a resistor it produces a voltage drop. We will assume the voltage across A is 8.5v and .5v across B. This makes point X = .5v.

The voltage drop across D is 7.5v and 1.5v across E. This makes point Y= 1.5v.

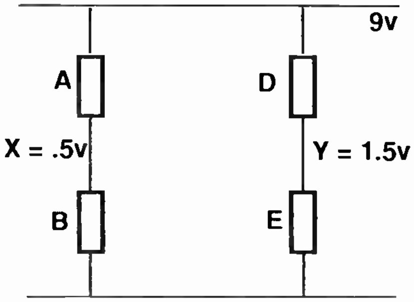


Fig: 4. The voltage at X and Y

This is very nearly the voltages on the transistor circuit we are dealing with so if we put C back into circuit, the current flows from the 1.5v end to the .5v end. This makes it flow from Y to X as shown in figure 5.

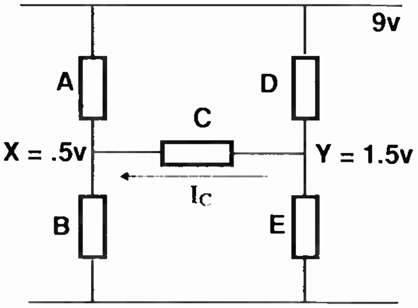


Fig: 5. Current direction through C

We do not know how much current is flowing but we know its direction.

Replace the bridge with the two transistor circuit on the previous page and you can see that the base of the first transistor is fed via the 100k resistor.

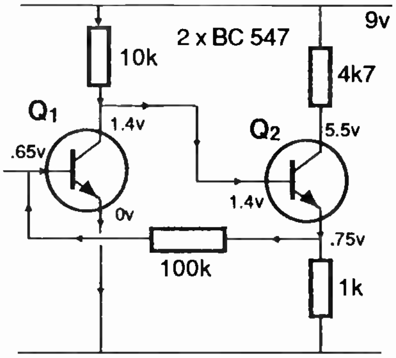


Fig: 6. The two transistors and the direction of current flow

We can now explain how the voltages are developed across each resistor.

When the circuit is first turned on, Q_1 does not see any bias on its base and is not turned on. This means we can effectively consider it removed from the circuit. However Q_2 is turned on via the 10k on its base and as the voltage on the base rises, (we are talking in slow-motion) the emitter follows, but is .65v lower. As the emitter voltage rises, it is passed to the base of the first transistor where it begins to turn it on when it is .65v.

This turns the first transistor into a component very similar to a variable resistor and it creates a voltage divider with the 10k resistor to put about 1.4v on the base of the second transistor. This is the point at which the two transistors stabilise.

The arrows on fig 5 show the direction in which the current flows and the voltages produced at the various points on the circuit.

I can see another question looming.

Why is the difference between the base and emitter of Q_2=.65v?

This voltage is called a characteristic voltage and it forms between the base and emitter leads of a transistor as soon as a voltage is applied to a circuit.

This voltage is most commonly given the value .6v however it does rise to .65v or .7v according to how much the transistor is turned on.

But since the increase is very slight, it is given the value of .6v to keep circuit analysis simple.

The slight voltage drop across the 100k is due to the current flowing through it to turn on the first transistor.

The 5.5v appearing on the collector of the second transistor is due to it being turned on via the 10k base resistor.

If it were fully turned on the collector-emitter voltage would be about .25v.

Questions

1. Current flows from a point of high voltage to a point of low voltage. true/false.

2. The .65v between the base and emitter is called the ____________ voltage.

3. The transistor circuit is turned on by the current flowing through the _______ resistor.

4. The voltage between the collector and emitter of a fully turned on BC 547 transistor is ______v.

5. Give 2 names for the 100k resistor.

6. Is the transistor circuit AC coupled or DC coupled?

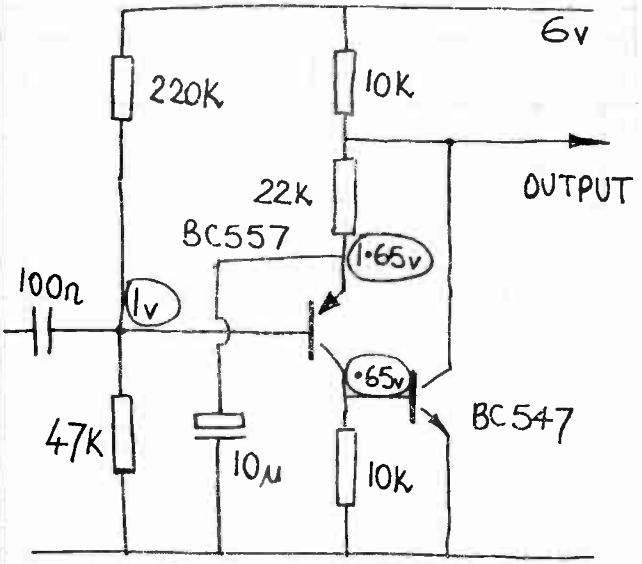
7. From fig 6, determine the voltage drop across the 10k resistor.

Answers:

1. true 2. characteristic 3. 10k 4.
.25v 5. feedback resistor or base-bias
resistor 6. DC coupled 7. 7.6v

A HIGH GAIN STAGE

THIS CIRCUIT OFFERS HIGH GAIN, GOOD STABILITY AND NEEDS FEW COMPONENTS.



A HIGH-GAIN DC COUPLED AMPLIFIER

THE FIRST FACTOR TO UNDERSTAND IS THE 'QUIESCENT STATE.' — IN OTHER WORDS 'HOW THE CIRCUIT TURNS ON', & MAINTAINS AN EQULIBRIUM OR 'REST STATE.' — IN WHICH THE TRANSISTORS ARE, JUST AT THE POINT OF 'TURN ON'.

THE CIRCUIT STARTS UP THIS WAY:

THE 220K/47K FORMS A VOLTAGE DIVIDER WITH THE MID-POINT AT 1v $\left(V = \frac{47}{220} \times 6 = 1v \right)$

THIS IS THE STARTING POINT FOR THE BIASING OF THE CIRCUIT & IS THE VOLTAGE FOR THE BASE OF THE FIRST TRANSISTOR.

THE 220K/47K COMBINATION SET THE POTENTIAL FOR THE CIRCUIT. — THE BASE OF THE FIRST TRANSISTOR DOES NOT SET THIS VALUE.

NEXT WE GO TO THE EMITTER OF THE FIRST TRANSISTOR. THE VOLTAGE BETWEEN THE BASE & EMITTER MUST BE VERY CLOSE TO ·65v (SINCE THE TRANSISTOR IS AT THE POINT OF JUST BEING TURNED ON.) THIS MEANS THE EMITTER MUST BE 1·65v.

THE 'TURN-ON' OF THE FIRST TRANSISTOR PRODUCES A VOLTAGE DROP ACROSS THE 10K COLLECTOR LOAD RESISTOR AND THIS IS ·65v DUE TO THE BASE-EMITTER JUNCTION OF THE SECOND TRANSISTOR. THIS VOLTAGE IS ENOUGH TO BEGIN TO TURN ON THE SECOND TRANSISTOR.

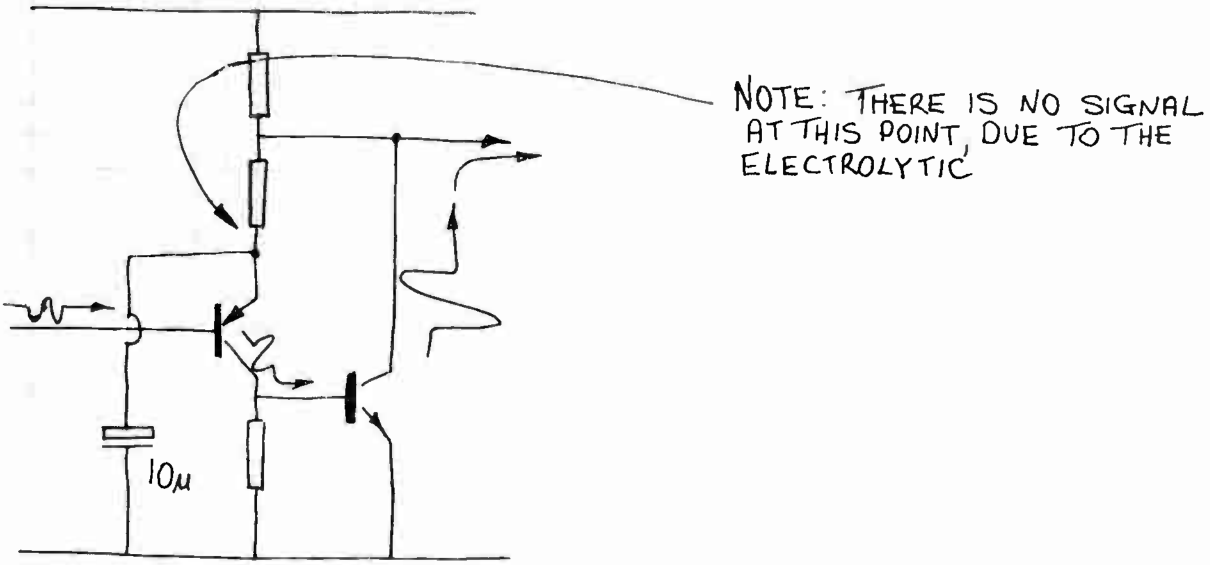
THE VOLTAGE ON THE COLLECTOR OF THE SECOND TRANSISTOR FALLS. THIS PUTS A REDUCED VOLTAGE ON THE JOIN OF THE 10K & 22K RESISTORS AND THE CURRENT FLOW THROUGH THE 22K RESISTOR CONTROLS THE 'TURN ON' OF THE FIRST TRANSISTOR.

THIS CREATES A STABLE CONDITION CALLED THE 'REST STATE', 'EQULIBRIUM', QUIESCENT STATE' OR 'DC STATE.'

HOW DOES THE CIRCUIT AMPLIFY ?

WHEN CONSIDERING THE AC OR AMPLIFYING STATE, THERE IS ONE IMPORTANT POINT TO REMEMBER. THE EMITTER OF THE FIRST TRANSISTOR IS EFFECTIVELY 'FIXED' OR 'RIGID' AS FAR AS THE SIGNAL IS CONCERNED. IN OTHER WORDS THE EMITTER DOES NOT SEE ANY AC SIGNAL — YOU WILL SEE HOW & WHY ON THE NEXT PAGE.

THE SIGNAL PATH IS AS FOLLOWS:

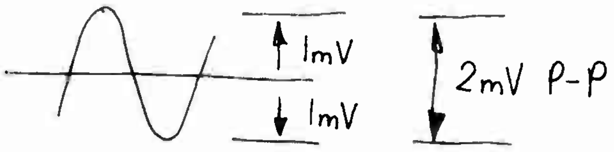


THE SIGNAL PATH.

THE 10μ ELECTROLYTIC IS DESIGNED TO KEEP THE EMITTER FIXED OR 'RIGID' AND IF IT WERE TO BE REMOVED, THE CIRCUIT WOULD HAVE NO GAIN AT ALL.

THE EMITTER MUST NOT MOVE WHEN A SIGNAL IS BEING PROCESSED.

HERE IS HOW THE STAGE WORKS: SUPPOSE A 2mV P-P (PEAK-TO PEAK) SIGNAL IS SUPPLIED TO THE BASE OF THE FIRST TRANSISTOR. WHEN THE WAVEFORM IS GOING LOW, THE BASE-EMITTER VOLTAGE IS INCREASING AND THE FIRST TRANSISTOR TURNS ON SLIGHTLY MORE.



INPUT SIGNAL

IF WE ASSUME THE FIRST TRANSISTOR HAS A GAIN OF 33, THE COLLECTOR VOLTAGE WILL RISE 33mV. THE VOLTAGE ON THE BASE OF THE SECOND TRANSISTOR RISES 33mV AND IF WE ASSUME IT ALSO HAS A GAIN OF 33, THE VOLTAGE ON THE COLLECTOR WILL FALL $33 \times 33 \simeq 1{,}000\text{mV} = 1\text{V}$. THUS THE GAIN OF THE STAGE = 1,000.

THE OUTPUT WILL FALL 1V & RISE 1V MAKING A 2V P-P SWING WHEN A 2mV SIGNAL IS APPLIED. THE VALUE OF THE ELECTROLYTIC HAS TO BE CHOSEN SO THAT IT WILL NOT HAVE TIME TO CHARGE OR DISCHARGE BY ANY APPRECIABLE AMOUNT, WHEN THE SIGNAL IS BEING PROCESSED AND THUS THE EMITTER REMAINS FIXED AT THE 'QUIESCENT POTENTIAL OF ABOUT 1·65V.

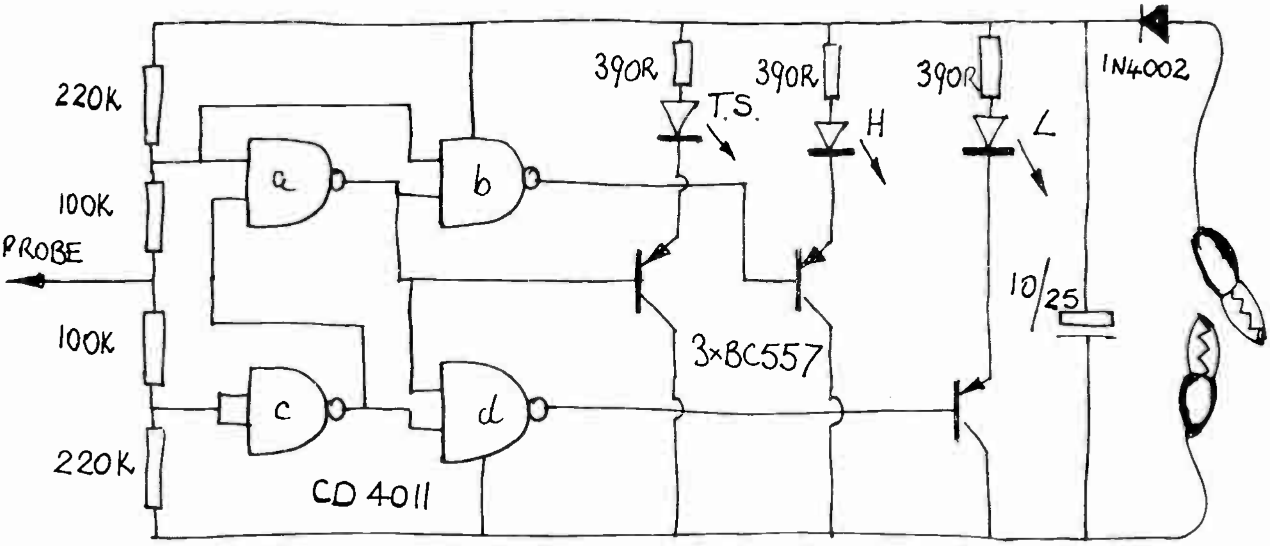
THE TWO TRANSISTORS WILL NOT SHARE THE AMPLIFICATION EQUALLY, BUT FOR SIMPLICITY WE HAVE TAKEN THEM TO BE EQUAL.

TRI-STATE

DIGITAL ELECTRONICS IS BUILT AROUND THE CONDITION THAT EVERY DATA LINE (AND ADDRESS LINE ETC) IS EITHER HIGH OR LOW. THUS TO PRODUCE THE VALUE 128, FOR EXAMPLE, WE NEED 7 DATA LINES.

WHEN TESTING A DIGITAL CIRCUIT WE ACCEPT THE FACT THAT NO LINE SHOULD BE AT ANY POTENTIAL OTHER THAN ZERO OR SUPPLY VOLTAGE.

BUT THE ADVANCEMENT OF TECHNOLOGY HAS CREATED CHIPS ABLE TO RECOGNISE <u>3</u> STATES ON EACH LINE — LOW, OPEN OR HIGH IMPEDANCE & HIGH. THESE ARE CALLED "TRI-STATE" OR TRINARY DEVICES & 7 TRI-STATE LINES CAN HAVE 2187 COMBINATIONS AS COMPARED TO 128. WHEN TESTING A TRI-STATE DEVICE IT IS HANDY TO HAVE A 3-STATE LOGIC PROBE. THE CIRCUIT BELOW SHOWS HOW ONE CAN BE MADE FROM A QUAD 2-INPUT NAND GATE & 3 BUFFER TRANSISTORS.

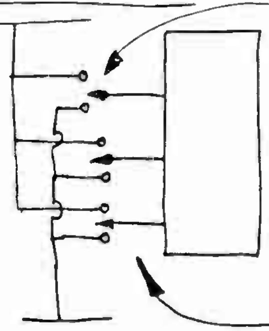


3-STATE LOGIC PROBE

THE CIRCUIT ABOVE SHOWS THE PRINCIPLE OF HOW A TRI-STATE DEVICE DETECTS THE THREE STATES AND PRODUCES ONE-OF-THREE DISCRETE OUTPUTS.– IT'S ALSO A 3-STATE LOGIC PROBE!

THE TRINARY CODE IS:

3 – ONE DATA OR ADDRESS LINE
9 – TWO " " "
27 – THREE " " "
81 – FOUR " " "
243 – FIVE " " "
729 – SIX " " "
2187 – SEVEN " " "
ETC:



THESE CONNECTIONS CAN BE EITHER A DIP SWITCH OR PC TRACKS. THE TRACKS ARE CUT OR BRIDGED TO CREATE HIGH MID OR LOW STATE.

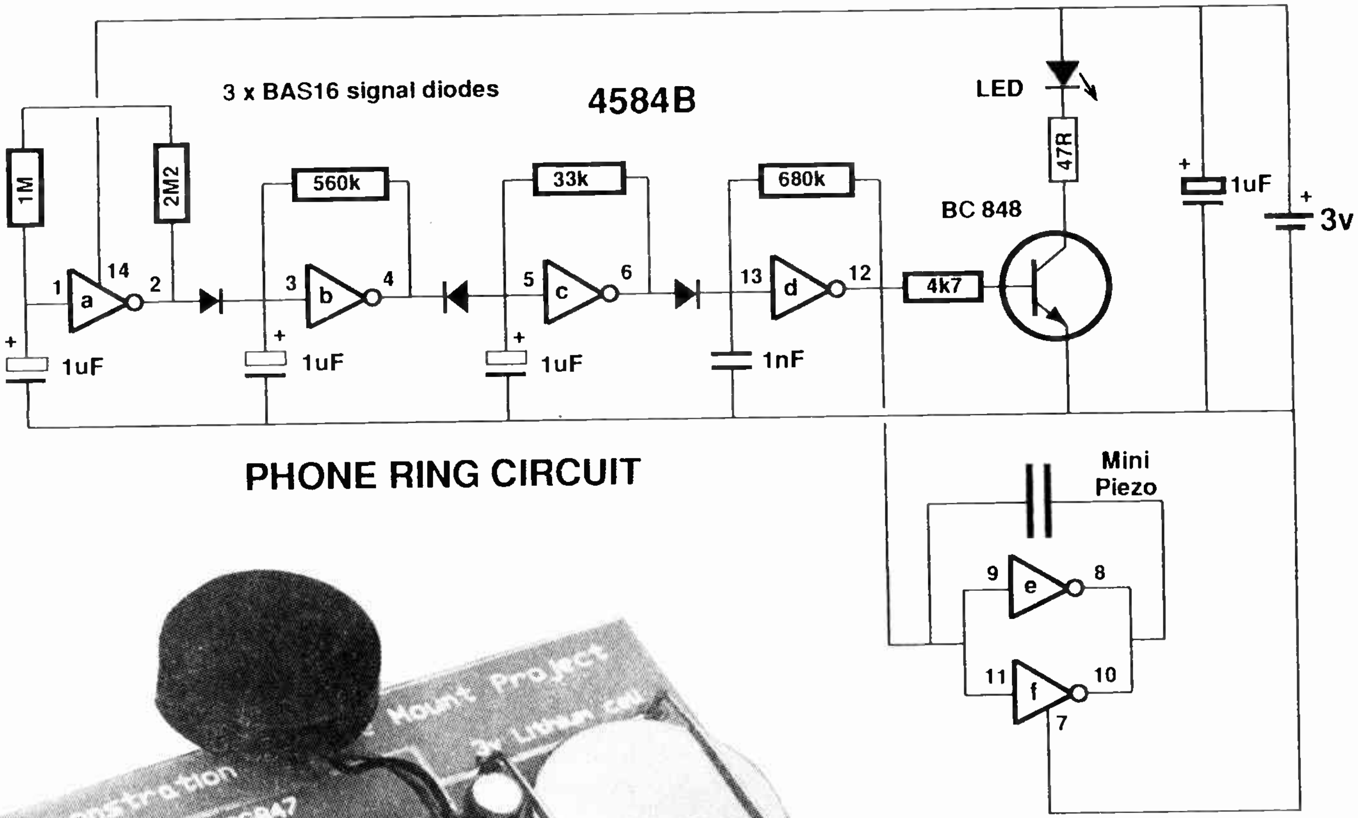
A TRINARY ENCODER WITH 3 ADDRESS LINES. ENCODING IS DONE BY CONNECTING EACH LINE HIGH OR LOW OR NON-CONNECTED TO PRODUCE AN 'OPEN-CIRCUIT' STATE

PHONE RING

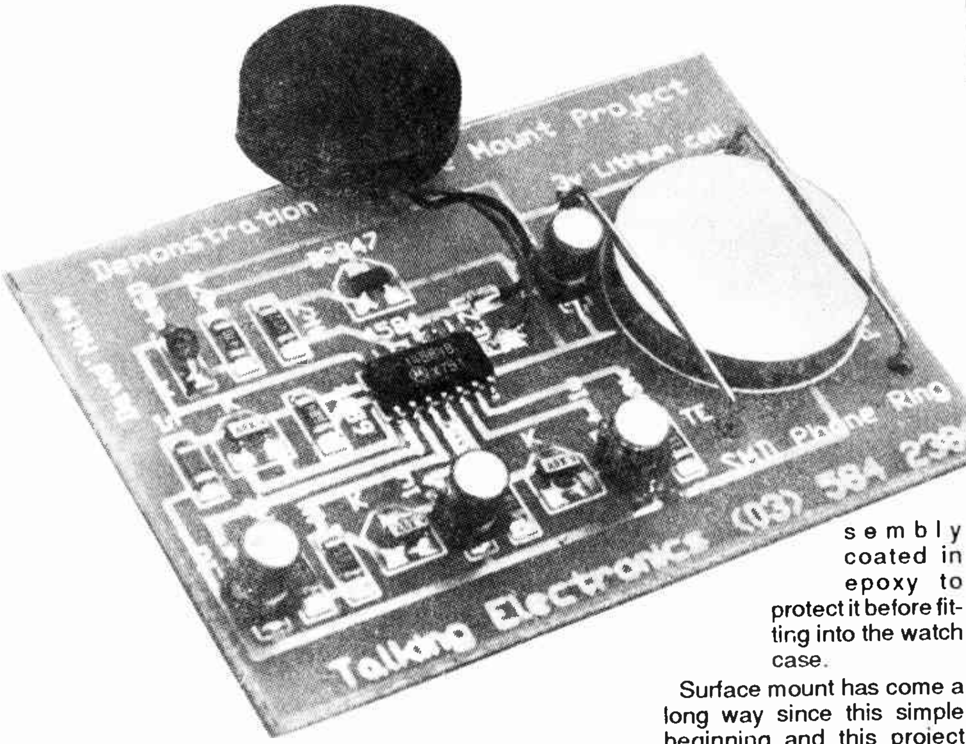
A DEMONSTRATION SURFACE MOUNT PROJECT

Parts & PC: $12.50
PC board only $2.50

Circuit design: David Halse
Text: Colin Mitchell



PHONE RING CIRCUIT



This project has been specially designed to introduce you to SMD (Surface Mount Devices).

Surface Mount is really not new. It started as far back as 1940 with a hybrid circuit in a digital watch. A chip was cemented onto a slab of ceramic material having gold tracks and film resistors. The LED display was mounted in a similar fashion and the whole assembly coated in epoxy to protect it before fitting into the watch case.

Surface mount has come a long way since this simple beginning and this project uses the latest components in a TELEPHONE RING SIMULATOR. It has been laid out on a demonstration board to give you plenty of room so that you can fit the components by hand.

Normally, a circuit using SM would be too small and fiddley to build by hand and couldn't be presented to beginners, but we have attempted to make this project as simple as possible by spacing it out and identifying the components so that almost anyone can put it together.

PARTS LIST

All components are surface mount

Resistors

1 x 47R (marked 470)
1 x 4k7 (marked 472)
1 x 33k (marked 333)
1 x 560k (marked 564)
1 x 680k (marked 684)
1 x 1M (marked 105)
1 x 2M2 (marked 225)

Capacitors

1 - 1nF ceramic (102)
4 - 1uF electrolytics

Semiconductors

3 - BAS16 signal diodes (A6)
1 - BC 848B transistor (1K)
1 - red, orange or green LED
1 - 4584B hex Schmitt trigger

Miscellaneous

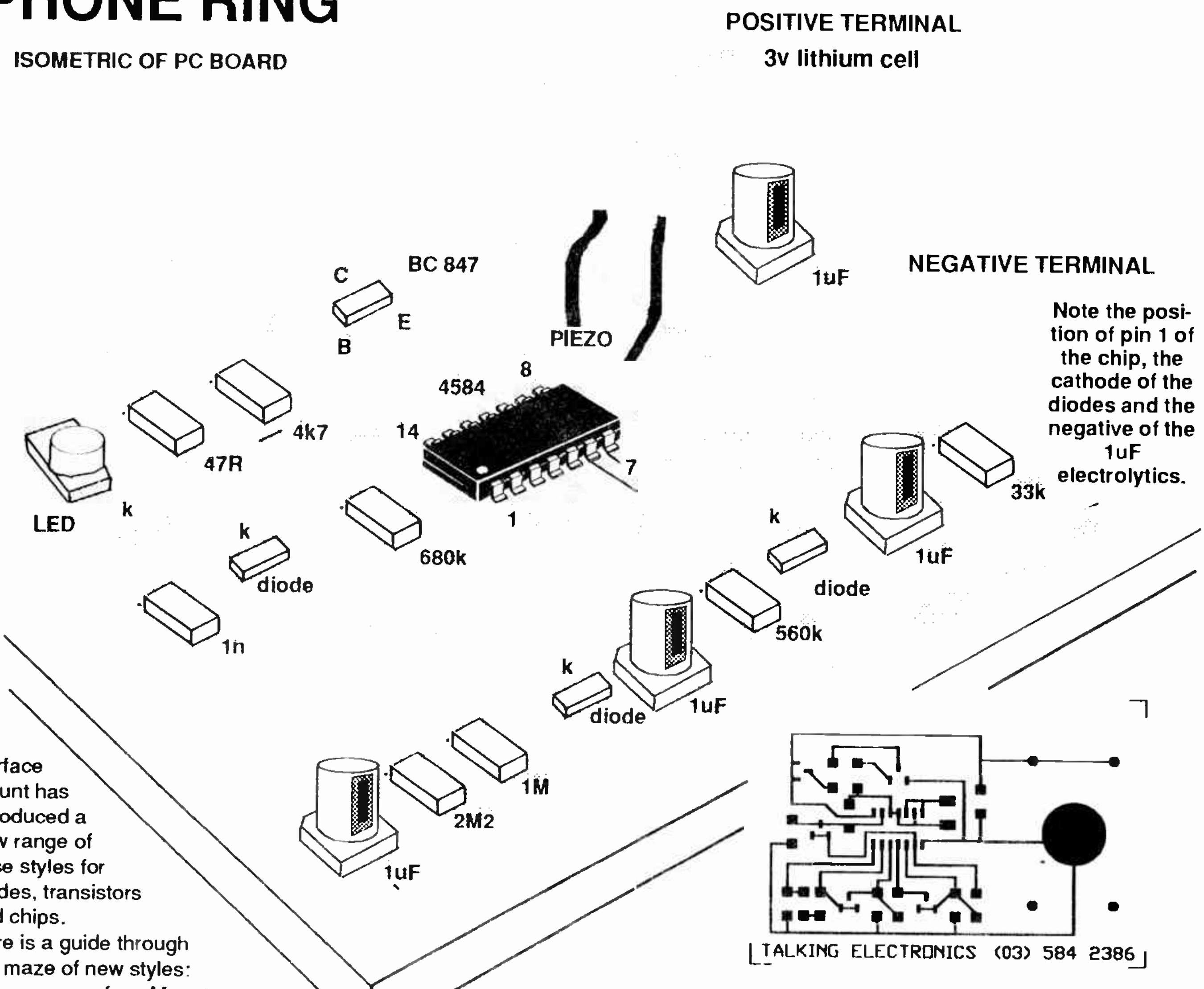
1 - mini piezo
1 - 3v lithium cell type CR 2032
10cm tinned copper wire
1 - paper clip for holding parts

1 - Phone Ring PC board

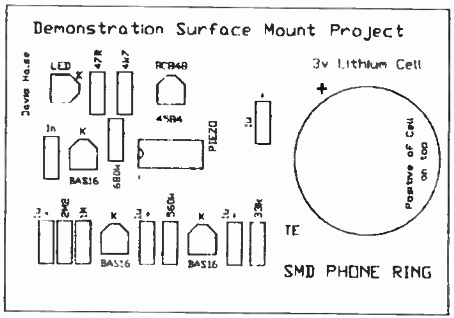
Although Surface Mount is rapidly gaining popularity with large manufacturers, it has hardly made an entry in the

PHONE RING

ISOMETRIC OF PC BOARD



Note the position of pin 1 of the chip, the cathode of the diodes and the negative of the 1uF electrolytics.



Surface Mount has introduced a new range of case styles for diodes, transistors and chips.
Here is a guide through the maze of new styles:
SO means surface Mount.
SOT is the case style for 3 or 4 leaded devices.

CASE STYLE	MEANING
SOT 23	3-leaded package
SOT 143	4-leaded package
SO 8	8-pin Dual in Line package
SO 14	14 pin DIL package
SO 16	16 pin DIL package
also SO 24 and SO 28	
PLCC 44	44 pin IC with 11 pins on each face
PLCC 68	68 pin IC with 17 pins on each face
PLCC 84	84 pin IC with 21 pins on each face

and many more.

	Marking	Vce:	Gain:
BC 846A	1A	80v	125-500
BC 846B	1B	80v	125-500
BC 847A	1E	50v	125 -900
BC 847B	1F	50v	125 -900
BC 847C	1G	50v	125 -900
BC 848A	1J	30v	125 -900
BC 848B	1K	30v	125 -900
BC 848C	1L	30v	125 -900

The general purpose NPN transistor used in this project is a plastic SOT-23 type. It is marked 1K. (It is actually a BC 848B).
Here is the Philips range of BC 846, 847 and 848 silicon planar epitaxial surface-mount transistors and the marking on the case.

hobbyist area.

The reason for this is two-fold. Surface mount components are difficult to obtain at the best of times, especially in small quantities, but more important, they are so tiny that manual handling is almost impossible.

When you see them you will see what I mean. They are so small that the slightest puff of wind will blow them off the workbench. If you have poor eyesight, it may be out of the question, but for the rest of us, it's a challenge worth investigating. To help you we have put together a kit, and when you buy one you will appreciate the features of surface mount and the problems we had in putting the project together.

The first problem we encountered was sourcing the components.

We contacted more than 15 suppliers who sell SM to get details of price, size and availability. From the information we collected we had to go to 5 of them to buy the parts!

Some had one item, others had a few more and all in all it was a time consuming exercise.

But the difficulty in locating the parts was not the only problem. The variation in costs was also considerable. Some suppliers had low prices but no stock while those with high prices had plenty of stock! Isn't it always the way!

If we were in a position to buy large quantities, bulk prices would have helped, but this is not possible when you are just starting out and need small quantities.

The other factor controlling the price is the value of the component. High value capacitors and electrolytics are considerably more expensive than low values. To keep costs down, it is important to be able to design a circuit around the cheapest components. That's why we used 1uF for the capacitors.

Now that we have done all the spadework, we want you to try Surface Mount for yourself and put this project together.

When you do, you will learn how to identify, solder and handle these tiny components and see why we say "Surface Mount has not been designed for manual assembly."

THE SIZE OF SURFACE MOUNT

Surface mount is the transition between the components we know today and those of tomorrow.

As far as designers are concerned, Surface Mount is only a temporary, intermediate stage to assist in reducing the size of a product to bring it on the market as soon as possible; while the circuit is further developed and perfected.

The aim of a designer is to put all the circuitry into a single custom-designed chip. But going from conventional componentry to final design is often not possible in one step. Sometimes it requires a few intermediate stages, requiring custom chips plus a few discrete components. To do this, it is convenient to use surface mount.

Products of tomorrow will be designed around a single dedicated chip with only the need for batteries, switch and speaker etc.

We can see this already with calculators, watches, LCD games, cameras and many more brilliantly designed products. They contain a single dedicated chip and nothing more!

There are still a lot of other devices in the transitional stage and these are currently using SM technology to reduce the size.

As the demand for a particular product increases, the cost of re-designing the circuit (and the chip) becomes economical. Eventually everything is incorporated into a single chip and the evolution is complete.

This is the way surface mount is assisting designers to bring out new products in steps and stages and as it gets phased out of one design, another is taking on the transition.

It's difficult to know how long surface mount will be around, but just like everything else, it will eventually be outmoded by a radical new approach.

Until this time comes, there will be a demand for engineers to design and work in this field and new openings are appearing all the time.

We really shouldn't be presenting a "hands-on" project for Surface Mount as it has been exclusively designed for robot handling, where "pick and place" machines take components from carriers, spools, hoppers, tubes etc and place them on a PC board with really amazing speed and precision.

But if you intend to design projects in this medium, it's absolutely essential to know how big they are, so that you can get some idea of the space they occupy and how the board will turn out.

It's also essential to know how the devices are attached and the process of soldering so that you can design the board correctly.

Since the board is Wave Soldered, it is important to place the components at 90° to the action of the wave so that they do not form a shadow and prevent the solder from touching the pads.

This also applies to placing components in the shadow of taller components, and there's 100 other tricks you have to learn.

So, if you want to start, here's your opportunity. There's nothing like experiencing it first hand and if you put a kit together you can at least say you have got off the ground.

SURFACE MOUNT ASSEMBLY

Since there are no leads on surface mount components, we do not need any holes in the board (for multilayer boards, holes are required to join one layer to the next - they are not for the components) and the components can be loaded at impressive rates of something like 3600 devices per hour for a single head machine.

To prevent them dropping off the board before the soldering process, tiny drops of glue are used and this keeps them firmly in position so that the boards can be turned up-side-down for wave-soldering.

Although Surface Mount devices are more expensive than conventional components, the higher cost is offset by the savings in board space, loading time and neatness of the final design.

This is where Surface Mount wins hands down. A Surface Mount project looks much smarter and more up-to-date than a conventional design. The size of the board can be reduced by up to 50% and this makes it very attractive for products that need to be compact such as cameras, video machines, computers, and almost any other item you can think of.

Some new chips are only available in Surface Mount and this forces manufacturers to take on the new technology.

This is exactly what happened to us. Our new speech chip (our solid-state tape-recorder project) is only available in surface mount and this forced us into the new technology. The same is happening in design laboratories all around the world and in fact, SM is seeing a growth rate of 15% per year with much of the new growth taking place in the high-volume, high-technology area.

The range of components is increasing too and already we have Surface Mount coils, inductors, transformers, and other devices you never thought could be produced in such minûte form. There is no limit to the ingenuity of engineers. Eventually standard components will be taken over completely and although this may take a number of years it will certainly occur. We have already seen the demise of the valve, the 1 watt resistor and many other components. It's only when I see them in a museum that I marvel at the leaps we have made in technology.

If you think this won't happen to conventional componentry, you are kidding yourself. These changes are as certain as progress itself. They are driven by economics and economics runs the world.

Surface Mount has arrived and is here to stay. Manufacturers can see the savings in this area and are setting the pace.

And, believe me, the pace is mind blowing. Apart from miniaturisation brought about by surface mount, we have large scale integration and multilayer PC boards. These have combined to shrink devices from desk-top size to palm size - with 10 times the features and 100 times the power!

Manufacturers of VCR's, TV's, automotive instruments, cameras, computers and TOYS have all opted for surface mount as their preferred form of construction.

Why have we included toys? Because toys represent one of the greatest driving forces in the electronics industry. Many of the recent advancements in electronics have taken place through the medium of toys.

Talking dolls, whistling keychains, swearing keyrings, etc, have all introduced the "dob of electronics."

If you have ever taken a whistling or talking keyring apart, you will find it contains a single chip mounted directly on the PC board and covered with a dob of potting compound. Some of the earlier designs used discrete chips and a few resistors but as the designs were tidied up, this was converted to the "dob of potting compound."

The reason why manufacturers use toys as the proving ground is quite simple. It provides a huge market that can be supplied and tested in a very short space of time. This means the designers get rapid feedback and the product can be updated and perfected very quickly.

Speech chips have followed this trend. Early chips cost more than $70 each while the latest are surface mount and cost less than $10! You can buy 30 seconds of digitised speech on a keychain or in a credit card for less than $8!

The main problems with early speech chips was understanding the robotised speech. It was difficult to work out what was being said. But the new chips are so clear that you think it's a tape recording.

HANDLING SURFACE MOUNT

You won't believe anything I say about the size of these components until you see them for yourself.

The size is totally unbelievable and it may take a while to build up enough courage to take them out of their carrier strips.

Normally these devices are not handled by humans and it was never intended for them to be touched at all. The fact that some components have values marked on them is merely a result of pressure from end-users.

There is no real need to have any markings on them as they are handled from start to finish by computer controlled insertion equipment.

Even testing and alignment of the built-up board can be carried out by robot testers and so component marking is a bonus for us.

A very small percentage of surface mount devices are soldered by hand in short-run productions and in these cases the operator works under a low magnification lenses or with the naked eye. To do this sort of work you need to have very good eyesight, nimble fingers and a calm temperament.

Once the initial shock of the size subsides, you can get down to organising your soldering equipment and see if you are going to be able to physically handle the task. You may need tweezers to pick up the parts and something to hold them in place while soldering.

To do this properly you really need three hands but if this is not available, you will have to use some other means of holding the part while feeding the solder and using the iron.

If you have someone that can help you, now is the time to enlist their assistance.

I'm not going to discuss the need to be an expert at soldering as the sheer size of the components will keep any absolute beginner away.

However I am going to say that you can forget the cheap and rugged 40 watt soldering iron, the instant heat iron and many of the other so-called electronic soldering irons such as the gas iron, soldering gun and even the 700°F soldering station. They are all far too hot and/or too cumbersome for this type of work. You need a soldering iron or station with a temperature of 320°C to 350°C and a very fine tip. When I say fine, I mean a tip that will almost prick you if you touch it.

This fineness is absolutely essential for soldering the pins of the IC as the lead spacing is half that of conventional IC's. Some of the other components can be soldered with a medium tip, but certainly not the IC.

We will not be glueing the components to the board before soldering as the glue is very expensive and has a life of only a few months. Instead we will be holding each item in place with a probe (such as a paper clip or fine screwdriver) while tacking it in place, prior to soldering.

This is where you can ask for assistance by getting someone to hold the component or add the solder while you solder it in place.

Some components, such as ceramic capacitors, are not identified in any way while those that are marked, require a magnifying glass to read the numbers.

We have placed the components in a carrier strip in the kit and enclosed a note to let you know how they are arranged.

Do not take any of them out of the strips before they are required as you will not be able to identify them if they are mixed up. The old motto "look but don't touch" certainly applies.

As we said in the introduction, this project is a TELEPHONE RING CIRCUIT using a mini piezo as the output device and a CMOS Schmitt trigger as the oscillator and driver.

One of the outputs of the chip also drives a LED via a transistor and this has been done to add a transistor to the board.

Some constructors will say the chip is the hardest component to fit while others will have enormous difficulty with the transistor.

In fact, this project would be ideal as a soldering test for advanced students as it will not only test soldering skills but also neatness, placement of parts and identification.

I believe a similar project was passed around a group of 20 workers at a hi-tec plant with the requirement to desolder all the components from the model and solder them back in place.

I understand that all the components withstood 20 solder and desolder operations without a failure.

The fact is, surface mount components are extremely robust if soldered quickly at the correct temperature. They are designed to withstand a 10 second submersion in molten solder or other fluid, but if you subject them to a higher temperature, you run the risk of premature and permanent damage.

ASSEMBLY and SOLDERING in INDUSTRY

There are three types of Surface Mount assembly. The first is placement of surface mount components to one or both sides of the board. The second has both surface and through-hole components on one or both sides. The third type has through-hole components on the top side and surface mount components on the bottom.

The different loading techniques for these boards calls for different soldering methods and the most common methods are: Reflow and Wave.

In the Reflow method, solder is screened onto the pads in a printing operation or individually added by means of a gun. The trackwork has been previously protected with a mask to prevent solder creating shorts and bridges. The components are then added and kept in place with solder paste or tiny dobs of non-conductive glue.

The boards are then passed through an infra-red or convection oven that allows the solder to melt.

Another method of reflow is to immerse the board in a saturated vapour of a boiling Fluorinert liquid.

The vapour, at the temperature of the boiling liquid, gives up its heat to the components, causing the solder to flow.

In the wave soldering process, the board is dipped in flux and placed upside-down over a bath of molten solder. A wave of solder is created that rises up to touch the board and complete the soldering process.

These processes sound very simple but in fact involve a high degree of technical skill. For instance, if a reasonably complex board has 100 faulty joints per million, the yield is zero and thus every board has a faulty connection!

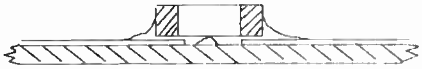
With surface mount, the soldering process not only has to provide good electrical connection but since the leads do not go though holes, it has to provide good mechanical connection too.

The design of a surface mount board becomes much more critical than a through-hole board due to the size of the components, the size of the lands, the placement of the components and the consideration given to heat stress both during and after soldering.

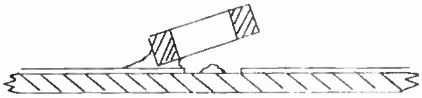
This is an entire subject on its own and technical centres can be contacted for more information for those who want to be involved in this area.

Along with the different soldering processes there are a range of soldering faults, where the components have either dropped off the board or begun to stand up due to a number of problems. The most common fault is called "tombstoning" where capacitors, resistors and packages stand on end after soldering. This results from improper pad design, unequal solder mass, shadowing of the component, misplacement of components, poor quality solder paste and wrong soldering temperature.

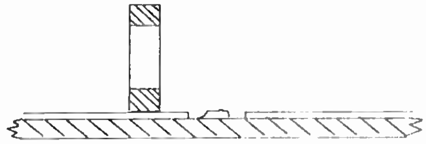
Fortunately, we wont have any of these problems in this project as everything will be soldered by hand.



Perfect connection



"Drawbridge" fault



"Tombstone" fault

Fig. 1: Two faults due to insufficient glue, and other factors.

HOW THE CIRCUIT WORKS

The circuit consists of 6 building blocks and the first is the inverter between pins 1 and 2. This forms a low frequency oscillator with a 1uF and 1M + 2M2 resistor. It governs the overall timing of the ring by creating an ON and OFF time. When the output is LOW, the tone is emitted from the piezo. When the output is HIGH, the tone is inhibited and this produces the silence between the rings.

This oscillator has an equal mark-space ratio to give the "rings" the same length of time as the silence.

The second oscillator operates at about twice the frequency of the first (this can be seen by the different value of the resistors as both capacitors have the same value).

The frequency has been adjusted so that it produces two highs during the interval when it is activated, see figure 2. The second oscillator does not produce two full cycles but only one and a half as it is the HIGHs that are required.

During each of these HIGHs, the third and fourth oscillators produce a warble that simulates the 33Hz ring of the "bell." The third oscillator generates the 33Hz frequency and this gates the fourth oscillator to produce a 1kHz tone for the piezo.

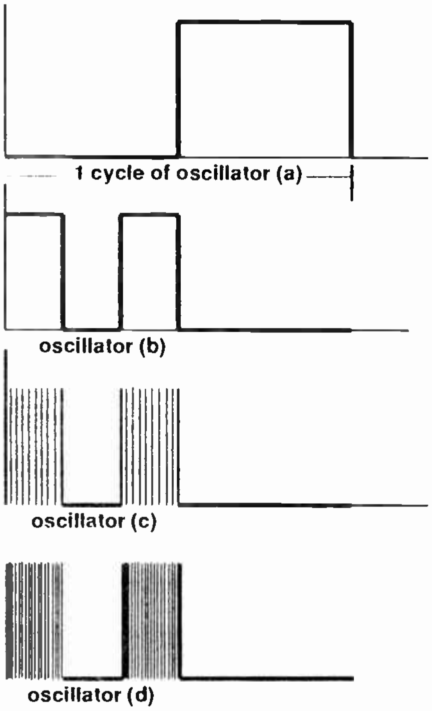


Fig. 2: Oscillator (a) provides the overall ON/OFF timing for the ring. When it is HIGH, oscillator (b) produces two HIGH's. Oscillator (c) produces about 10 high's for each HIGH of oscillator (b) and oscillator (d) produces about 40 HIGH's for each HIGH of oscillator (c) to give the characteristic phone-ring.

The output of this oscillator drives the base of the buffer transistor and also one side of the piezo. The other side of the piezo is connected to the output of two buffers in parallel and this provides good pull-down capability when the left side of the piezo is high.

The only fault in the design of this circuit is the drive to the left-hand side of the piezo. We should have included driving buffers to give it the maximum swing and thus the maximum output. But since we did not have any left over, this is the best we could do.

When the piezo is driven from a pair of buffers on each side, it sees a voltage swing of nearly twice the rail voltage and this gives it the highest output.

The tone is also passed to a LED via a transistor to give a visual indication of the operation of the circuit.

A 47R resistor has been included in series with the LED to limit the current. It is essential to include a resistor as the LED drops a fixed voltage (called the characteristic voltage drop) when it is illuminated and the transistor drops a fixed voltage across the collector-emitter terminals when it is turned on.

The voltage drops are 1.7v for the LED and .5v for the transistor. This adds up to 2.3v and thus we must include a resistor to drop .7v from the 3v supply rail. By making the resistor 47R we allow a maximum of 1.4mA to flow.

Without this resistor the power rails would be pulled down to 2.3v every time the LED is turned on.

This would cause (a) a very high current to flow through the LED and (b) faulty operation of the circuit as the power rails fluctuate.

The 1uF electrolytic across the power rails reduces the impedance of the battery and provides uniform rail impedance during the life of the battery.

A lithium battery has been used as it produces 3v so that we only need a single cell to provide the minimum voltage for the chip.

THE GATING DIODES

Between each of the oscillators is a diode called a gating diode. Its function is to turn the oscillator on and off when required. Here is how it works. We will use the second oscillator as an example, as shown in figure 3.

When the first oscillator (between pins 1 and 2) is HIGH, it is equivalent to connecting the anode end of the diode to the positive rail (as shown in figure 3) and this will have the effect of charging the electrolytic. The diode will be able to supply more current to the electrolytic than can be bled away by the 560k resistor and thus the capacitor remains charged. This means the inverter (between pins 3 and 4) will not change state and it is thus "jammed."

When the first oscillator goes LOW, the diode is effectively connected to the negative rail and ceases to have any effect on the second oscillator.

By turning the diode around the other way, the oscillator will be blocked or jammed by a LOW from the previous oscillator as the diode will bleed away any charging current so that the capacitor will not rise higher than about .6v. This is shown in figure 4.

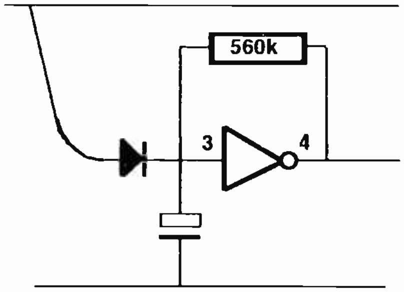


Fig. 3: An oscillator "jammed" by a gating diode. A HIGH on the diode prevents the oscillator working.

This is a very handy way of gating or controlling an oscillator by the use of diodes.

CONSTRUCTION

The object of this project is not to rush it but take it slowly and produce a neat result.

Start by creating a clear space on the workbench and get all the necessary tools and equipment ready. Make sure all the parts are in the kit by checking it against the parts list and lay everything out neatly in readiness. Look at the carrier strips so that you know what's inside.

Clean the tip of your soldering iron on a wet sponge and open out the paper clip supplied in the kit to form a probe to hold the parts during soldering.

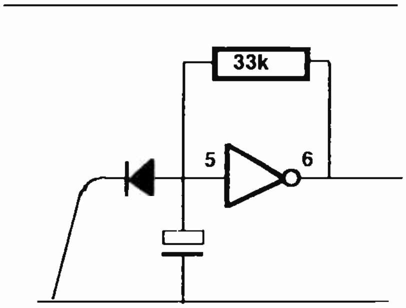


Fig. 4: An oscillator "jammed" by a gating diode. A LOW on the diode prevents the oscillator working

Take a little time to look at the legend on the board for the position of each part and also refer to the circuit diagram and isometric to see where everything goes.

Make sure you know where each of the parts is to be placed before starting as it will be very difficult to remove something once it is soldered in place.

Some of the parts are not identified so don't remove anything from the carrier strips until they are needed.

There are two methods of construction. You can start at one end of the board and fit each part as you come to it or take one component at a time from the carrier strips and solder it in place.

It does not matter which method you adopt, however I suggest you fit the IC first. We have not included a socket for the chip as it is more expensive than the chip itself and they are rarely used in any case - so you will have to be extremely careful, not to damage it.

Firstly position the chip on the board so that pin 1 aligns with the first land and make sure all the rest line up too. The dot or dimple on top of the chip indicates pin 1 as shown in figure 5.

Tack the two middle pins first so that the chip does not move then solder the rest of the pins. Use very fine solder and take no more than one second to solder each pin. You should stop after a few connections to allow the chip to cool down as we don't want to damage it.

Now we come to all the micro components. This is where the fun begins. Choose one of the methods suggested above and remove one of the parts from a carrier strip. Drop it on the board with the identification numbers upwards and use the paper clip to move it so that it is on top of the appropriate lands and aligned squarely. Keep it in place with the paper clip while you tack one end, and then the other.

The tacking process is done by adding a little solder to the pads before the component is placed in position.

After the component has been positioned, this solder can be reheated to hold the part while the other end is tacked in place. After this, you can go over the joints again, adding a little more solder and making sure the connections are perfect.

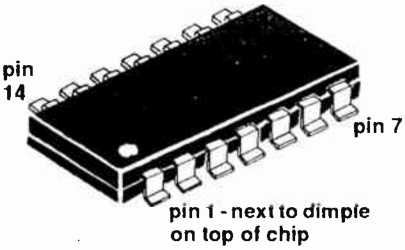


Fig. 5: The surface mount 4584B IC

Don't press too hard with the clip or the iron and don't move the component with the iron as this will make it stick to the tip and cause it to heat up too much.

When you have soldered one end, wait a few seconds before soldering the other as this will allow the component to cool and prevent it getting too hot.

This is important as the temperature of the tip of the iron will be about the absolute maximum any of the components can tolerate and the only way to prevent damage is to limit the soldering time to one or two seconds.

The reason for this is the junctions of the semiconductors are very close to the point of soldering and any overheating will cause degeneration in performance and even premature failure. The LEDs are also very critical as the light-emitting crystal will lose its output at the slightest amount of overheating. The transistor will lose gain if overheated while the signal diodes are slightly more tolerant however they become leaky if subjected to too much heat. The electrolytics can also suffer considerably by overheating, so take care.

While taking care with the temperature and soldering times, you must also remember the orientation of the components as they will not work if placed around the wrong way. The placement of the transistor is fairly obvious as it has three leads and you can see which way around it goes. The diodes come in the same package as the transistor and you must not confuse the two.

The collector of the transistor is in the centre of one side and the base and emitter terminals on the other side. Refer to figure 6 to identify the terminals.

The cathode of the diode is in the centre of one side of the chip and the lead closest is the anode. The third lead is "no connection."

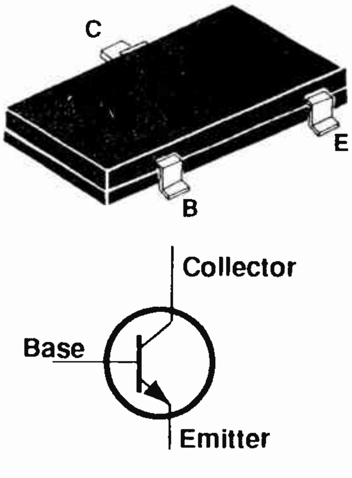


Fig.6: The pin-out of the surface mount BC 848 transistor

If the LED is a 2mm axial lead type, the cathode lead is marked with a cross. Or if it is a true surface-mount LED, the pin in the middle of one side is the cathode. This lead must be placed over the letter "k" on the board.

The piezo is fitted to the two lands marked "Piezo" and the leads can be soldered either way around as the piezo operates on AC and is not polarised.

A single 3v lithium cell is fitted under two tinned copper wire straps at one end of the board to supply power to the circuit. These straps are made by placing the cell in position and bending the copper wire over it and through the holes. They are then soldered in position. The straps connect to the positive of the cell while the negative makes direct contact with the board. The straps should keep the cell tight so that it makes good contact with the board.

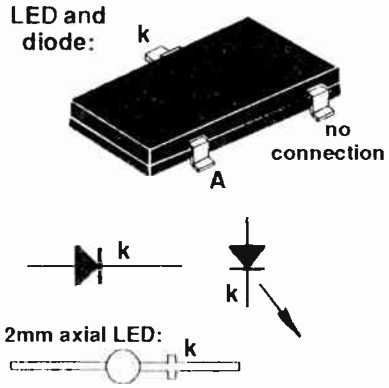


Fig. 7: The pin-out for the diode and LED.

When the cell is fitted, the LED will begin to flash and the piezo will produce a sound similar to a phone ringing.

If it doesn't, you may have a fault and if this is the case, you can count yourself lucky as you will be able to go over the project and diagnose the fault with the assistance of our "If It Doesn't Work section." This is where you will start to learn about electronics and the project will have great benefits.

IF IT DOESN'T WORK

If the circuit doesn't produce a sound similar to a phone ringing, you will have to work out where the fault is coming from by reading the section on "How The Circuit Works." There are possibly over 50 faults with a circuit as simple as this as any two components could be swapped, any of them could be faulty due to overheating or the board could have a short between the tracks.

To locate the problem, here is the approach:

The first thing to do is measure the internal impedance of the battery. This is done by setting the multimeter to 500mA range and placing the probes on the battery for 1/2 second. The needle should rise to about 200mA or more to indicate the cell can supply driving current.

Next, measure the current taken by the circuit by placing a piece of plastic under the cell so that it doesn't make contact with the board. This plastic can be used as a switch to turn the project off when not required. Measure across the plastic with a multimeter set to 50mA (or 500mA to be on the safe side). The current should be about 1 to 2mA and you can change the range to 5mA to get an accurate reading.

If it is considerably more than 2mA, you have either damaged one of the components or created a short.

Make sure there are no solder bridges between tracks or under the chip by inspecting the board carefully. Next cut the negative track going to pin 7 of the chip so that half the circuit is removed. Re-measure the current to see if the remaining parts contain the fault. Refer to the circuit diagram to identify which components are in this section and if the fault persists, make another cut in the trackwork and "home-in" on the fault. This will save you removing any of the parts and testing them, as soldering and desoldering will create more problems than it solves.

If this doesn't find the fault, you will have to read on. In this type of project we start at the back-end and work to the front. This is because we have a LED and piezo to act as output devices to let us know what is happening and the extent of the fault.

We start with the LED and its driver transistor. If the LED does not light, the fault could lie in either of these components or the chip.

To locate the problem, take a voltage reading at output pin 12 of the chip.

The needle of the multimeter should flicker to correspond to the ringing of the circuit and if not, the fault will lie in the chip or one of the four oscillators.

If the needle flickers, go to the collector of the transistor. Here, you will see the needle sit at slightly above 1v (due to the characteristic voltage drop across the LED plus a very small drop across the resistor) and fall to slightly less than 1v when the circuit produces ring pulses. If the LED does not produce a glow when this occurs, it has either been damaged or is around the wrong way. If the needle does not flicker at the collector, the transistor has been damaged.

You can also measure the voltage at the base of the transistor. The reading you will get will only be about 100mV as the needle will not have time to rise to 650mV during the ring. To get an accurate indication of the signal you must measure it with a CRO.

If the sound from the piezo is not similar to that of a phone ringing, the fault will lie in one or more of the 4 oscillators.

Start at the first oscillator, between pins 1 and 2. Place the positive probe on pin 2 and set the multimeter to a low voltage. The needle will go high for about 1 second and low for the same duration. When the output is LOW, a tone is emitted from the piezo. If the output does not swing up and down, measure the voltage across the power rails (pins 7 and 14) of the chip.

If voltage is present, and the current consumption is about 2mA, the fault may lie in a damaged Schmitt inverter, a leaky 1uF capacitor or an open 2M2 or 1M resistor.

You cannot measure across the 1uF while the circuit is operating as the resistance of your meter will prevent it charging to 2/3 of rail voltage and the oscillator will not change state.

The only thing you can do is measure the output voltage. If it is HIGH, the input will be low (assuming the gate is working) and one of the feedback resistors may be open circuit. Set your multimeter to 10v range (assuming a 20k/v meter) and place the probes firstly across the 2M2 resistor and then across the 1M. If you detect a very slight movement of the needle, the circuit is working and the resistance of the meter is taking the place of the resistor. Replacing the appropriate resistor will fix the fault.

If the circuit produces a ring-ring-ring-ring without a pause, the gating diode between pins 2 and 3 may be faulty or not making contact.

If the output of the first oscillator is correct, the output of the second can also be detected on a multimeter by probing pin 4. This pin will give two high's during the ring tone and if a fault exists, you can diagnose it in a similar manner to the first gate.

The output of the third and fourth oscillators are more difficult to detect on a multimeter as the frequency is too high for the needle to respond.

The solution is to remove the piezo from its output terminals and place it between pin 6 and the negative rail. Here you will hear a series of clicks to correspond to the 33Hz oscillator, gated by oscillator (b).

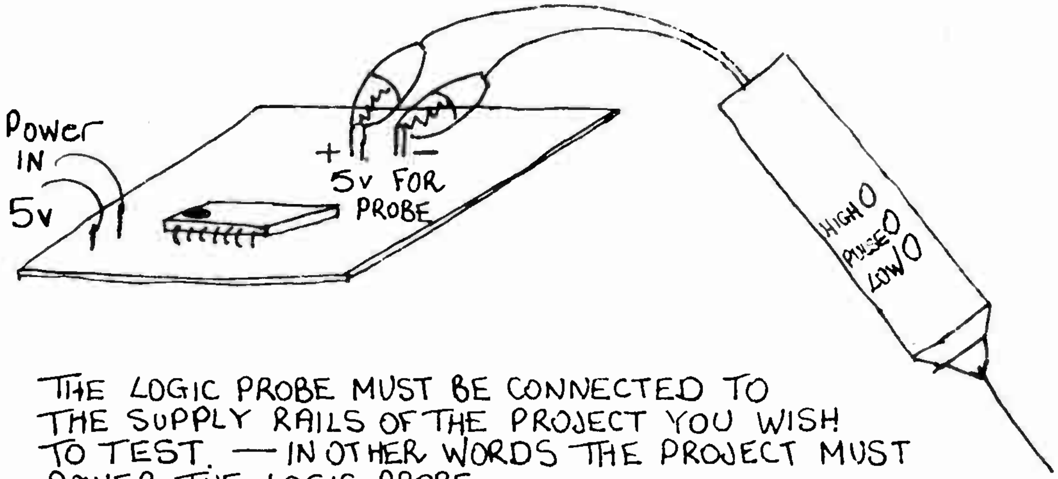
Placing the piezo between pin 12 and the negative rail will produce the ring sound except the output will be lower than when connected to the output terminals.

If you find one of the inverters has been damaged, you can use the one between pins 8 and 9. You will have to do a little rewiring, however if the chip is not drawing excessive current due to it being damaged, the change can be made. This just about covers everything and the project should be working perfectly by now - I hope so.

CONCLUSION

If you did not have any success, the best solution is to buy another kit and start again. The main problem will be soldering. Next time you will learn from your mistakes and the project will work first go. For those who tasted the joys of success, wait for our next surface-mount project. It's a speech chip that gives tape-recorder quality and is ideal for a whole range of applications. Hold your breath, it's coming.

USING A LOGIC PROBE



THE LOGIC PROBE MUST BE CONNECTED TO THE SUPPLY RAILS OF THE PROJECT YOU WISH TO TEST. — IN OTHER WORDS THE PROJECT MUST POWER THE LOGIC PROBE.

THERE ARE TWO REASONS FOR THIS.

FIRSTLY IT BRINGS THE DETECTING VOLTAGES (THE HIGHS & LOWS) OF THE PROBE IN LINE WITH THOSE OF THE PROJECT.

FOR INSTANCE, IF THE PROJECT OPERATES ON 5V, THE PROBE WILL BE POWERED BY A 5V SOURCE & THUS IT WILL REGISTER A 'HIGH' WHEN IT SEES A VOLTAGE BETWEEN 3·5 – 5V.

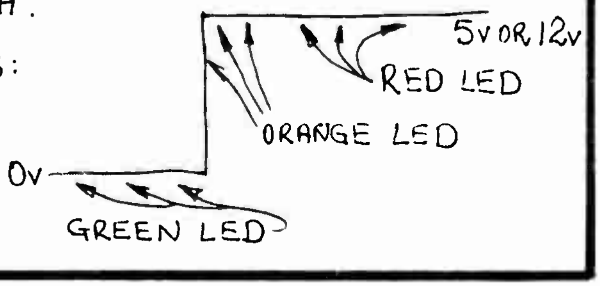
IF THE PROJECT OPERATES ON 12V, (FOR CMOS CHIPS) THE PROBE WILL REGISTER A 'HIGH' WHEN IT SEES A VOLTAGE BETWEEN 8 – 12V. OBVIOUSLY YOU DO NOT WANT THE PROBE TO REGISTER A HIGH WHEN IT SEES 3·5V – 5V (IN THE EXAMPLE ABOVE) AS THIS IS A LOW FOR 12V CMOS OPERATION.

THE SECOND REASON FOR POWERING THE PROBE FROM THE PROJECT IS TO CREATE AN EARTH RAIL FOR A "LOW" & A POWER RAIL FOR A "HIGH." IF A PROJECT HAS BOTH 5V & 12V RAILS, YOU MUST CHANGE THE PROBE VOLTAGE TO MATCH THE CHIPS (OR LINES) YOU ARE TESTING.

SETTING UP

WHEN THE PROBE IS CONNECTED TO THE POWER RAILS, NO INDICATOR LEDS SHOULD COME ON. — THE TIP IS "FLOATING". BY PROBING THE NEGATIVE RAIL (ZERO RAIL) THE GREEN LED WILL COME ON. BY PROBING THE POSITIVE RAIL, BOTH THE PULSE LED (ORANGE) AND RED LED WILL COME ON. THIS WILL INDICATE THE INPUT OF THE PROBE IS GOING FROM "ZERO" TO "HIGH".

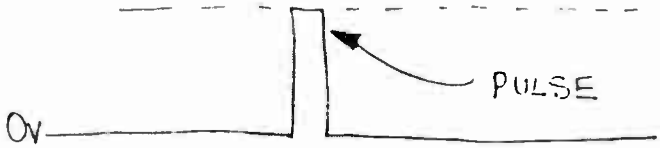
A GRAPH FOR THIS CAN BE SHOWN THUS:



THE ORANGE WILL ONLY STAY ON FOR A MOMENT AS IT IS A 'PULSE LED'.

— THE PULSE LED

THE PULSE LED INDICATES AN EXCURSION FROM LOW TO HIGH. IF A PULSE SUCH AS THE FOLLOWING, OCCURS:



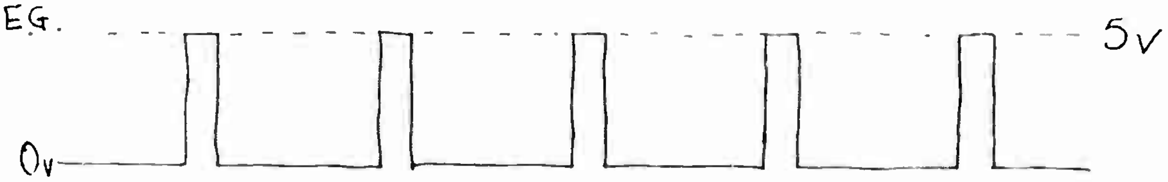
THE DURATION OF THE HIGH WILL BE VERY SHORT AND YOU WOULD NOT BE ABLE TO SEE THE 'BLINK' OF THE RED LED.

THE PULSE CIRCUIT PICKS UP THE PULSE AND EXTENDS THE DURATION OF THE ORANGE INDICATOR LED SO THAT YOU CAN SEE IT.

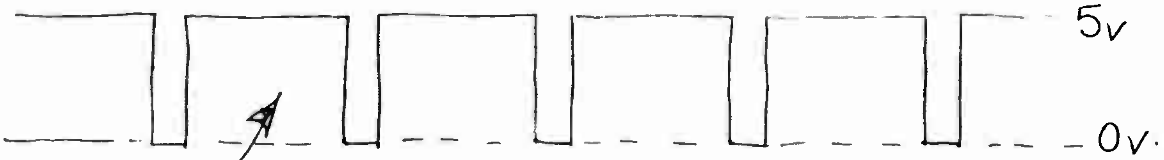
THE PULSE LED DOES NOT TELL YOU THE DURATION (HOW LONG THE PULSE WAS HIGH) OF THE PULSE. IT ONLY TELLS YOU THAT A PULSE OCCURED.

THE LOGIC PROBE CAN TELL YOU IF A LINE IS PREDOMINATELY HIGH OR LOW — BY LOOKING AT THE LEDS CAREFULLY.

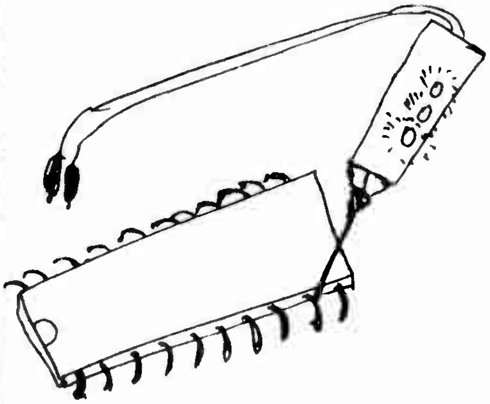
E.G.



FOR THE TRAIN OF PULSES ABOVE, THE GREEN LED WILL BE BRIGHT, THE ORANGE LED WILL INDICATE PULSES ARE PRESENT & THE RED LED WILL BE DIM.



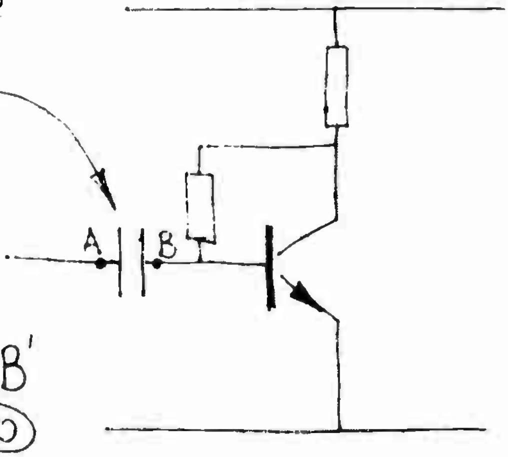
FOR THIS TRAIN OF PULSES THE GREEN LED WILL BE DIM, THE ORANGE LED WILL INDICATE PULSES ARE PRESENT & THE RED LED WILL BE BRIGHT.



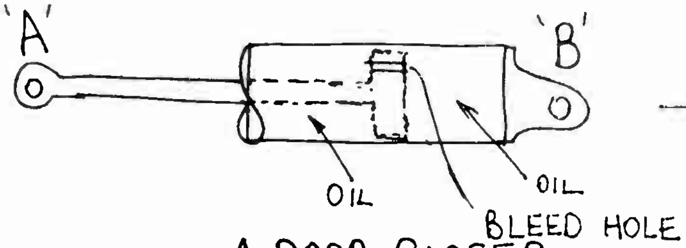
TRY TESTING A SIMPLE CIRCUIT YOURSELF AND WATCH THE LEDS. IF YOU KNOW WHAT IS HAPPENING ON THE PINS YOU CAN COMPARE WITH THE LEDS & THIS WILL HELP YOU "READ" THE PROBE.

How A Capacitor Works

THIS DISCUSSION WILL HELP YOU UNDERSTAND HOW A COUPLING CAPACITOR WORKS.



THE ANALOGY:



A DOOR CLOSER

WE HAVE ALL SEEN A DOOR CLOSER (OR SHOCK ABSORBER). IT CONSISTS OF AN OIL FILLED CYLINDER & PLUNGER. A SMALL BLEED HOLE IN THE END OF THE PLUNGER ALLOWS OIL TO PASS FROM ONE END OF THE CYLINDER TO THE OTHER AS THE PLUNGER IS WITHDRAWN OR PUSHED IN.

IF A PERSON HOLDS END 'A' & ANOTHER HOLDS END 'B', THE ASSISTANT 'B' WILL FEEL VERY LITTLE REACTION IF 'A' PULLS THE PLUNGER SLOWLY.

BUT IF 'A' PUSHES & PULLS VERY QUICKLY, 'B' WILL FEEL THE FULL EFFECT.

THE CAPACITOR IN THE CIRCUIT ABOVE BEHAVES EXACTLY LIKE THE SHOCK ABSORBER. —— IF THE VOLTAGE ON END 'A' IS ALLOWED TO RISE SLOWLY, THE CAPACITOR WILL CHARGE & END 'B' WILL NOT MOVE. (THIS MEANS THE TRANSISTOR WILL NOT SEE THE CHANGE IN VOLTAGE).

IF THE VOLTAGE ON END 'A' RISES & FALLS QUICKLY, END 'B' WILL FOLLOW EXACTLY & THE TRANSISTOR WILL SEE THE CHANGING WAVEFORM.

IF THE WAVEFORM RISES AT A 'MEDIUM' SPEED, THE CAPACITOR WILL PARTLY CHARGE & SOME OF THE REACTION WILL BE PASSED TO THE OTHER END.

THE TRANSISTOR MAY SEE 10% OF THE WAVEFORM, 50% OR 90% & THIS IS WHAT HAPPENS IN PRACTICE. —— THE COUPLING CAPACITOR PASSES SOME OR MOST OR NEARLY ALL OF THE WAVEFORM & ANY LOSSES ARE CALLED "STAGE COUPLING LOSSES."

NOTES:

— INCREASING THE SIZE OF THE CAPACITOR IS EQUIVALENT TO USING A LARGER SHOCK ABSORBER.

— A DC VOLTAGE ACROSS THE CAPACITOR IS EQUIVALENT TO EXTENDING THE ARM OF THE SHOCK ABSORBER.

— FREQUENCY IS EQUIVALENT TO PUSHING & PULLING THE ARM 'A'.

TRUTH TABLE QUIZ

Determine the state of output Y for the following conditions of the inputs:

A	B	C	1	2	3	4	5	6	7	8
0	0	0								
0	0	1								
0	1	0								
0	1	1								
1	0	0								
1	0	1								
1	1	1								

AND GATE

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

NAND GATE

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

XOR GATE

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

XNOR GATE

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

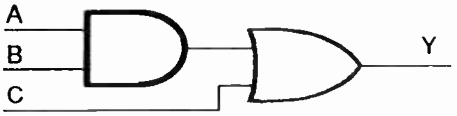
OR GATE

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

NOR GATE

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

1



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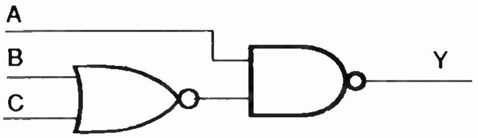

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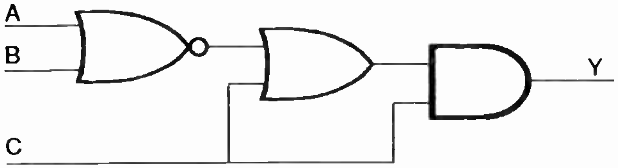

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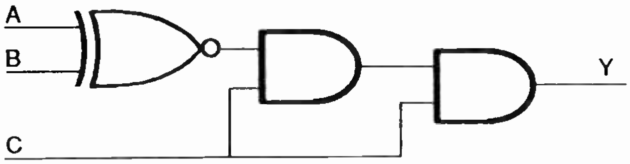

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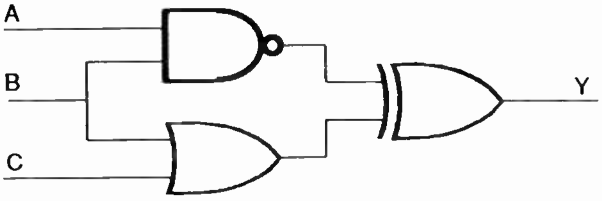

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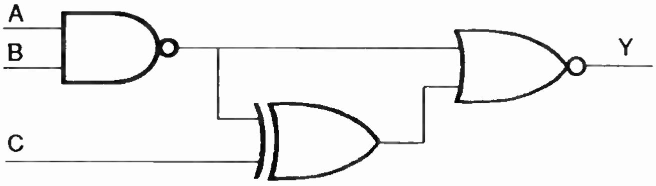

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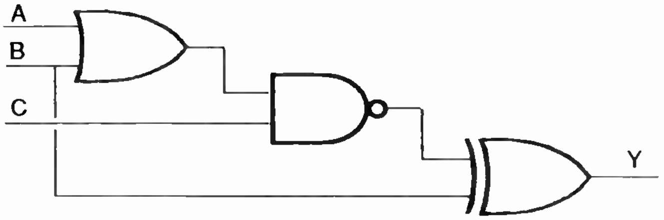

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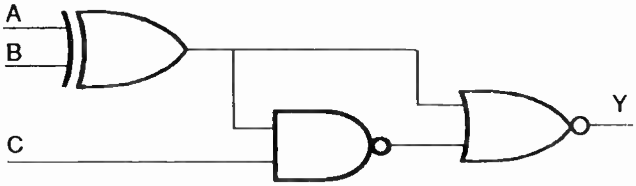


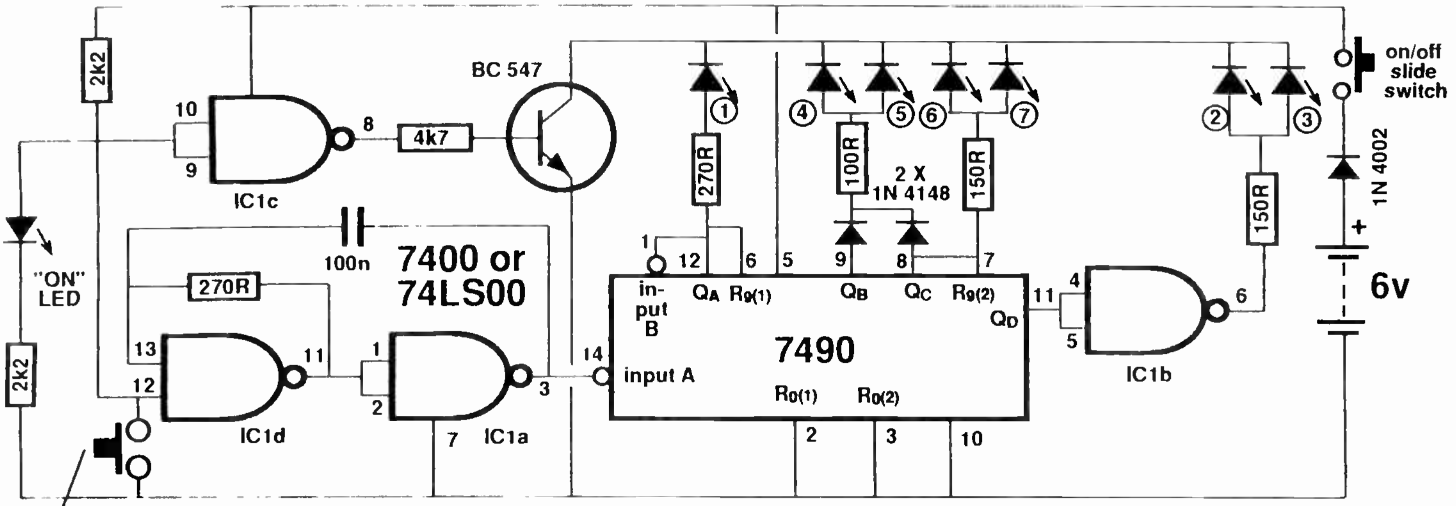
ANSWERS

A	B	C	1	2	3	4	5	6	7	8
0	0	0	0	1	0	0	1	0	1	0
0	0	1	1	1	1	1	0	0	1	0
0	1	0	0	1	0	0	0	0	0	0
0	1	1	1	1	1	0	0	0	1	0
1	0	0	0	0	0	0	1	0	1	0
1	0	1	1	1	1	0	0	0	0	0
1	1	1	1	1	1	1	1	0	1	0

TTL DICE

Learn about a very clever circuit

Parts & PC: $7.70
PC board only: $2.20
If you want hands-on experience with TTL chips, you should buy this kit.



Push button to freeze oscillator and display the result on a set of LEDs

TTL DICE CIRCUIT

Note: All LEDs must have the same characteristic voltage drop.

There's more to this circuit than first meets the eye.

It's a very clever design and just by reading the section on "How the Circuit Works," you will see how to gate chips (connect them together) to perform tasks that are completely different to that expected.

For instance, the 7490 is a decade counter with a divide-by-two and divide-by-five stage. No-where does it appear to have a divide by six feature as required by this dice circuit. So, why was it used? The reason is we don't just need a divide by six capability but a set of driving lines that turn on LEDs to give the same effect as the sides of a dice. And this is why this circuit is so brilliant.

It puts the 7490 in a count mode that starts at zero, increments to 1, 2, 3, 4 and when count 5 is reached the chip jumps to 9. This gives us six outputs: 0, 1, 2, 3, 4, 9. Don't jump the gun and say zero is not an output because we have a lot more technical discussion in store before you will understand how the LEDs are activated.

Firstly we will look at how the circuit works, then how it produces the dice effect.

The first two NAND gates are connected as a multivibrator, operating at a frequency of approx 10kHz. When the push button is pressed, the multivibrator freezes and the output of the 7490 counter appears on the LEDs.

When the button is released, the multivibrator starts again and the counter is continually being clocked "in the background." You are unable to see this on the display as the LEDs are turned off via the transistor when the button is not pushed. A power diode in the positive rail reduces the 6v to about 5.4v as TTL chips do not like any voltage above 5.5v.

HOW THE MULTIVIBRATOR WORKS

A multivibrator is another name for an oscillator. It's an oscillator with a square output and in our circuit the action commences with the 270R resistor across the NAND gate. A single gate will oscillate if a resistor is placed between input and output, but the frequency at which it oscillates will be very high and not controllable if a capacitor is not included. TTL gates are capable of oscillating at 50MHz and beyond if the input is tied to the output. This is higher than required for our project, so a capacitor is needed.

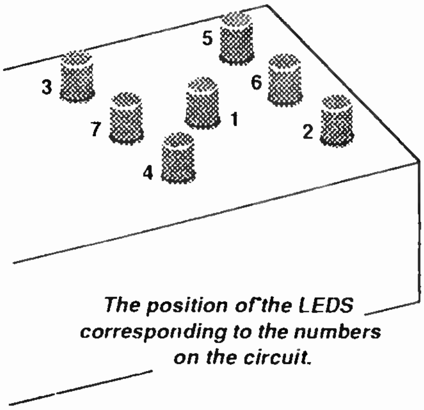
The function of the 2k2 resistor is to keep the input line HIGH when the switch is not pressed.

If you refer to the 4 NAND gate diagrams on the next page, you can see that if one input is HIGH, the output will change when the second input goes from LOW to HIGH, and the output is "out-of-phase" with the input.

If we connect a resistor (such as a 270R) between input and output, the gate will oscillate.

It happens like this:

Suppose both inputs are HIGH and the output is LOW. If we connect a resistor between input and output, the input line will be pulled LOW by the action of the resistor. When the input falls to just below half rail voltage, the output will go HIGH and this will be reflected back to the input line. When the input rises to just above half rail voltage, the output will go LOW again.

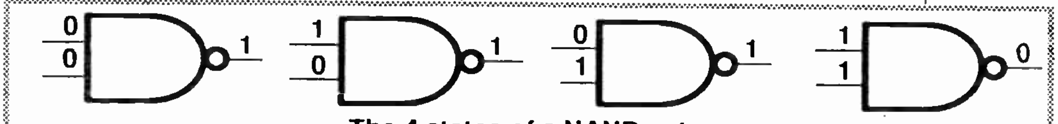


The position of the LEDS corresponding to the numbers on the circuit.

PARTS LIST
1 - 100R
2 - 150R
2 - 270R
2 - 2k2
1 - 4k7
1 - 100n
1 - BC 547 transistor
2 - 1N 4148 diodes
1 - 1N 4002 diode
1 - 7400 or 74LS00 IC
1 - 7490 IC
2 - 14 pin IC sockets
1 - 3mm red LED
7 - 5mm red LEDs
1 - push button
4 - AA cells (not in kit)
1 - mini SPDT slide switch
1 - UB5 small Jiffy box (not in kit)
1 - TTL DICE PC board

Depending on how long it takes for the voltage to rise and fall to the threshold levels and how long the output takes to react to the change in input voltage, so the frequency is set. For TTL chips this can be in the range of 50MHz.

But we don't require such a high frequency for this project and to reduce it we need to include a capacitor. The action of the capacitor is this: It slows down the rise and fall time for the input to see the threshold levels. This is how it does it:



The 4 states of a NAND gate

The second gate is wired as an inverter. Refer to the first and last diagram above and see that the output is out of phase with the input when the two inputs are of the same sign. This is the same as if the inputs were tied together, as is the case in the circuit we are discussing.

A 100n capacitor is connected between the output of the inverter and the input of the first gate. As you know, a capacitor takes time to charge up and discharge and if we go back to our discussion above, we will start with both inputs of the first gate HIGH. This makes the output of the first gate LOW and the output of the inveter HIGH. This means both ends of the capacitor are at the same potential and thus it is uncharged.

The action of the resistor is to pull the input of the first gate LOW, and in doing so it charges the capacitor. The capacitor takes a short time to charge and when the input is below mid rail, the first gate changes state and causes the second gate to change too.

The output of the multivibrator is now LOW and the capacitor keeps the input low while the resistor begins to discharge it then charge it in the opposite direction, thus increasing the voltage on the input. When it rises to above mid rail, the two gates change state again to repeat the cycle.

The time taken for the gates to change state are very short compared to the time taken for the capacitor to allow the voltage to rise and fall and thus the capacitor sets the frequency (in conjunction with the resistor).

When the button is pressed, one input of the first NAND gate goes LOW and if you refer to the diagrams above, you will see that the gate will not change state under this condition. Thus the button freezes the action of the multivibrator.

The push button also connects to another NAND gate, wired as an inverter and this gate drives the base of a transistor. When the button is pressed, the transistor conducts and connects the cathodes of the LEDs to the negative rail, thus turning on those LEDs that are driven by the outputs of the 7490.

Next we come to the counter IC:

THE 7490

The 7490 counter has 4 binary outputs. In other words it would drive a set of LEDs according to a binary table if it were not for the fact that it has an internal circuit that resets the count after 9 to create a divide by ten arrangement. (The first count is zero). It does this by having a divide-by-two stage and a divide-by-five stage.

The result is a BINARY COUNTER that has been CODED (wired) to give a DECIMAL (10) readout. This gives it its name BCD counter.

It also has two reset lines that reset the chip to zero and two reset lines that force the output to 9. The need for a reset to zero is obvious and the reset to 9 is used in BCD nine's complement applications.

Our circuit does not use the zero reset lines (they are tied low to prevent them coming into operation) but does use the reset to 9 feature. (Not for nine's complement but to achieve a count-to-six.)

If the 7490 is allowed to count normally, the outputs will go high according to the following table:

BCD COUNT SEQUENCE FOR 7490

COUNT	OUTPUT			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H

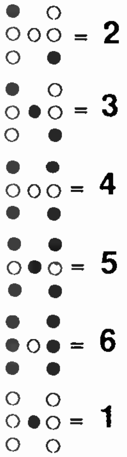
But we have gated the reset-to-nine inputs (pins 6 and 7) so that when 5 appears on the output (Q_A and Q_C HIGH) the chip is forced to go to 9 as shown above.

This means the 7490 will count: 0, 1, 2, 3, 4, 9, 0, 1, 2, 3 ,4, 9, etc etc.

Now, here comes the clever part. The outputs have been taken to LEDs that are arranged to form dots on the side of a dice.

When the count for the 7490 is zero, all outputs are LOW and you would expect no LEDs to come on. BUT one output (Q_D) goes to an inverter and when it is LOW, the output of the inverter is HIGH. Thus LEDs 2 and 3 come on to produce a "2!" When the 7490 is 1 the LEDs indicate "3." When the 7490 is 2 the LEDs indicate "4." When the 7490 is 3 the LEDs indicate "5." When the 7490 is 4 the LEDs indicate "6," and when the 7490 counter is forced to 9 the LEDs indicate "1."

HOW THE DOTS ARE CREATED:



7490 = 0 = ② ③ = = 2

7490 = 1 = ① ② ③ = = 3

7490 = 2 = ②③ ④⑤ = = 4

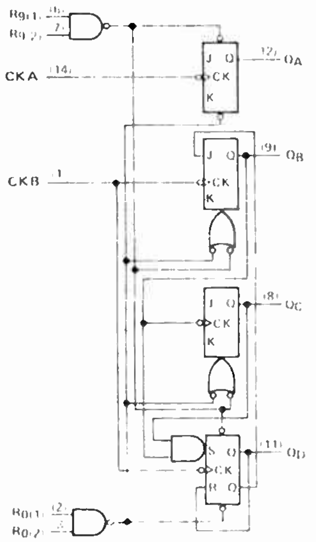
7490 = 3 = ①②③ ④⑤ = = 5

7490 = 4 =②③④⑤⑥⑦ = = 6

7490 = 9 = ① = = 1

FUNCTIONAL BLOCK DIAGRAM FOR 7490

PAGE 7-73 TEXAS INSTRUMENTS



TURNING ON A LED

We are going to take one of the LEDs (LED ①) and show how the current flows from the battery and through the LED to turn it on. This is a very long path so follow it closely.

Conventional current flows from positive to negative and when you are talking about current flow, we normally describe it in this direction, even though the device we are talking about (the Light emitting Diode) is an electronic device.

The current flow starts at the positive terminal of the battery and passes through a 1N 4002 power diode. This diode does not inhibit the current flow in any way as it flows through the switch and into the 7490 chip via the supply lead (pin 5).

Inside the chip the current is diverted to the outputs according to the state of the transistors inside the chip and comes out Q_A (pin 12) when this output is HIGH. It then goes through a 270R resistor and this limits the current. Later we will explain how much the resistor limits the current and show how its value is worked out. The current then flows through LED ① to turn it on. The current then flows through the collector-emitter junction of the BC 547 transistor, providing the transistor is turned ON by supplying a turn-on voltage and current to the base. The current continues to the negative of the 6v battery to complete the circuit. We already know that all the components mentioned must be in circuit for the current to flow and if, say, the switch is opened, the LED will not illuminate.

RESISTOR VALUES

The 270R reisistor (the letter R stands for ohms) in series with the LED is called a limiting resistor and the value we have chosen allows about 6mA to pass through the LED.

A Light Emitting Diode will illuminate when as little as 1mA flows through it but it is more general to allow about 10 - 15mA to flow. The maximum allowable current for a LED is 25mA

To work out the value of the limiting resistor we use ohms law and this is:

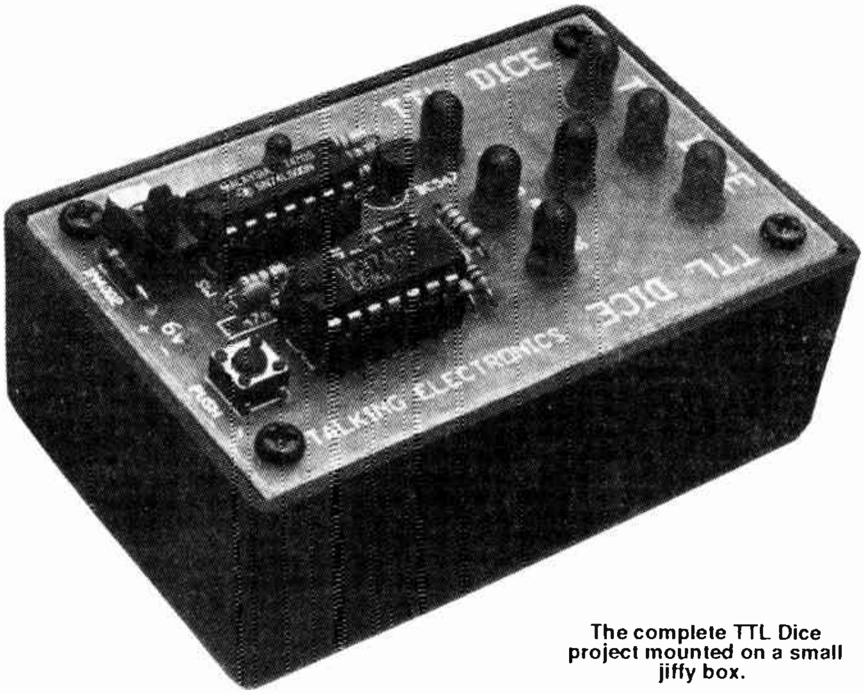
$$I = \frac{V}{R}$$

Where I is the current flowing (6mA or .006A in our case), V is the voltage across the resistor and R is the value of the resistor in ohms. We can re-arrange the equation to determine the value of resistance thus:

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

When an output goes HIGH it does not deliver full rail voltage but about 3.5v, for a rail voltage of 5.5v. Thus the chip loses about 2v in the driver stage.

A further voltage drop occurs across the LED. This drop is about 1.7v and is a characteristic of the LED that does not alter, no matter how much current is flowing. A further .1v is dropped across the collector-emitter leads of the transistor.



The complete TTL Dice project mounted on a small jiffy box.

This means the voltage appearing across the resistor is 3.5v - 1.7v - .1v = 1.7v

Using this value in the equation we get:

$$R = \frac{1.7}{.006}$$

$$R = 283R$$

The nearest standard-value resistor is 270R.

The same working applies to the other LEDs in the display so that the overall brightness is equal.

THE 2k2 RESISTOR

The purpose of the 2k2 resistor on the input of the 74LS00 is to make the input line to the switch go HIGH when the switch is not pressed.

Initially we designed the circuit with a 7400 and did not need to include the resistor as the input lines on this type of chip are pulled HIGH internally.

But when we fitted a low-power Schottky version, (74LS00) the LEDs did not go off fully when the circuit was clocking.

To fix this we had to include a 2k2 resistor on the input to make it go high. Thus we can specify 7400 or 74LS00 in the parts list.

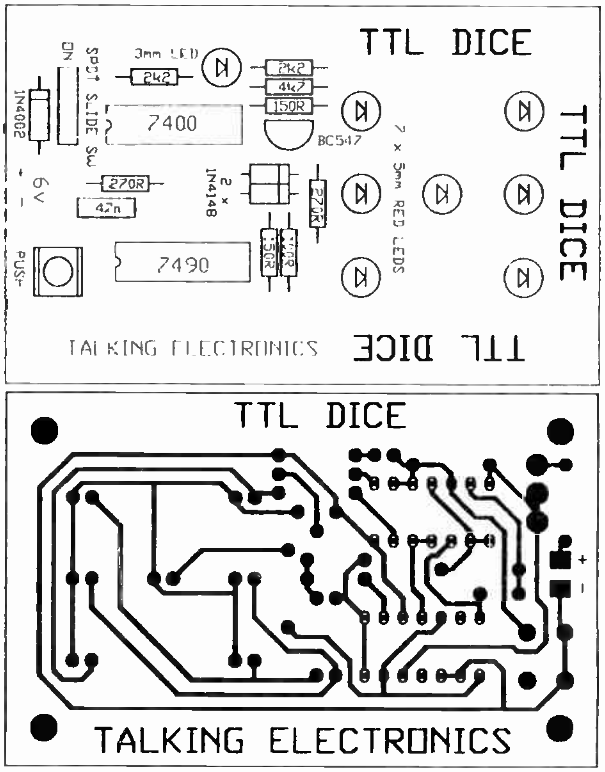
This is one of the pitfalls when changing a chip from one type to another or even changing the manufacturer.

Different chip types have different characteristics such as maximum operating frequency, output driving capability or input impedance etc.

Now that we have described how the circuit functions, I am sure you will want to put the circuit together and see how it works for yourself.

CONSTRUCTION

All the components mount on a PC



Full-size artwork for the TTL Dice

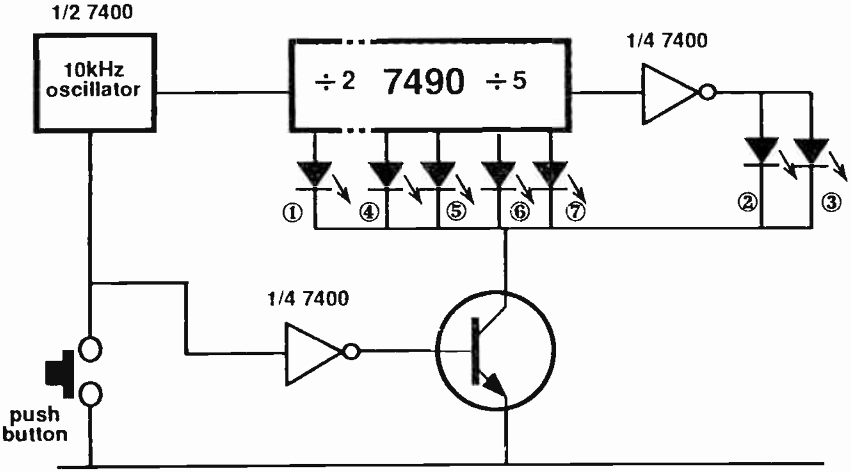
board that fits on top of a small jiffy box. The LEDs are mounted on the board in the same positions as shown in the diagram on the previous page. The cathode of each LED is identified on the overlay.

Fit the resistors, capacitor and diodes, then the IC sockets, transistor and switches. Push the two chips into the IC sockets so that the cut-out at one end of the chip fits over the mark on the PC board. Carefully solder 4 AA cells together to make a 6v battery and add leads to connect to the PC board.

The slide switch turns the circuit ON and the 3mm LED indicates "Power ON." When the push button is pressed, the LED turns off and a random number appears on the display.

You are now ready to use it for all kinds of board games. For games requiring two dice, you can build two units or push the button twice.

Switch the circuit off when not required as TTL chips consume a lot of power and that's why we have included a "power-ON" LED.



BLOCK DIAGRAM OF TTL DICE

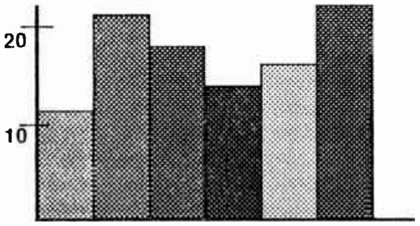
IF IT DOESN'T WORK

If your project doesn't work, the first thing to do is check the batteries. Funny things will happen with TTL when the voltage goes below 4v so don't use old cells for the supply. Check the cells with a multimeter set to 500mA range and make sure each cell will deliver 500mA. Do this quickly to prevent the meter being damaged.

Next measure the rail voltage. This can be done at pins 5 and 10 of the 7490 or pins 14 and 7 of the 7400 IC. It should be 5.4v as a power diode in the positive line drops .6v. The voltage must not be below 4.5v.

The 3mm "ON LED" should come ON when the power is applied and if not, it may be around the wrong way or damaged due to excessive heat during soldering.

When the push button is pressed, the mini LED goes off and the display illuminates. If this does not happen and the 3mm LED does not go off, the switch may be faulty or not making contact with the trackwork. Check the fact that the LEDs in the display are receiving current from the chip(s) by shorting between the collector and emitter terminals of the transistor when the circuit is oscillating.



HISTOGRAM FOR THE TTL DICE

If some of the LEDs do not come on or are very dull, they may have been damaged during soldering. If LEDs from only one of the outputs are illuminated, the 7490 may not be clocking and the fault will most likely be the oscillator section. This is made up of gates IC1d, IC1a, the 270R resistor and 100n capacitor. The 2k2 resistor on pin 12 keeps the pin high so that the gate maintains oscillation. If this pin is not at about 70% of rail voltage or higher, the gate will not oscillate.

If you are still having trouble, buy another kit and put it together more-carefully. Don't let the project beat you and don't put it down until you get it working perfectly. If all fails, we have a repair service and for $5.00 plus $3.00 post we will look at your project and get it working.

QUESTIONS

1. The block diagram above shows how the gating transistor connects the cathodes of the LEDs to the negative rail. Why is this transistor necessary?

2. The diagram above shows a histogram of 100 pushes:

Make a similar graph using the results of 500 pushes. How does your graph compare with ours? Explain the differences.

3. How does the circuit create random numbers?

4. If the push button is activated at exactly 1 second intervals, what value will show on the display?

5. The 7490 is a divide-by-two and divide-by-five. Explain how it has been wired as a divide-by-6.

6. Explain what the circuit is doing when the push button is not pressed.

7. Under the section "Turning on a LED," we said that when we fitted a 74LS00 and did not include the 2k2 pull-up resistor, the LEDs in the display did not turn off fully. Why is this?

8. Complete the following: (a) Pressing the push button (inhibits, freezes, activates) the 10kHz oscillator. (b)The 4k7 resistor on the base of the BC 547 allows the output of the gate to go (low, high) to turn ON the transistor. (c) The base of the transistor will not rise above: 6v, 5.6v, 3.5v, .6v, 1.6v, .2v, 0v.

9. Can you describe 2 faults with the circuit.

ANSWERS

1. It turns off the display so that the LEDs can be clocked "in the background."

2. Your histogram will be different to ours as it requires a very large number of pushes to create a graph where all the values are equal.

3. The random numbers are created by the different time interval between each of the pushes of the button. We create the randomness of the circuit.

4. The SAME value will appear on the dispay each time.

5. When the chip reaches 5, Q_A (count of 1) and Q_B (count of 4) are wired to reset-to-nine inputs $R_{9(1)}$ and $R_{9(2)}$ and this forces the chip to go to 9, giving it a count-to-six feature.

6. It is counting in the background.

7. Gate IC1c did not turn off fully and kept the transistor ON slightly.

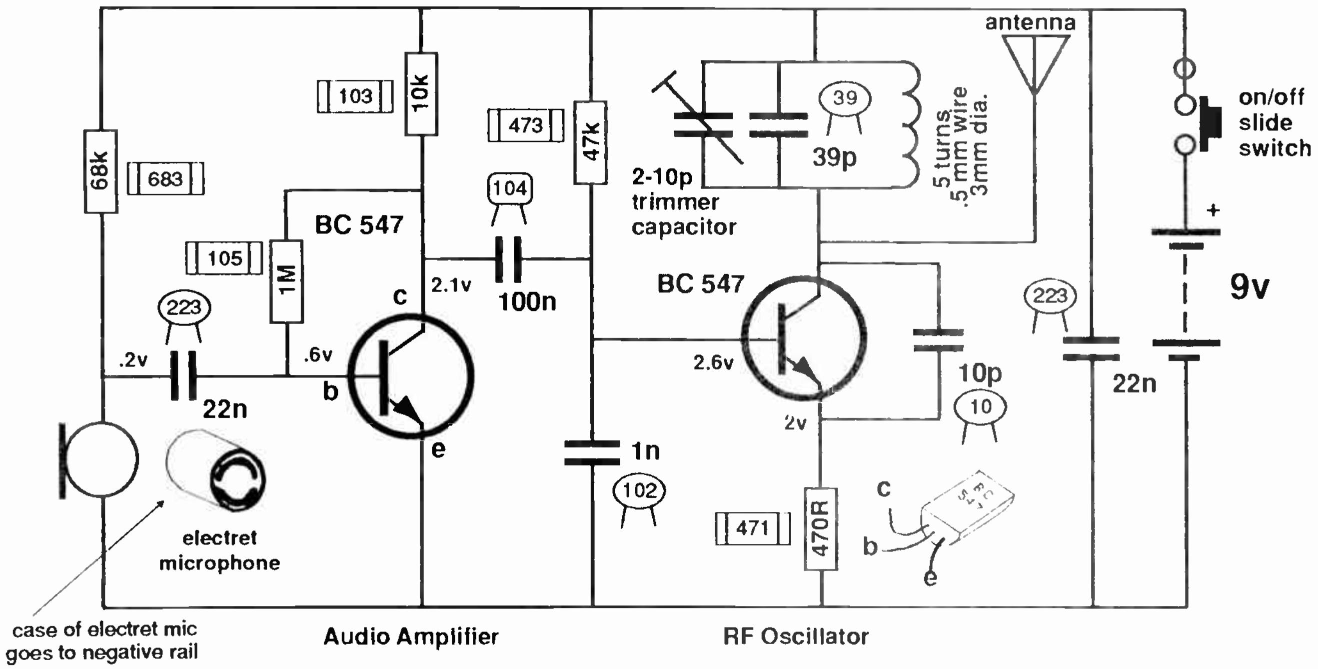
8. (a) Inhibits, freezes - (both the same function) (b) HIGH (c) .6v

9. (a) Some of the LEDs are in parallel. LEDs don't like this as one LED will drop a slightly lower characteristic voltage than the other and take more current so that it will be brighter.

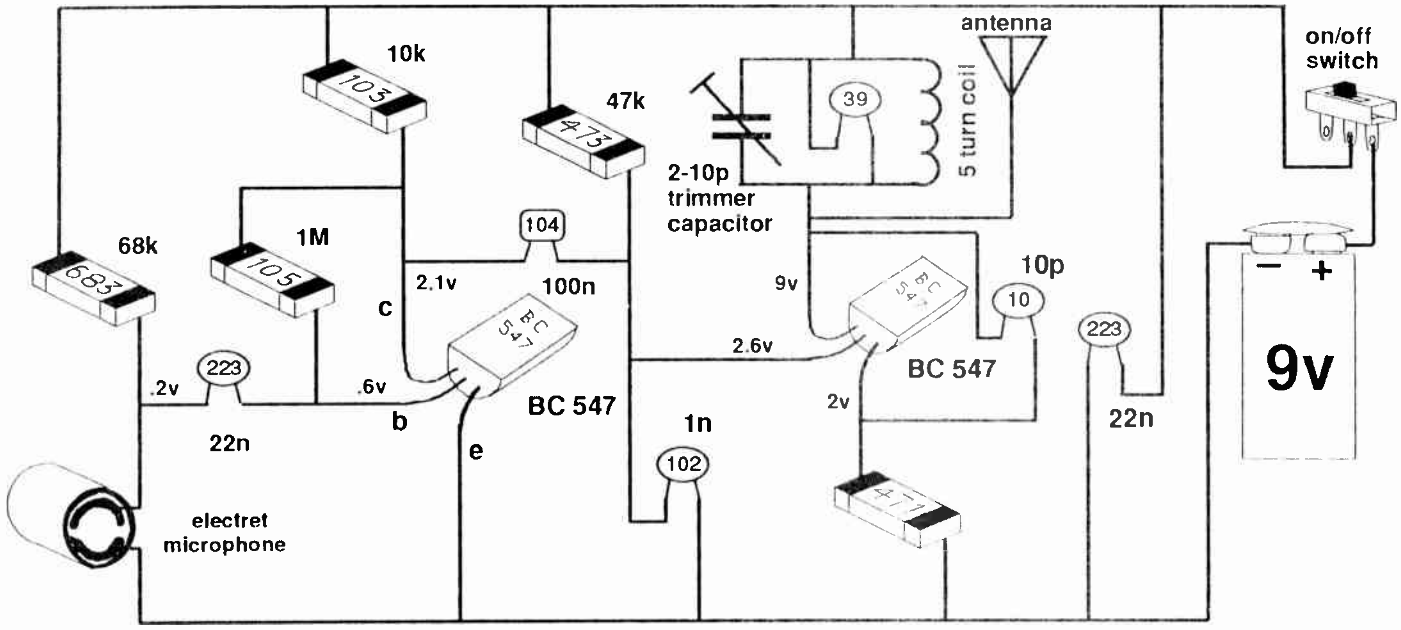
(b) Four LEDs are driven off Qc and this is too much for the output. Some of the LEDs will be duller than others. This circuit has been adapted from overseas and has been presented for the ingenious way the 7490 has been used.

UNDERSTANDING A CIRCUIT DIAGRAM

– Comparing a schmatic with a Printed Circuit Board Layout



VOYAGER MkII CIRCUIT



VOYAGER Mk II CIRCUIT

The 4 diagrams on this page and P 55 cover the Voyager MkII. This project can be found in "14 FM BUGS TO BUILD."

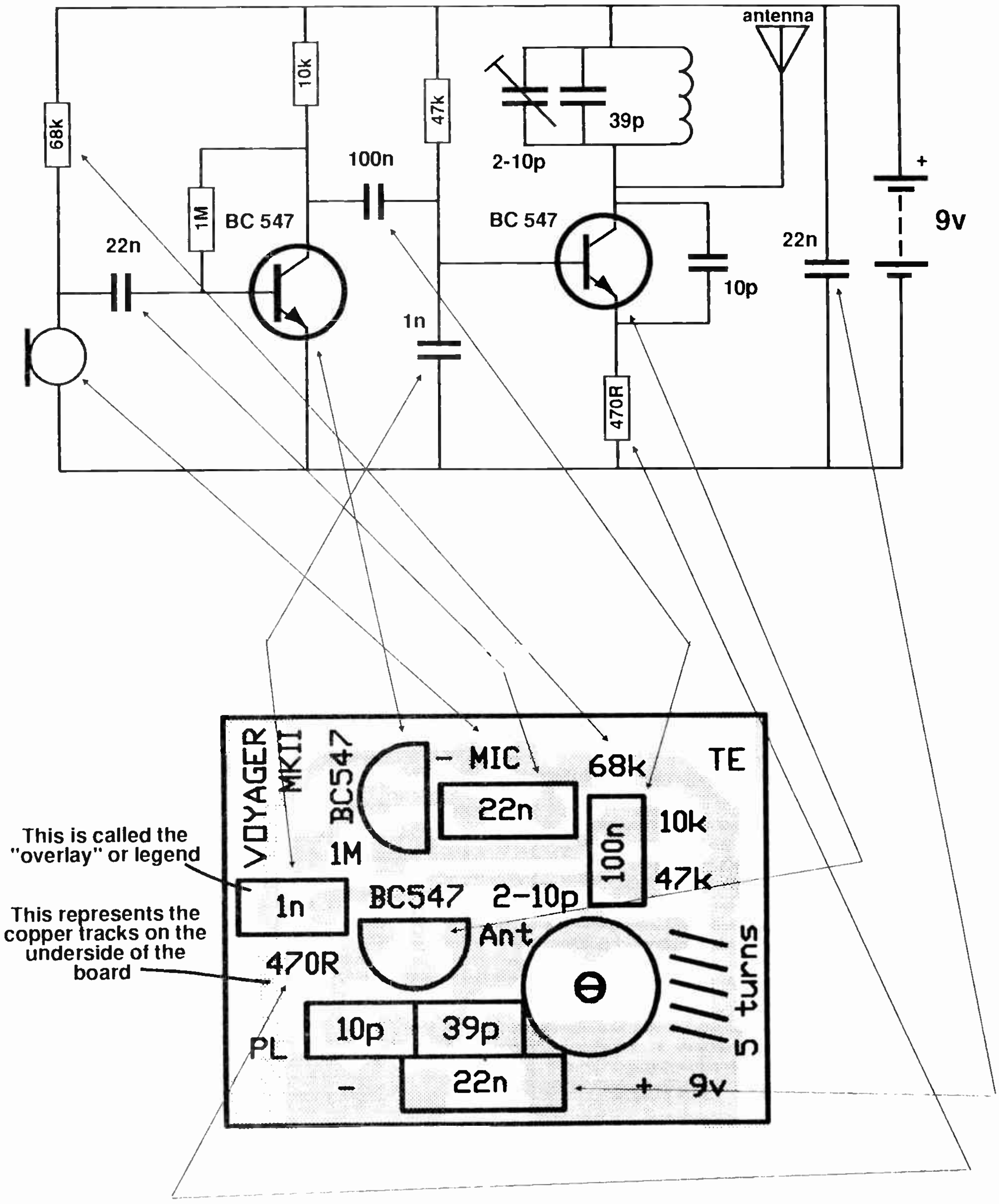
The top diagram is called a CIRCUIT DIAGRAM or SCHEMATIC. It shows how the components are connected together. Each item is shown as a symbol. But sometimes the symbol does not tell you what the component looks like.

The lower diagram shows this better - especially the transistors, electret microphone and surface mount resistors. The third diagram, on the following page, shows the symbols without any line-diagrams, as you would find in most books, and the fourth diagram shows the PC board with the OVERLAY on top of the board to show where the components are placed.

The shaded areas represent the copper tracks under the board.

You are required to complete the matching of the symbols with the overlay.

The shaded sections on the printed circuit board overlay are the copper tracks on the underside of the board. These tracks connect the parts together like the lines on the circuit diagram. Some of the components have been matched up. Match up the remaining components:



This is called the "overlay" or legend

This represents the copper tracks on the underside of the board

TTL TRAINER KIT & PC $31.70

Concluding the experiments in STARTING IN TTL

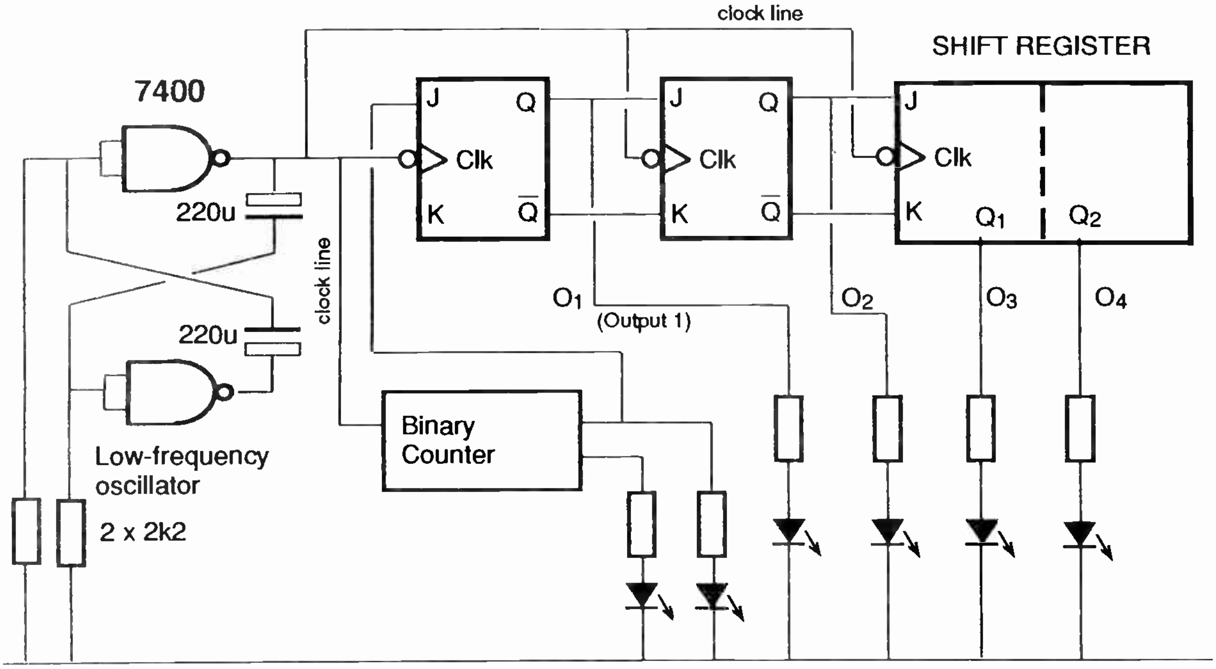
We continue the experiments in STARTING IN TTL (from Electronics Notebook 1 reprint 1993), with one more experiment.

But before going through the experiment, I suggest you get out your "Deck" and build up the experiment on page 97 of Electronics Notebook 1. If you have not used the Deck for some time it will be best to go back over a few of the previous experiments to familiarise yourself.

If you have not yet bought the Deck, I suggest you buy a kit and put it together as soon as you can. It will help you enormously with the concept of TTL to show how the various gates operate and how counting and shift operations can be performed with flip flops when they are connected in particular ways.

We take up our discussion with the layout on P97 of STARTING IN TTL (contained in Electronics Notebook 1). The demonstration produces a single LED, running across the 4 LEDs at the bottom of the Deck.

The circuit for this is as follows:



THE RUNNING LED EXPERIMENT

The first thing the circuit does is to shift data across the display. This is "junk" and is not taken into account as it can be any random values according to the output of the flip flops when power is first turned on.

The output of the first shift register produces LOWs until it gets a HIGH from the binary counter.

This will put the first shift register into Toggle mode with J and K HIGH and output Q will produce a HIGH on the falling edge of the clock.

This will set-up the second flip flop in the SET mode, ready for the next cycle of the clock.

On the next cycle the first flip flop will toggle off and the second flip flop will be SET and put a HIGH on output Q, ready for the next clock cycle.

On the third clock cycle, the first flip flop will see a LOW from the binary counter and remain in the RESET mode. The second flip flop will go to the RESET mode but the HIGH from output Q will have already set the flip flop inside the shift register and on the falling edge of the clock the output of the shift register will go HIGH and illuminate the first LED.

This process continues one more time and the effect is the LED jumps across the display, one place to the right, after each clock cycle.

You will notice the third and fourth LEDs are controlled by the pre-wired shift register under the board and the circuit diagram shows the J and K lines are connected to the previous block to obtain the controlled shift function.

THE TWISTED RING COUNTER

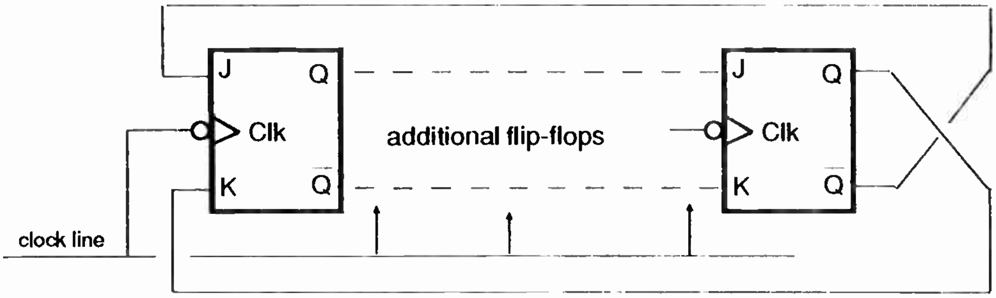
The final experiment in this course is a counter.

It is given the name Johnson Counter or "Twisted Ring" counter due to the inversion or twist between the last and first flip flop.

This gives the counter the ability to automatically fill the flip flops with "1," then empty them out and repeat the process. A simple ring counter will count to a number equal to the number of flip flops but a twisted ring counter will count to 2n where n is the number of flip flops in the counter.

This type of circuit may seem very complex for the operation it is performing but you must remember it came from a very early era in digital processing and many improvements have been made since then. However it demonstrates how counting and division was developed.

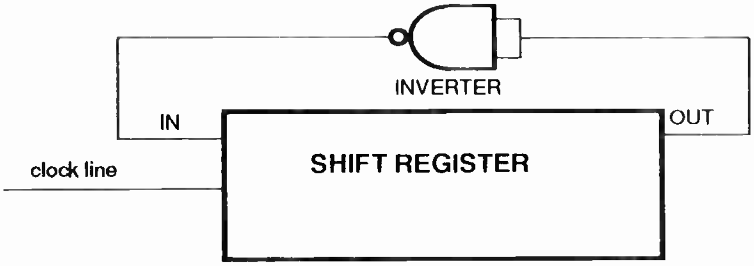
The main advantage with this type of counter is its high speed capabilites and the ease of gating to get various values of division.



THE JOHNSON or "TWISTED RING" COUNTER

By taking an output from the fourth flip flop, a division of 2n (or 8 in our case) can be achieved. This simple effect is the basis to counting and division.

The counter can be created by using individual flip flops as shown in the diagram above or a shift register with an inverter between the output and input. In our experiment we have used a combination of both and wired a NAND gate as an inverter as shown in the diagram below:

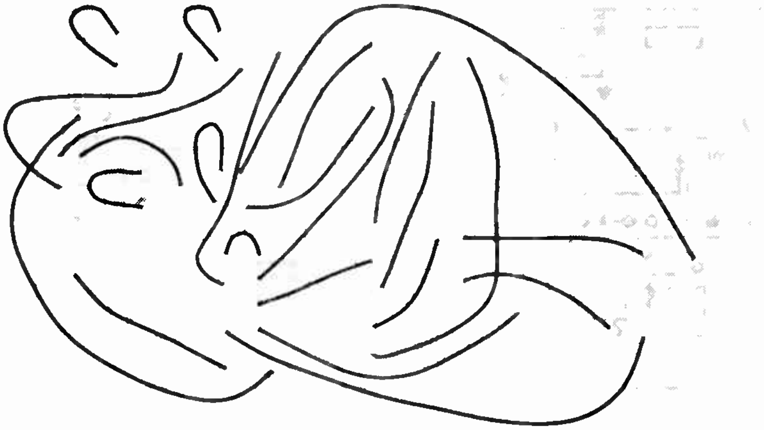


THE JOHNSON COUNTER

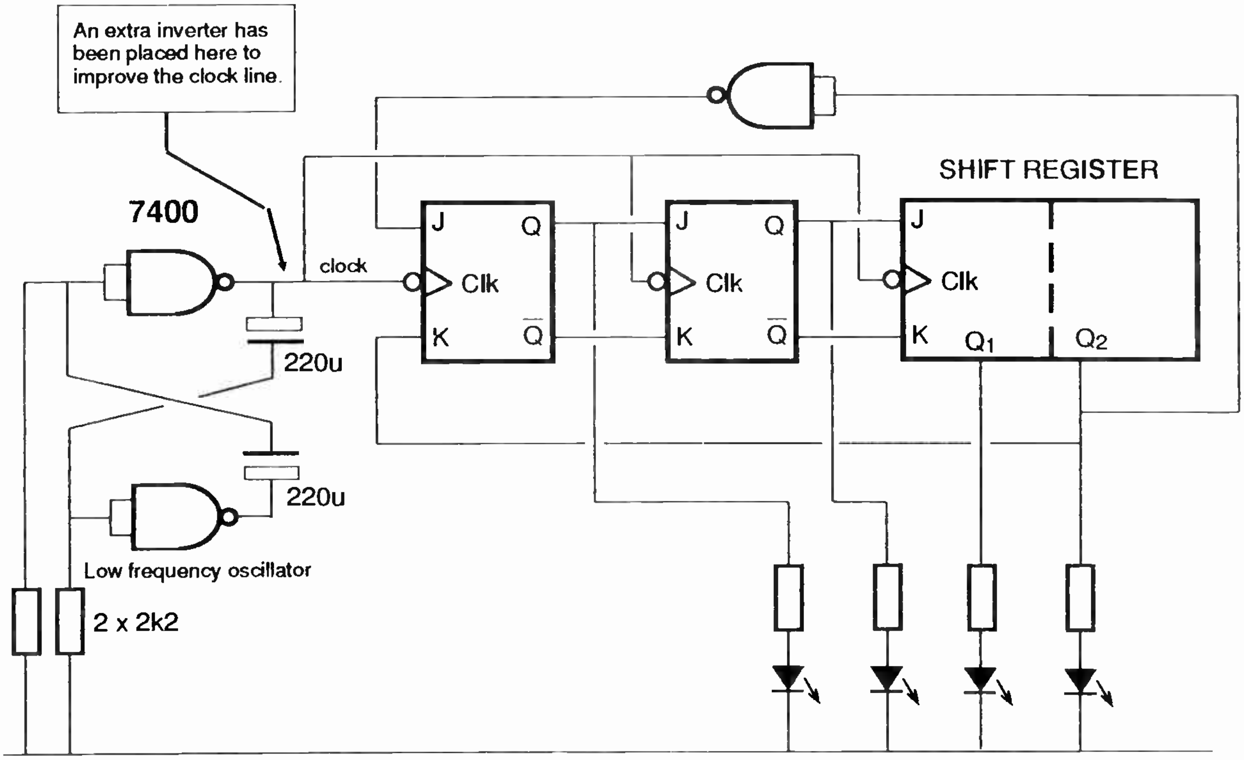
Construct the circuit on the Deck by following the layout diagram below and turn the power on.

The outputs will gradually fill with "1's" then empty out. The tone circuit will allow you to keep track of the clock cycles and you can count the pulses from the time when the fourth LED comes on to the next time the LED comes on to see if your circuit is dividing the clock frequency by 8.

24 Jumpers needed (Use 4 jumper leads of your own)



THE JOHNSON COUNTER EXPERIMENT



THE "TWISTED RING" or JOHNSON COUNTER

Questions:

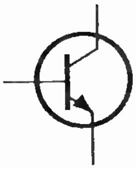
1. What is the maximum division for our Johnson Counter? How many (clocked J-K) flip flops are in the counter above?
2. If six flip flops are used in a Johnson Counter, what is the maximum division?
3. What is the maximum count for a 5 flip-flop Johnson Counter?

Answers: 1: 8,4 2: 32 3: 16.

SYMBOLS QUIZ

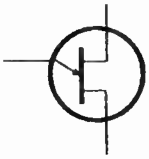
See Learning Electronics-2 Page 70 for assistance.

Match each symbol with its correct name:


1


2


3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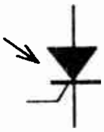
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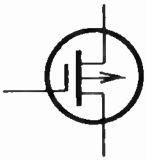
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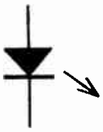
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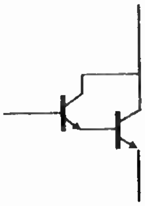
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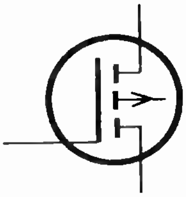
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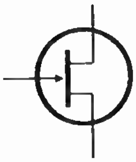
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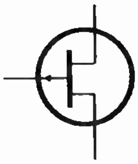
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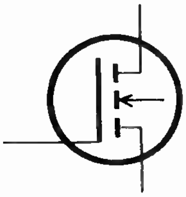
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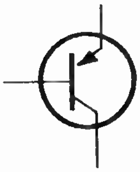
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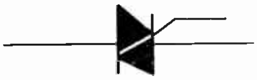
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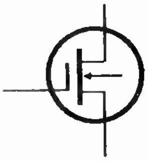
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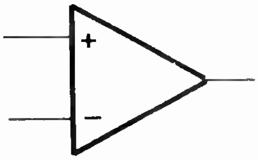

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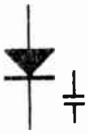
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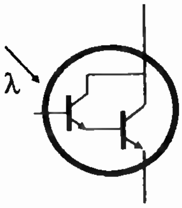

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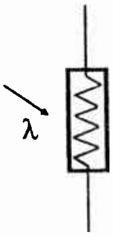

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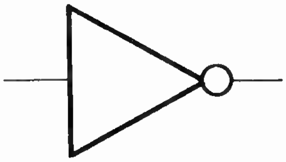

23


24

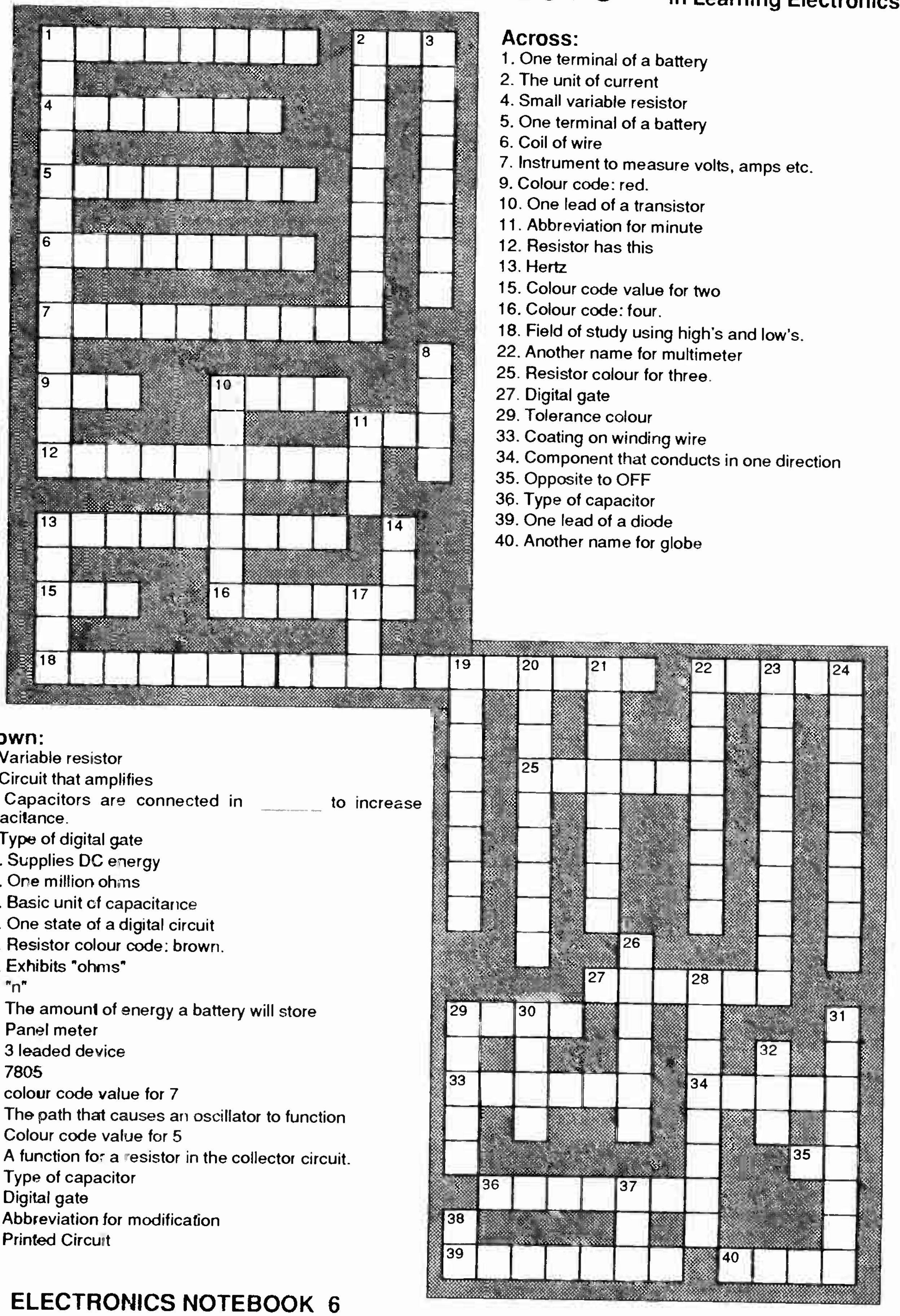

25

Select from these:
(a) LASCR (Light Activated SCR)
(b) N-channel JFET (Junction-field-effect transistor)
(c) P-channel JFET (Junction field-effect transistor)
(d) Inverter
(e) NPN transistor
(f) PNP transistor
(g) tunnel diode
(h) N-channel enhancement-type MOSFET
(i) P-channel enhancement-type MOSFET
(j) PUT (programmable unijunction transistor)
(k) diode
(l) TRIAC
(m) OP AMP (operational amplifier)
(n) Varicap Diode
(o) NPN Darlington Transistor
(p) LED (Light Emitting Diode)
(q) SCR (Silicon Controlled Rectifier)
(r) UJT (Unijunction Transistor)
(s) Zener diode
(t) LDR (Light Dependent Resistor)
(u) Photo Darlington Transistor
(v) Zener Diode (Alternate Symbol)
(w) P-channel depletion-type MOSFET
(x) N-channel depletion-type MOSFET
(y) DIAC (Diode AC Semiconductor)

ANSWERS:
1. (e) NPN transistor
2. (q) SCR
3. (k) diode
4. (r) UJT
5. (a) LASCR
6. (i) P-channel depletion-type MOSFET
7. (p) LED
8. (o) NPN Darlington transistor
9. (w) P-channel enhancement-type MOSFET
10. (b) N-channel JFET
11. (j) PUT
12. (c) P-channel JFET
13. (h) N-channel enhancement-type MOSFET
14. (f) PNP transistor
15. (s or v) Zener diode
16. (l) TRIAC
17. (x) N-channel depletion-type MOSFET
18. (y) DIAC
19. (m) OP AMP
20. (n) Varicap diode
21. (u) Photo Darlington Transistor
22. (t) LDR
23. (d) Inverter
24. (s or v) Zener diode
25. (g) tunnel diode

CROSSWORD No: 3

All the answers will be found in Learning Electronics-2



Across:

1. One terminal of a battery
2. The unit of current
4. Small variable resistor
5. One terminal of a battery
6. Coil of wire
7. Instrument to measure volts, amps etc.
9. Colour code: red.
10. One lead of a transistor
11. Abbreviation for minute
12. Resistor has this
13. Hertz
15. Colour code value for two
16. Colour code: four.
18. Field of study using high's and low's.
22. Another name for multimeter
25. Resistor colour for three.
27. Digital gate
29. Tolerance colour
33. Coating on winding wire
34. Component that conducts in one direction
35. Opposite to OFF
36. Type of capacitor
39. One lead of a diode
40. Another name for globe

Down:

1. Variable resistor
2. Circuit that amplifies
3. Capacitors are connected in ______ to increase capacitance.
8. Type of digital gate
10. Supplies DC energy
11. One million ohms
13. Basic unit of capacitance
14. One state of a digital circuit
17. Resistor colour code: brown.
19. Exhibits "ohms"
20. "n"
21. The amount of energy a battery will store
22. Panel meter
23. 3 leaded device
24. 7805
26. colour code value for 7
28. The path that causes an oscillator to function
29. Colour code value for 5
30. A function for a resistor in the collector circuit.
31. Type of capacitor
32. Digital gate
37. Abbreviation for modification
38. Printed Circuit

IQ TESTS

About 30 years ago IQ tests were very popular. Although very few people knew what they meant or how they worked, they were given to everyone, of all ages, to determine their ability.

And a lot rested on the results.

I know, I did at least 3 different IQ tests during my years at school and was told the results would be given back in a few days. But, as you can imagine, they never were and I was forever in the dark as to how well I did.

This made me very sceptical about the honesty of those who ran the tests (the teachers) and also the reliability of the tests themselves. In fact I became to dislike the tests so much that I called them "Idiotic Questions" and when you realise how some of the answers are worked out, you will agree too.

Some of the questions require you to stumble upon the most irrational solution and there's no way of working them out if you don't happen to hit upon the answer. I haven't included anything like this in the test that follows but included some very clever problems.

Since I was never told my IQ, I became curious as to how the system worked and how I fared in the structure of things. After reading a number of books on the subject I came to the conclusion that a rating of about 120 - 130 was appropriate for a bright student and decided to take a test on my own to generate a score.

After a lot of searching, I found a book containing a set of tests and that's how I came to get a score of 126.

I'm not saying I'm bright, but at least the score didn't put me in the dodo category and you feel you can face the challenges of life, knowing that you have sufficient aptitude to tackle anything that might come your way.

By definition, the IQ scale is divided so that 50% of the population falls into the range 90-110, 25% is below 90, 14% have an IQ between 110 and 120, 7% have an IQ between 120 and 130, 3% have an IQ between 130 and 140 and 1% have an IQ above 140.

Without us knowing it, the results of the IQ tests I took at school were used to grade me into classes and I finished up being put with students of a similar rating. This was conservatively called "streaming," whereby the school finished up with a "bright" class, a "medium" class and lots of "dummies." Everything was geared for channelling the students down a narrow path to suit the "system." The whole aim being to provide students (fodder) for the universities.

The system gave no consideration to anything other than literacy and numeracy skills and any interest in areas outside these was given no encouragement at all. The thought of taking up a manual occupation was considered too low to contemplate.

Fortunately things have changed slightly. The system has realized the need for a broader range of topics and has introduced new courses to suit the needs of industry and commerce.

But the main factor that sounded the death of the IQ test was the introduction of anti-discrimination laws. Laws that prevented anyone being assessed with a numerical value. It became no longer lawful to produce a quantitative value of a person's capability, for purposes of grading, employment or promotion etc.

This has led to a generation of students and workers being completely unfamiliar with the term IQ.

If you're one of them, you will find the concept of IQ quite fascinating. With the following test you can work out your own IQ and see how you fit in to societies structure. Don't place too much importance on the result as you really can't base your whole intelligence around 50 silly questions. But it's a good bit of fun.

WHAT IS IQ?

IQ stands for Intelligence Quotient and as you know, the word quotient is the result of division in mathematics. IQ is the ratio of mental age to chronological age and an IQ of 100 means you have an intellect equal to your physical age.

This may not mean much but if you have an IQ of 70, 80 or 90, you are below the mentality of the average man in the street.

Even to have "average" mentality is nothing impressive as the average Australian has very little ability, capability, capacity for learning, or understanding of even the simplest things around him. He knows nothing about banking, finance or budgeting and wastes more than 25% of his earnings on gambling or paying off loans.

He has very little interest in learning new things, understanding what's going on in the world, or improving his position in life. (50% of the population don't know if the moon revolves around the earth or the sun!)

He reads less than one book per year and cannot interpret the wording on a simple contract. If you think I'm wrong, take the debt situation in Australia. The average worker owes more than $6,000 in credit for personal, pool and car loans etc. and each year the debt is increasing.

By contrast, the average Japanese has a bank surplus of $15,000 and the difference between the two is not simply $21,000, but much more!

Don't think that being "average" or just above average is going to get you anywhere in this world. You must have a capability of at least 50% above the average person to be able to handle your own finances, and you must improve your material situation by at least 10% each year just to stay in line with inflation!

Whether IQ testing is good or bad is not the point of this article.

I personally think it puts an individual into a category that does not truly represent his capability. But it does provide a measure of assessment and providing you take the test yourself and keep the results private, I don't see any harm in finding out your own score.

In some respects, IQ tests don't tell you very much as they concentrate on only very few attributes. If you are capable of anything outside these, the score can be quite misleading. For instance I have never seen a question on music, sport, electronics or gardening, so the tests are really quite narrow.

If you can plough a straight field or create a piece of artwork, the IQ test lets you down. Why should "intelligence" be limited to someone with a degree or doctorate - they generally can't even replace the washer in a dripping tap!

IQ tests (along with so many other tests) are really a trick (or a con, if you like). The educational system has fooled us into believing that intelligence only comes with schooling and you must get a degree or diploma to "make it" in the world.

But this is not the only path to success and self esteem.

Fortunately this school of thinking has been blown apart recently where many of the "professions" have been exposed as riding on the back of the worker while indulging in total fraud.

A recession is a great leveller and it has been shown that those with manual skills have just as good a chance, if not better, of staying in employment during the depths of a recession.

Everyone has a capability. Sometimes it's obvious, othertimes it's hidden and it would be wonderful to devise a test that covered all fields of endeavour and produced a realistic result.

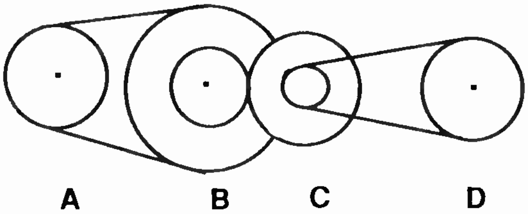
Unfortunately this has not been done and if you were to produce something realistic it would be of considerable length and closely follow our everyday activities anyway. So, if a measure of your material wealth were to be a measure of your intelligence and if you are just starting out in life, this test may give you a forward look at your prospects. Give it a go.

TEST 1

TIME LIMIT: 30 Minutes.

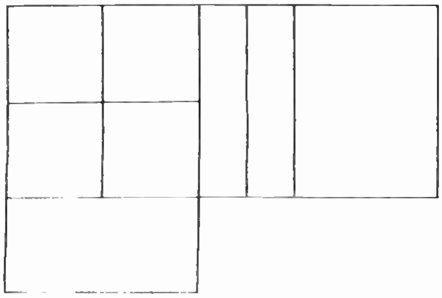
1. Insert the missing number:
2 6 10 14 —

2. If 'A' rotates clockwise. Indicate rotation of D:

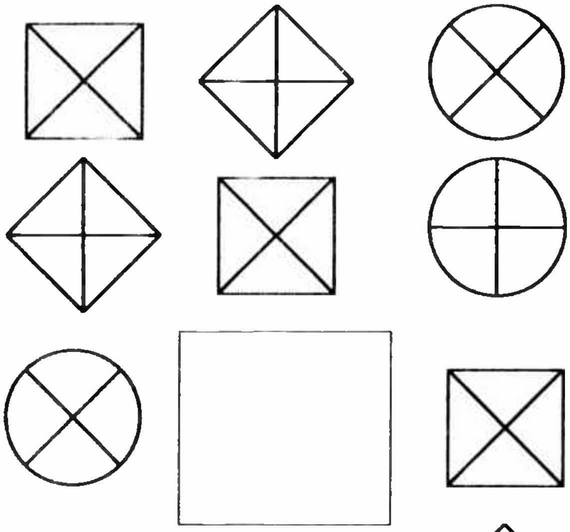


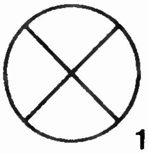
3. If a chocolate and wrapper costs 62¢ and the chocolate costs 60¢ more than the wrapper, how much does the wrapper cost?

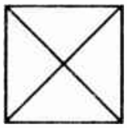
4. How many rectangles (including squares) in this figure:



5. Which of the 6 numbered figures fits into the vacant square:




1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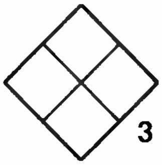
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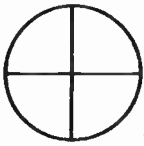
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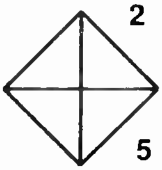
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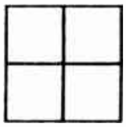
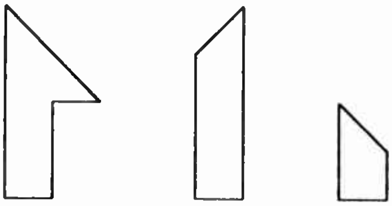

6

6. The posts for a barbed-wire fence are 5 metres apart. How long is a fence consisting of 20 posts?

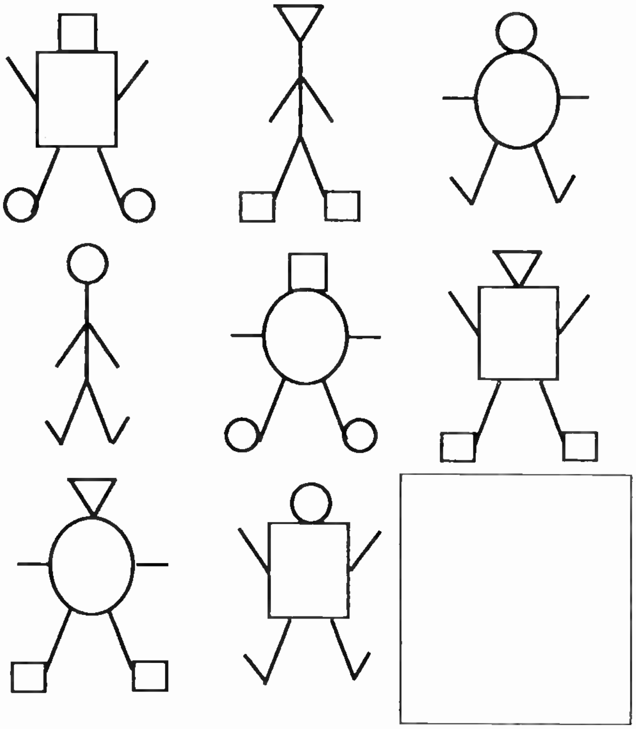
7. Fit these 3 pieces together to create a letter:

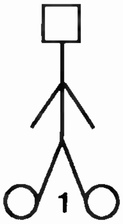


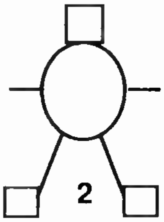
8. Does an iceberg rise higher in fresh water or salt water?

9. Insert the missing number:
8 10 14 18 — 34 50 66

10. Which of the 6 numbered figures fits into the vacant square:




1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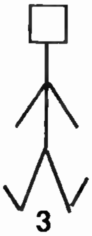
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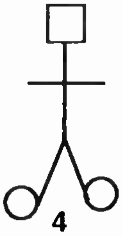
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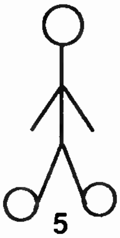
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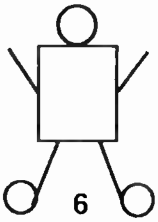
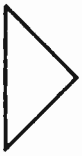
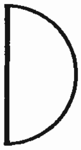

6

11.

 is to cube

as  is to: ________

12. Each letter sounds a word. What did the man order:

FUNEX
SVFX
FUNEM
SVFM
OKMNX

13. Write down eleven thousand, eleven hundred and eleven as a single number.

14. Insert the missing numbers:

3	6	12	24	
96	48	24	12	

15. If a man and a half digs a hole and a half in an hour and a half, How long does it take 1 man to dig 5 holes?

16. How many months have 30 days?

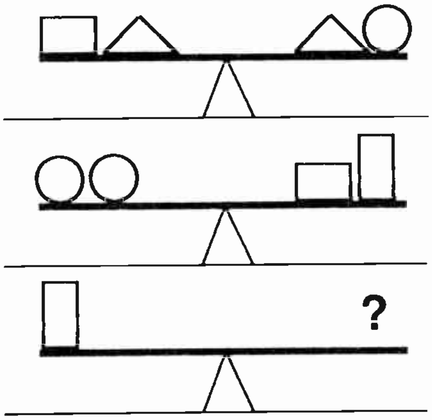
17. Insert the missing letter:

B E I L P —

18. How many 3cm cubes fit into an 8cm cube?

19. There's a saying "SPEED KILLS" is this true?

20. Identify the shape to make the third beam balance:



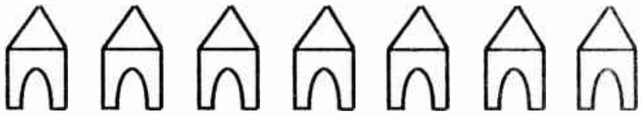
a 

b 

c 

21. What is 10% 0f 110?
(a) 10, (b) 11 (c) 1100, (d) 1 (e) 1.1

22. How can six dogs be put into the kennels below:



23. Which is greater:

$$\frac{1}{4} \quad \text{OR} \quad \frac{1}{3}$$

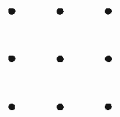
24. To half of 43, add one quarter of 34. Double the answer and take away 7. What is the result?

25. How many posts, each 3 metres apart, are needed to make a fence 12 metres long?

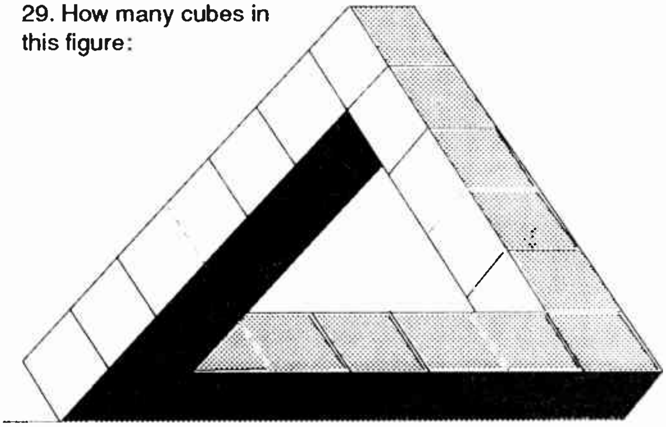
26. Which is lighter, milk or cream?

27. What is the next number in the sequence: 2 4 8 16 32?

28. Join the dots with four connected straight lines:



29. How many cubes in this figure:



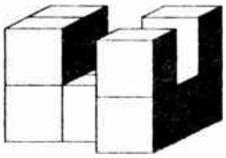
30. A refrigerator is placed in a completely insulated room with a power point, and the fridge door is left open. The fridge is turned on. Will the fridge cool the room?

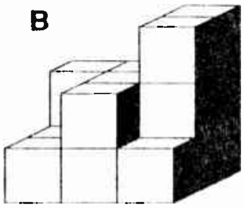
31. QUAD is to OCT as TRI is to . . .

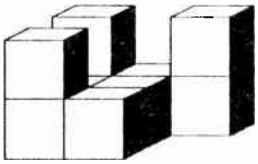
32. If 10 men can build 30 houses in 60 days, how long will it take 5 men to build 15 houses?

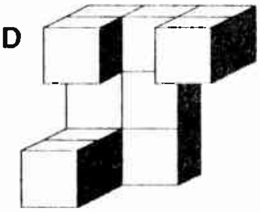
33. If a snail climbs out of a 30 metre well by climbing three metres each day and falling back two each night, how long does it take him to climb out of the well?

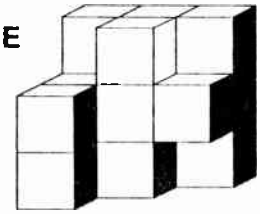
34. Which two blocks fit into each other to form a perfect cube.

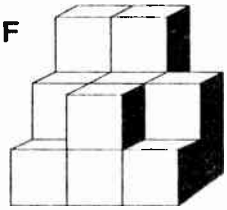
A


B


C


D


E


F


35. If a boat in a lake tips a ton of iron ore into the water, will the level of the lake rise, fall, or remain the same?

36. If two cars start at the same point on a straight highway, each facing in opposite directions and travel 4 km then make a left turn and travel 3km, how far apart will they be?

37. What is one-fifth of 25% of $100.

38. If it takes a clock 15 seconds to strike 6 o'clock, how long does it take to strike 12 o'clock?

39. Two identical cups of hot coffee. Which will cool to drinking temperature faster? The one to which milk is added immediately or the one to which the same quantity of milk is added later?

40. If a brick weighs 2 kilograms and half a brick, what is the weight of a brick and a half?

41. What is the largest square peg that can be fitted into a 2cm diameter round hole?

42. Two men have 8 litres of water in a container. They have a 5 litre jar and 3 litre jar. How can they divide the water equally?

43. If a lilly in a pond doubles its size every day and completely fills the pond at the end of the 30th day, on which day was it half the size of the pond?

44. What is the fifth letter after the letter before the eighth letter in the alphabet?

45. Which is the odd-man out:
Shelley Byron Chaucer Menzies Keats

46. Which is the odd-man-out:


a

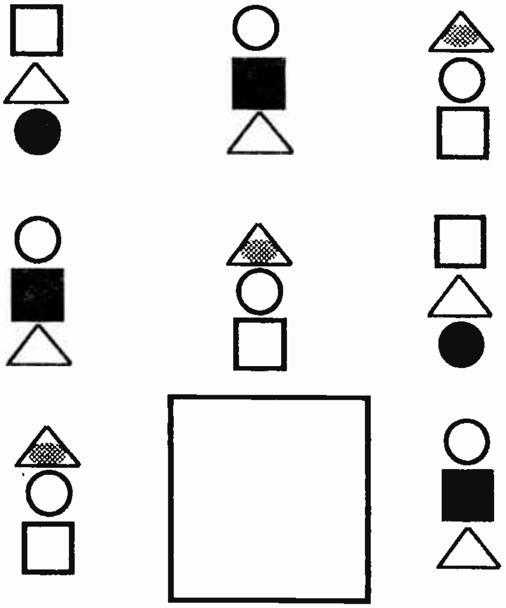

b


c


d


e

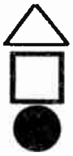
47: Select the figure that fits into the square:

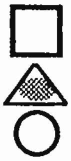



A


B


C


D


E

48. Insert the missing number:

20 35 15 30 10 25 ___

49. What is one-quarter of the product of the following three numbers: 8, 4, 12. (product means multiply)

50. The head of a fish is 9cm long. Its tail is as long as its head and half the back. The back is as long as the head and tail together. How long is the fish?

IMPROVING YOUR IQ

There are a number of books on the market with sample IQ questions and tests to show you how to improve your IQ. But there are two sides to this. It may be good or it may have a falsifying effect.

If you get pre-coached, the novelty and newness of IQ questions will be lost and the results you get in a test may not reflect your real ability. An IQ test only has credibility if the questions are unknown to the candidate. Even the format of the questions should be substantially new. That's why many of the questions are presented in a new and novel way; different to any other tests you may have undertaken.

The idea is to give everyone an equal opportunity at getting them correct.

Although I don't believe in IQ tests as a begin-all and end-all to grading, I think it's one of the factors (out of many) that you can use to help make an assessment.

As such, it's an interesting experiment to take a test and see how your rating compares with others.

IQ is a mathematical value you can't use professionally but you can hold in the back of your mind to reinforce your feeling of self-confidence. It's a great bolster to your self-confidence.

However, as far as I am concerned, there is one major fault with IQ tests. They do not take into account the fact that some candidates guess some of the answers.

This should be taken into account when the results are analysed. To prove my point, I increased my score by more than 10 points on a particular test simply by guessing some of the answers rather than leaving them blank.

Some would say it's good to guess and make a calculated assessment, but my interpretation is guessing is dangerous and it should be represented as a negative when the marks are analysed.

My overall opinion of IQ testing is that you become more proficient at answering the questions after attempting a number of tests and especially if you try some of the IQ improvement programs.

The question is: does the higher score reflect your higher level of intelligence or simply your ability to answer the questions more proficiently. Who knows?

Try the IQ test on P 62. If tests like this prove popular, we may have more in forthcoming publications. Let us know what you want.

ANSWERS

Go through your answers and cross out any that were complete guesses.

1. 18 1 mark

2. Anticlockwise 1 mark

3. 1¢ 2 marks

4. 23 1 mark

(you also get the mark if you got between 19 and 22)

5. 5 1 mark

6. 95 metres 2 marks

7. The letter "T" 3 marks

8. Salt water 2 marks

9. 26. The numbers rise by:
2, 4, 4, 8, 8, 16, 16. 1 mark

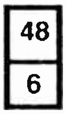
10. 1 1 mark

11. Solid cylinder (add the mirror piece and extend in the third dimension) 2 marks

12. Have you any eggs?"
Yes, we have eggs"
Have you any Ham?
Yes, we have ham"
OK, Ham and eggs" 2 marks

13. 12,111 2 marks

14.



Double the top row and halve the bottom row 2 marks

15. 7.5 hours 3 marks.
It takes one man 1.5 hours to dig a hole.

16. 11 months have 30 days. Some have more, but February has only 28 or 29 in a leap year. 1 mark

17. S 1 mark

18. Only 8 will fit. 2 marks

19. No. Speed does not kill. It's deceleration that kills! 1 mark

20. either "a" or "b" 2 marks
if you got only "a" 1 mark

21. (b) 2 marks

22. Write the words "SIX DOGS" in the kennels 2 marks

23. 1/3 is greater 2 marks

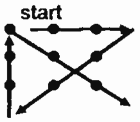
24. 53 2 marks

25. 5 posts 2 marks

26. Cream - that's why it floats. 1 mark

27. 64 - each number is doubled 1 mark

28.



1 mark

29. 17 1 mark

30. No. Whenever energy enters a room the temperature rises. 2 marks

31. HEX or SEX 1 mark.

32. 60 days. 3 marks

33. On 27th morning the snail is at the 27 metre mark. It climbs 3 metres during the 27th day and reaches the top. Hopefully it won't fall back! 2 marks

34. C and E 1 mark

35. fall 2 marks

36. 10km apart 2 marks

37. 5 2 marks

38. 33 seconds 1 mark

39. Later 1 mark

40. 6 kilograms 1 mark

41. √2 or 1.414cm 2 marks

42. There are many answers. One is to tip the 8 litre into the five litre then tip the 5 litre into the three litre. Tip the 3 litre back into the 8 litre and tip the two litres in the 5-litre jar into the 3 litre. Now fill the 5 litre and tip one litre into the three litre. You will have 4 litres left in the 5-litre jar. 3 marks

43. At the end of the 29th day. 1 mark

44. L 1 mark

45. Menzies. All the other were great poets 1 mark

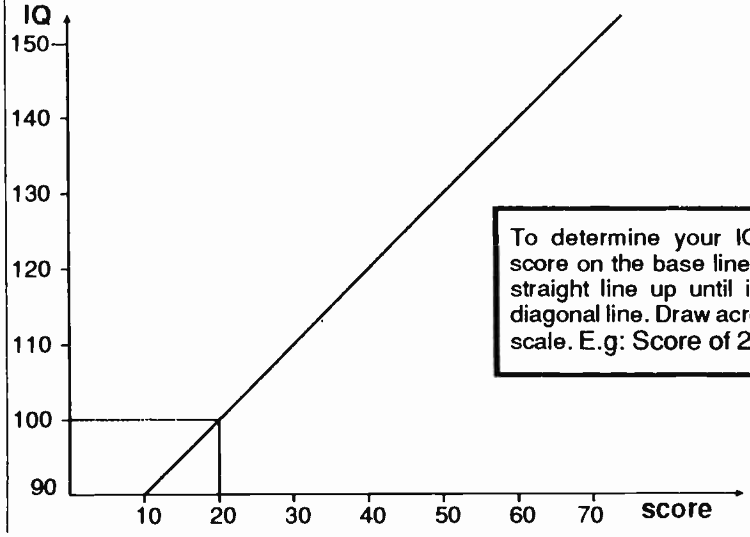
46. (d) all the others can be rotated to produce the figures. 1 mark

47. C (the diagonals are the same!) 1 mark

48. 5 1 mark

49. 96 2 marks

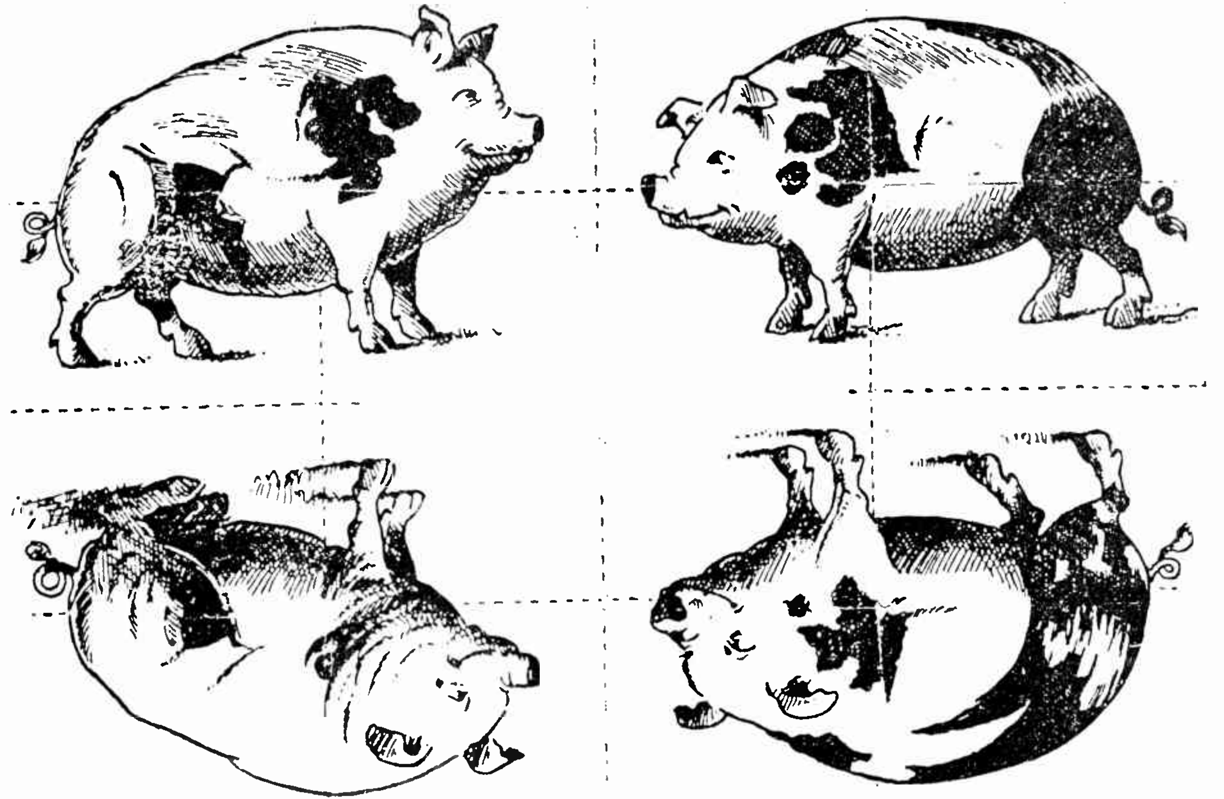
50. 72cm 3 marks



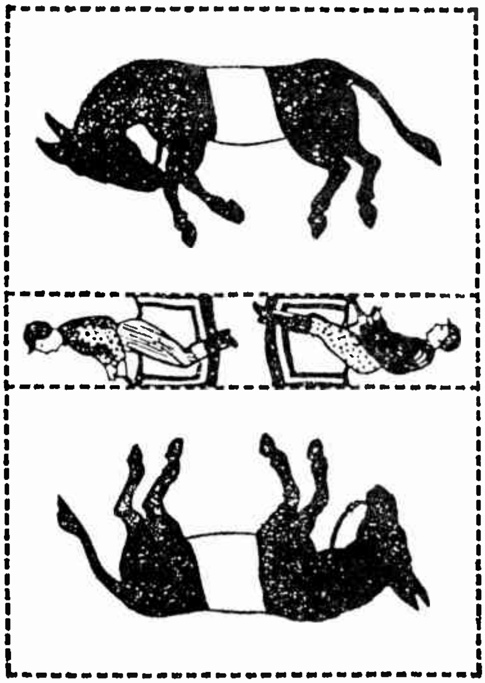
To determine your IQ, find your score on the base line and draw a straight line up until it meets the diagonal line. Draw across to the IQ scale. E.g: Score of 20 = 100 IQ

MORE PUZZLES

Here are three more puzzles I could not leave out. They are very old and hopefully you will have never seen them before.



Fold on the dotted lines to find the fifth one



Cut out the three pieces and make the jockeys ride the donkeys (without folding).

THE FIVE HOUSES

This is one of the popular puzzles of the 80's. Everyone wanted to know the answer. But it has never been released as its obvious once you work it out.
The question is: Who drinks the water and who owns the Zebra?

Here are the clues:

1. There are five houses numbered from left to right.
2. The Englishman lives in the red house.
3. The spaniard owns the dog.
4. Coffee is drunk in the green house.
5. The Ukranian drinks tea.
6. The green house is immediately (to your) right of the ivory house.
7. The Old Gold smoker owns snails.
8. Kools are smoked in the yellow house.
9. Milk is drunk in the middle house.
10. The Norwegian lives in the first house.
11. The man who smokes Chesterfields lives in the house next to the man with the fox.
12. Kools are smoked in the house next to the house where the horse is kept.
13. The Lucky Strike smoker drinks orange juice.
14. The Japanese smokes Parliaments
15. The Norwegian lives next to the blue house.

GLOSSARY OF TERMS

Rev Jan '94

AC Alternating Current. The "mains" or "AC" is electrical current that constantly varies in amplitude sinusoidally. The voltage of the mains also changes direction but in this case we refer to the current changing direction.

AC Voltage A voltage that is constantly changing direction.

A/D Converter Circuit that converts analogue signals into a digital equivalent.

Access Time The time required to send or receive data from a specific memory location.

Accumulator Central register of a processing chip where arithmetic or logical operation can be performed. Also the name given to a rechargeable battery such as a car battery.

Active Component. A component that provides gain or amplification such as transistor, integrated circuit, valve - such as a triode value, See Passive for opposite.

Adder Circuit that can add binary numbers.

Address A specific location within a system's memory map.

Address Bus Bus that carries the value of the location in memory.

Address Decoder Circuit that detects the presence of a particular address.

Aerial (Antenna) A length of wire designed to transmit or receive radio waves.

AF Audio Frequency. Generally the range 20Hz to 20kHz.

AFC Automatic Frequency Control. Similar to Automatic Fine Tune (AFT) A circuit that keeps a receiver in tune with the wanted transmission.

AGC Automatic Gain Control. A circuit that adjusts the gain of a stage so that the volume is constant even though the input signal may vary over a wide range.

Alternating Current (AC) An electric current whose direction changes direction with a frequency independent of circuit components.

ALU Arithmetic Logic Unit. The section of a microprocessor that carries out all arithmetic and logic operations.

AM Amplitude Modulation. Where audio signals increase and decrease the amplitude of the "carrier wave."

Ammeter Instrument for measuring the current in amps, milliamps or microamps. Milliammeter. Microammeter.

Amp The unit of electrical current. Also milliamp (1/1,000amp and microamp 1/1,000,000amp i.e. one thousandth of an amp and one millionth of an amp). One amp corresponding to the flow of about 6×10^{18} electrons per second.

Ampere-hour Corresponding to the flow of 1 amp for 1 hour i.e. 2.2×10^{22} electrons.

Amplify A circuit that increases the amplitude of a signal.

Amplitude The highest value reached by voltage, current or power during a complete cycle.

Analogue A system in which data is represented as a continuously varying voltage.

AND gate Gate that produces a logic 1 when all of its inputs are 1. In all other cases the output is 0.

Antenna A length of wire or similar that radiates (such as a transmitting antenna) or absorbs (such as a radio antenna) radio waves.

Artificial Intelligence The capability of machine to learn and correct itself and adapt to new situations

ASCII American Standard Code for Information Interchange. The most widely used code that assigns a specific sequence of binary digits to alphanumeric and control codes.

Assembly Language Next step up from machine code it consists of letter codes called mnemonics that stand for machine code instructions

Astable A circuit that has no stable state and thus oscillates at a frequency dependent on component values.

Asynchronous A form of data transmission (parallel or serial) that is not synchronised.

Audio A signal that can be heard with the ears.

Automatic Frequency Control (AFC) A circuit that automatically maintains the frequency of any source.

Automatic Gain Control (AGC) A circuit that automatically controls the gain of another circuit to maintain a constant output during variation in input waveform.

Autotransformer A transformer that has a single winding with tappings, rather than two separate windings. Transformer action still applies and the only difference is the transformer does not provide isolation as with a true primary and secondary situation.

AVC abbreviation for automatic volume control.

Back Electromotive Force Back emf. The emf that opposes the normal flow of current in a circuit.

Balun Comes from **Bal**ance/**un**balanced transformer. Used for example to connect a balanced antenna to an unbalanced (coaxial) transmission line.

Base One terminal of a transistor. Generally the input lead. It separates the collector and emitter regions.

BASIC Beginners All-Purpose Symbolic Instruction Code.

Battery A device for supplying DC voltage. A group of cells is called a battery.

BAUD Measure of serial transmission speed - bits per second. 1 baud is one bit per second.

BFO Beat Frequency Oscillator. An adjustable frequency oscillator with an output that can be mixed with the final intermediate frequency signal to produce audio.

Bias A Voltage whose main function is to set the operating characteristics of an electronic device. e.g. bias resistor.

Bimetallic Strip A strip consisting of two metals with different coefficients of expansion bonded together. When the strip is heated it bends and this can be used to open or close contacts.

Binary Number System based on the number 2. The binary digits are 0 and 1.

Bipolar transistor The most common form of transistor.

Bistable Circuit that has two stable states.

Bit Binary digit - the smallest unit of binary data.

Blocking Oscillator An oscillator in which blocking occurs at the end of a cycle. This type of circuit usually employs a transformer.

Bootstrapping A technique used to provide 100% positive feedback in a circuit to improve the output.

Bottoming A transistor in the fully conducting state.

BPS Bits Per Second - the number of bits transmitted over a serial link in one second.

Breadboard A board for holding components that make a circuit. The components can be removed an reused without being damaged. Also called a proto-typing board.

Bridge - generally a short-circuit on a PC board caused by solder joining two adjacent tracks.

Bridge rectifier a full-wave rectifier in which there are four arms - each containing a diode.

Bubble Memory Serial memory in which small magnetic bubbles are used as the storage medium.

Buffer A temporary memory location in which data is stored prior to use. In analogue use it is a circuit that isolates the driving circuit from the driven circuit.

Bug Fault or error in software or hardware. Also a transmitting device.

Bus A group of lines to convey information from a source to a destination.

By-pass capacitor. A capacitor that provides a path of low impedance - low resistance to AC signals.

Byte A group of binary digits that combine to make a word. Generally 8 bits. Half byte is called a nibble. Large computers use 16 bits and 32 bits.

C Core A magnetic core that is moulded or cut into the shape of the letter "C"

CAD Computer Aided Design

Capacitance Letter C. Units: Farad F, microfarad uF, nanofarad nF, picofarad pF. A capacitor has capacitance. The property that allows a component to store electric charge when a potential difference exists between its terminals. Stray capacitance - unwanted capacitance - created by the proximity of other components.

Capacitor An electronic component that stores electrical charge.

Cascade A method of connecting circuits in series so that the output of one is the input of the next.

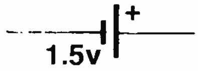
Cathode - identified by the letter k - the banded end of a diode

Cathode Ray Oscilloscope CRO. An instrument with a screen that provides a visual indication of the waveform at any point in a circuit.

CCD Charge-coupled Device. A charge transfer device that consists of an array of MOS capacitors in which charges can be moved through a semiconductor substrate in a controlled manner. The effect can be used for imaging such as in the CCD solid-state camera.

Cell A single source of voltage - usually producing 1.5v but a lithium cell produces 3v.

Central Processing Unit (CPU) That portion of a microprocessor that controls the arithmetical and logical operations.



Ceramic capacitor Generally a single layer capacitor that is flat and has a brown coating. Also have the name monoblock or monolithic in which the capacitor is made even smaller by creating multi-layers and coated in orange or blue paint.

Cermet A potentiometer made from a alloy of ceramic and metal. Provides stable properties at high temperatures.

Character A symbol that conveys an item of information.

Chip Another name for Integrated Circuit or the piece of silicon on which semiconductors are created.

Choke An inductor designed to present a high impedance to alternating current.

Circuit All the components that create a project. A drawing of the circuit is called a circuit diagram or schematic.

Class A amplifier A linear amplifier in which the output current flows over the whole of the input cycle. The angle of flow = 2π.

Class AB amplifier A linear amplifier in which the output current flows for more than half but less than the whole of the input cycle. The angle of flow is between π and 2π.

Class B amplifier A linear amplifier in which the output current is cut off when the input signal is zero. The angle of flow = π. Two transistors are connected to provide full output waveform.

Class C amplifier A non-linear amplifier in which the output current flows for less than half the input cycle. The angle of flow is less than π.

Class D amplifier An amplifier operating on pulse-width modulation. Input signal produces a square wave modulated with respect to its mark-space ratio. Push-pull switches operate with one on the high input level and the other on the low level.

Clipping Distortion of a signal that is unable to produce its peaks.

Clock. Clock pulse. Clock frequency. A building block that produces periodic signals.

CMOS Complimentary Metal-Oxide-Semiconductor. Family of logic devices that uses p-type and n-type channel devices on the same IC. It has the advantage of offering medium speed and very low power requirements.

Coax Coaxial cable. A round cable with a central conductor and screening around with an insulating medium between.

Coil A conductor wound in a series of turns.

Collector One terminal of a transistor.

Colour code. Resistor colour code & capacitors & chokes.

Colpitts Oscillator An oscillator in which a tank circuit is connected between collector and base and in which the tank capacitance is made up of two capacitors in series across the inductor. The tapping of the capacitors goes to the emitter.

Common Base Connection Same as grounded base connection. A mode of operation in which the base is common to both the input and output circuits and is usually earthed. The emitter is used as the input terminal and the collector as the output terminal. (Grounded = grounded to AC signals)

Common Collector Connection Grounded collector connection. Also called the emitter-follower. A mode of operation in which the collector is common to both the input and output circuits and is usually connected to one of the power rails.

Common Emitter Connection Same as grounded emitter connection. A mode of operation for a transistor in which the emitter is common to the input and output circuits. The base is the input terminal and the collector is the output terminal.

Comparator A building block such as a differential amplifier that compares two inputs and produces an output that is a result of the comparison.

Compiler A program that translates the instructions in a program written in a high level language, into machine code.

Complementary transistor. A PNP and NPN pair used in a push-pull circuit.

Condenser Obsolete term for capacitor.

Conductor Material that offers a low resistance to the passage of current.

Control Bus Bus on which system control commands are passed between elements of a system.

Conventional current flow. During the beginning of the invention of electric circuits it was thought that current flowed from positive to negative. See Electron Flow for the opposite direction of flow.

CP/M Stands for Control Program/Microprocessor. A type of operating system in which a program of instructions tell the computer how to work.

CPU Central Processing Unit. This is the same as MPU Microprocessor Unit. This chip carries out all the number crunching and control operations.

CRO Cathode Ray Oscilloscope. A piece of test equipment with a Cathode Ray Tube to display waveforms and signals of a circuit under test.

CRT Cathode Ray Tube. The tube inside an oscilloscope.

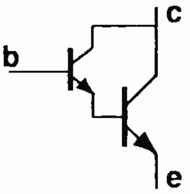
Crystal Oscillator Oscillator using a quartz crystal for accurate control of frequency.

Current Current is measured in amps (milliamps and microamps). It is the passage of electrons. Conventional current flows from positive to negative. Electrons flow from negative to positive - called Electron Flow.

Cut-off Frequency The frequency at which the gain or amplification is unity.

D/A Converter Circuit that converts digital data into an analogue signal.

Darlington Pair Two directly coupled transistors in which the emitter of the first drives the base of the second.



DAT Abbrev for Digital Audio Tape.

Data Bus Bus that carries data between various elements of a system.

DC Direct Current. A current that flows in one direction only.

DC Voltage. Voltage that is present in one direction only.

Decibels (dB) A logarithmic unit to express the ratio of values of power and sound.

Decoupling Circuit layout and components chosen to reduce interference on a systems supply rails.

Detune To adjust the frequency of tuned circuit so that it is lower than the original frequency of operation.

Dielectric A solid, liquid or gaseous material that can sustain an electric field and act as an insulator.

Digital Electronics The branch of electronics dealing with information in binary form.

DIL Dual In Line The most common package in which the pins of an IC form two parallel lines.

Diode A semiconductor that allows current to flow in one direction only.

Diode drop The forward voltage developed across a diode when it is operating.

Dipole A balanced antenna, usually half a wavelength long and fed (or taken off) at its centre.

Direct Current (DC) A current that does not change in direction.

Direct coupled amplifier (dc amplifier) An amplifier in which the output of one stage is coupled to the input of the next without the use of a capacitor. This type of amplifier will amplify Direct Currents and low frequency waveforms.

Direction Finding Also Radio Direction Finding. The use of radio signals to determine the direction from which a transmission is coming from.

Discrete A term used for a circuit made up of individual components.

Distortion The amount by which a circuit or component fails to reproduce accurately the characteristics of the input.

DMA Direct memory access between computer and peripheral

DRAM abbreviation for Dynamic Random Access Memory.

D-Type Flip Flop Also called Data type or Delay Flip Flop.

Duplex A method of transmitting data between two points in both directions simultaneously and independently. - same as full duplex. **Half Duplex** - between two points but only in one direction at a time. **Simplex** - transmitting data in only one direction.

Dynamic Memory. Data stored in capacitors. Memory is volatile and the capacitors need to be refreshed at intervals.

EAROM Abbrev for Electrically Alterable Read-Only Memory.

Earphone - (earpiece) A device for turning electrical energy into sound waves - fits in your ear.

Earth - ground. Can mean a connection to the earth itself or the negative lead or to the chassis or any point of zero voltage. see also ground plane.

ECL Emitter Coupled Logic. Where transistors are held in the turned-on state to increase the speed of the gate.

EEPROM also **E^{2}PROM** Electrically erasable programmable read-only memory. A ROM that can have is data erased by the application of a voltage on certain pins of the chip.

Electret Microphone A very sensitive device for picking up sounds. Consists of a very thin plastic diaphragm that is metallised and polarised with a static charge with opposite charges at the extremities. It is the electrical equivalent of a permanent magnet. The diaphragm connects to the input lead of a FET (Field Effect Transistor) and the transistor amplifies the movement on the diaphragm.

Electrolytic A type of capacitor that has a liquid or paste between the plates to increase its capacitance.

Electron Flow The direction in which electrons flow. This is from negative to positive - as electrons are negatively charged.

EMF electromotive force. Symbol: E. Unit: volt. The property of electrical energy that causes a current to flow.

Emitter One terminal of a transistor.

Emitter Follower - see Common Collector connection.

EPROM Erasable Programmable Read Only Memory. Form of ROM that can be erased (by exposure to Ultra Violet Light) and reprogrammed.

Exclusive OR Logic element that features two inputs. The output will be 1 only when one or the other (but not both) is logic 1. In all other cases the output is 0.

Fan-out The maximum number of inputs (such as chips) that a given chip (or circuit) can drive.

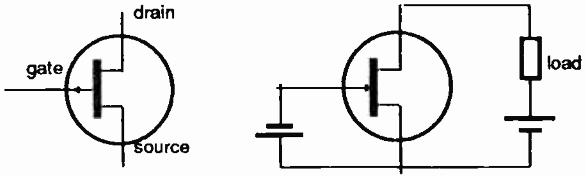
Farad. The unit of capacitance. "F"
This is a very large value and the most common units are micro farad (uF) and nano farad (n).

Feedback Occurs when some or all of the output of a device (such as an amplifier) is taken back to the input. This may be accidental (such as the acoustic feedback from a speaker to microphone) or intentional, to reduce distortion.

Ferrite Rod Aerial A coil of wire wound on a ferrite material to increase the inductance of the coil. It's signal capturing capability.

Fibre Optics An optical system that uses one or more glass or perspex fibres as a light guide for transmitting optical images (data).

Field Effect Transistor (FET) A transistor that makes use of the field established in a p-type or n-type channel semiconductor material to control the flow of current through the channel.



p-type FET **n-type FET**

Field Strength The value of a received radio wave.

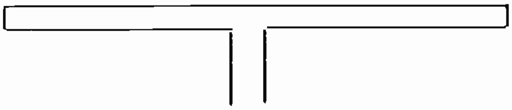
Field Strength Meter A device for measuring the strength of electromagnetic radiation (radio waves).

Flip Flop An astable multivibrator. A square wave oscillator that has no stable states. Also half a shift register.
Flip flops can be unclocked and triggered by the input pulses or CLOCKED by a clock pulse to a special clock input.
5 different types are available:
D-type flip flop - (D stands for delay) This is a clocked flip flop in which the output is delayed one clock pulse.
R-S flip flop - A simple reset-set flip flop.
J-K flip flop.
RST flip flop in which the three inputs are Reset, Set and Toggle.
T flip flop in which the input line will toggle the flip flop (cause it to change state).

FM Frequency Modulation. Where voltage levels change the frequency of a carrier wave.

FM Band The range 88MHz to 108MHz.

Folded Dipole An antenna that has an impedance of about 300ohm and consists of two closely parallel half-wave dipoles, joined together at their outer ends.



folded dipole

Forward Bias also called forward voltage.

Frame Aerial - also called loop aerial. Aerial wire wound in a rectangular shape so that it can be rotated to pick up the strongest signal.

Frequency The number of cycles per second for any periodic waveform - measured in cycles per second - now called Hertz.

Frequency Modulation FM Modulation where the frequency of the sinewave carrier alters with the amplitude of the modulating signal.

Full Scale Deflection FSD The maximum value on the scale of an instrument.

Fuse a short length of wire that will easily burn out when excessive current flows.

Fusible-link Memory A type of read-only memory that is programmed by providing a pulse to blow a fuse at locations where an open circuit is required.

Gain The ratio of the output level of a circuit to the input. This will be positive for an amplifier and negative for an attenuator.

Gate Element of a digital circuit. Also one of the terminals of a Field Effect Transistor (FET).

Geiger Counter Geiger-Müller Counter. A gas filled tube used to detect ionizing radiation, especially alpha-particles.

Greencap A type of polyester capacitor that the manufacturer dips in green paint to make it distinctive from all other capacitors.

Ground Plane The earth or negative rail of a circuit. A large or significant mass that presents the effect of earth (ground) to a signal.

Hall Effect When an electric current is passed through a semiconductor and a magnetic field is applied at right angles, a potential develops across the semiconductor that is perpendicular to both magnetic and electric fields.

Handshaking Set of command signals that arbitrate between two sections of a system in communication with each other.

Hardware The physical components that go to make up a computer system.

Harmonic A sinusoidal component of a waveform that is a whole multiple of the fundamental frequency. An oscillation that is an integral sub-multiple of the fundamental is called a subharmonic.

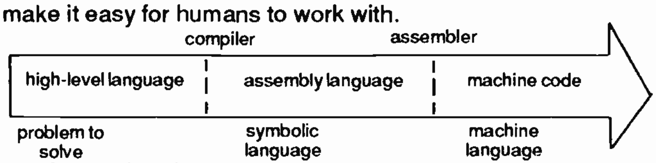
Hartley Oscillator. An oscillator in which a parallel tuned tank circuit is connected between the base and collector of a transistor.

Henry The electromagnetic unit of inductance. 1 Henry occurs when a back emf of 1 volt is produced when current is changing at the rate of 1 amp per second.

Hertz - Hz The unit of frequency in cycles per second.

Hexadecimal code A 4-bit binary code linked to the number 16. The Hex scale: 0, 1, 2, 3, 4, ,5 ,6 ,7 8, 9, A, B, C, D, E, F. In binary form: 0000, 0001, 0010, 0011, 0100, 0101, 0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111.

High-Level Programming Language A language containing words and symbols that are close to normal English to make it easy for humans to work with.



Horizontal polarization Polarization is determined by the position of the radiating element with respect to earth. Thus a radiator that is parallel to the earth radiates horizontally.

Hysteresis A delay in the change of an effect.

IC Integrated Circuit - also called a "chip."

IGFET Insulated Gate FET.

I^{2}L abbreviation for Integrated Injection logic.

Impedance Similar to resistance but applies to AC circuits. The opposition a component in a circuit offers to the flow of alternating current at a given frequency. If the frequency changes, the impedance changes too. Impedance is measured in ohms and has the symbol "Z" with the unit **ohm**.

Inductance A changing current in a coil produces a changing magnetic flux. The changing magnetic flux results in an induced current flowing in the coil. The unit is Henry. One Henry is the inductance of a circuit that produces a counter-force of 1 volt when the current flowing is changing at the rate of 1 amp per second.

Input That part of a circuit that accepts a signal for processing.

Input/output (I/O) Those operations used to pass information into or out of a computer.

Insulator Any material that resists the flow of current.

Insulated-gate field effect transistor (IGFET)

Integrated Circuit Commonly called an IC. A circuit component consisting of a piece of semiconductor material containing up to thousands of transistors and diodes.

Interface Usually refers to the hardware that provides communication between various items of equipment.

Interference A disturbance to the signal in any communications system.

Interlock A safety device that allows a piece of equipment to only operate under certain conditions.

Inverter A circuit in both analogue and digital systems that provides an output that is inverse to the input. Also a circuit that converts DC to AC.

I^{2}R loss That loss (heating effect) produced when a current flows through a conductor.

Jack (plug and socket) A type of plug and socket previously called a telephone plug and socket. These come in three sizes, 6.4mm (old telephone size), 3.5mm and 2.5mm. The male part is called the jack plug and the female part is called the socket. The plug consists of a shaft with a small ball on the end to make easy insertion into the socket. Part-way down the shaft is an insulating section to form the second conductor.

JFET Junction Field Effect Transistor.

Junction The join of two conducting materials.

k or K k = kilo = 1,000 such as 1,000 ohms In digital terms $K = 2^{10}$ or 1024.

K Band Microwave band from 10.9 to 36 gigaherts.

Kilobyte (K) 1024 bytes.

kc/s Kilocycles per second. Replaced by kHz. See Hertz.

Kilowatt-hour kWh A unit of energy when one kilowatt of power is expended for one hour. Example: A radiator bar is usually rated at 1,000 watts and this switched on for one hour consumes one kilowatt-hour of electricity.

LAN Abbreviation for Local Area Network.

LASER - from Light Amplification by Stimulated Emission of Radiation.A source of intense monochromatic coherent radiation in the visible, ultraviolet or infrared regions of the electromagnetic spectrums.

LCC abbreviation for Leadless Chip Carrier.

LCD Liquid Crystal Display - a reflective display that requires very low power for operation.

L-C Oscillator Oscillator in which the frequency determining components are an inductor and capacitor.

Lead Acid cell. Commonly called the wet cell or accumulator or car battery. A cell consisting of spongy lead cathodes and lead dioxide anodes with dilute sulphuric acid as the electrolyte.

Leakage The passage of electric current that is unintended.

LED Light Emitting Diode. A diode that emits light when current is passed through it. It has two leads: cathode (k) and anode.

LDR Short for Light Dependent Resistor. A layer of Cadmium Sulphide material that changes resistance according to the amount of light falling on it.

Light Pen Pen-shaped input device used in conjunction with a Visual Display Unit or TV screen.

Liquid Crystal Display - see LCD above

Loudspeaker A device for converting electrical signals into sound waves.

LSI Large Scale Integration. IC's containing between 100 and 10,000 circuit elements. Also VLSI Very large scale integration.

Machine Code Set of binary instructions that control the operation of a micro processor.

Mains The source of domestic power. This is 240v AC 50Hz in Australia.

Megohm One million ohms. Written as "M."

Mega Multiplier indicating that a quantity should be multiplied by 1,000,000.

Memory Part of a system in which data is stored.

Memory Map A diagrammatic representation of the memory allocation within a system.

Micro - one millionth. e.g. microfarad - uF. Micromicrofarad is now replaced with picofarad - pF.

Microphone A device for converting sound waves into electrical current. See Electret microphone.

Microprocessor The Central Processing Unit in a computer system. Also called CPU.

Milli one thousandth e.g. one milli-watt - 1mW. one milli-amp 1mA. one milli-volt - 1mV.

Mnemonic A word or group of letters, usually 2 or 3 to help memory such as LD for load or DST for destination.

Modem MOdulator-DEModulator. The most common example is a device that connects a computer to the telephone system.

Monostable Circuit with two states. Only one state is stable.

Morse Code A series of dots and dashes transmitted by a tone to represent letters. The earliest form of transmission before voice transmission.

MOS Metal Oxide Semiconductor. Technology used in the manufacture of semiconductors.

MOSFET Metal-Oxide-Silicon-Field-Effect-Transistor. See FET. Also Metal-Oxide-Semiconductor FET.

Motor-boating In audio amplifiers - an unwanted low frequency noise similar to the sound of a motor boat.

Moving Coil Instrument The movement (the pointer assembly) in an analogue multimeter is an example of a moving coil. The amount the coil turns in a magnetic field depends on the current flowing.

Multimeter General purpose test instrument used to measure voltage, current and resistance.

Multiplexing Combining a number of signals so that they share a common transmission channel.

Multivibrator A building block in which the output is either HIGH or LOW. There are three forms of multivibrator: Monostable, bi-stable and astable. The monostable has only one stable state, the bi-stable has two stable states and the astable is free-running (no stable states).

Multiples and sub-multiples of Units:

Multiplication factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Muting Also known as squelch. Inhibiting the output of a radio receiver by automatically reducing its gain in the absence of an input signal.

NAND Gate. Gate whose output is 0 when both inputs are 1 and 1 in all other cases.

Nano One thousand millionth. 1/1,000,000,000. e.g 1nanofarad - 1nF. 1nF is equal to 1,000pF. 1,000nF is equal to 1uF and one million uF equals one Farad.

Nibble Half a byte

Negative Feedback Feedback from the output of an analogue circuit that tends to oppose the input. This has the effect of stabilising the circuit

Ni-cad Nickel-Cadmium cell. Type of rechargeable battery.

NMOS n channel MOS Metal-Oxide-Semiconductor

Non-Volatile Memory Memory in which the data is not lost when power is removed.

NOR gate Gate whose output is 0 if any of its inputs is a 1.

NOT gate Logic element that acts as an inverter.

NPN Type of bipolar transistor using n-type p-type n-type material in its manufacture.

Object Code The code used directly by a microprocessor.

OCR Optical Character Recognition

OHM The unit of resistance usually shown as the symbol "R" one thousand ohms is written "k" and one million ohms is written "M." Ohms are measured with an ohm-meter and is one of the ranges on a multimeter, called the "ohms range."

Ohm's Law Written as I=V/R where I is the current flowing, V is the voltage and R is the resistance.

Omni-directional Antenna An antenna having a non-directional radiation pattern.

Operational Amplifier (op-amp) One of the basic building blocks of analogue circuits - a high gain stable amplifier with a voltage gain of 100 to 100,000 or more.

Opto Isolator A device that provides electrical isolation between two sections of a circuit.

OR gate Logic gate whose output will be at 1 if any of its inputs is at 1.

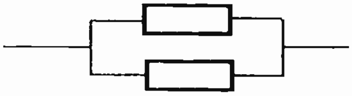
Oscillator A building block that produces an alternating waveform.

Oscilloscope See Cathode Ray Oscilloscope. (CRO)

Output That part of a circuit where the processed signal is available.

PABX Private Automatic Branch Exchange.

Parallel Resistors, cells, switches and batteries etc can be connected in parallel. see diagram:



Passive Component A component that does not provide any amplification or gain such as a resistor, capacitor, LED, volume control, battery, globe. Components that are NOT passive: transistor, valve, IC, (these are called ACTIVE)

PCB Printed Circuit Board.

Peak Inverse Voltage (PIV) The maximum voltage applied to a device in the reverse direction.

Peak to peak amplitude The value between the maximum and minimum of a waveform in one period.

Phoneme A single unit in speech. Two or more phonemes make a syllable.

Photocell A device that changes resistance when light falls on it. Similar to a light dependent resistor or LDR. This cell does not produce an output current - see Solar cell for output current.

Phototransistor A transistor with a window on the top face to allow light to fall on the active surface. Also available as a Darlington photo-transistor to produce a very sensitive light detecting device.

Pico (p) 10^{-12}

Piezo Sounder Small crystal element that can emit very high sound levels while requiring low current. Also called a Piezo diaphragm as it has no active circuit connected to the diaphragm. A piezo buzzer has an active circuit connected to the diaphragm to emit a sound when a DC voltage is applied.

PNP Type of bipolar transistor using p-type, n-type, p-type semiconductor material.

Polarised A component or plug etc that must be fitted around a certain way. e.g: Thick and thin pins spaced apart so that the plug cannot be inserted around the wrong way.

Polyester A type of capacitor. See Greencap.

Positive feedback Type of feedback that causes oscillation in analogue systems.

Potentiometer (pot) Variable resistor. Has three terminals. The two ends of the resistor and the slider or moving arm.

Power Supply Device that supplies DC power to a system.

Primary The input side of a transformer. A non-rechargeable cell such as a torch cell.

Probe Similar to a pen with the needle point and connected to a lead of a test instrument - able to get into tight places for test purposes.

PROM Programmable Read Only Memory. Memory that can be programmed by the end user but cannot be altered after programming. The memory elements are usually formed by fusible links.

Q band Microwave frequencies from 36 - 46 gigahertz.

Q-Factor Quality factor. The amplification of an oscillating (tuned) circuit. The ratio of the voltage produced by the circuit divided by the voltage applied to it.

Quiescent Current The standing current that flows in a circuit when the signal is not applied. The quiescent current is usually very low or lower than when processing a signal.

RADAR Radio Direction And Ranging

Radio Frequency RF for short. That part of the spectrum from approx 50kHz to gigahertz

RAM Random Access Memory Read/Write memory.

R-C Resistance-Capacitance such as R-C coupling

RDF Radio Direction Finding. A radio or other apparatus with an antenna that is rotated to pick up the maximum signal and thereby determine the direction in which the signal is coming from.

Receiver (Rx) A circuit in which electrical waves or currents are converted into audible signals.

Rectifier A device that passes current in only the forward direction.

Regenerative Receiver An amplitude modulated (AM) radio receiver in which positive feedback is used in order to increase the sensitivity and selectivity of the receiver.

Register A word-sized location in a microprocessor.

Relaxation Oscillator An oscillator in which the output voltage changes suddenly during each cycle.

Relay Electromechanical device containing a coil and set of contacts. The contacts close when the coil is activated.

Resistance The measure of the ability of a material to pass a current.

Resonant Frequency The frequency at which resonance occurs. In a parallel resonant circuit, the current in the circuit is a minimum and the voltage is a maximum.

Resistor Passive component with a known resistance. The value of resistance is usually shown by a set of coloured bands on the body of the component.

RF abbreviation for Radio Frequency.

RMS abbreviation for Root Mean Square

ROM Read Only Memory. Memory whose contents are fixed at the manufacturing stage.

R-S flip flop see flip flop.

S-Band Microwave frequencies from 1.55 to 5.2 gigahertz.

Schottky diode - hot carrier diode. A diode using an aluminium-silicon junction in which carrier storage is negligible, leading to very fast on and off states and thus very fast switching speeds. The forward voltage is 0.3v.

Schematic Another name for a circuit diagram.

Schmitt Trigger A building block in which the input must be taken to about 70% of rail voltage before the output will change. The lower level for change is about 30%. This produces a gap and thus noise is prevented from entering.

Screened Pair A shielded pair of wires.

SCS - silicon controlled switch.

Secondary The output side of a transformer. A re-chargeable battery such as a car battery. Also called accumulator. The battery does not make electricity but simply stores energy in chemical form.

Self-bias - Bias developed from the supply rail due to circuit components and a dropper resistor rather than a separate battery.

Semiconductor Material that is neither a conductor nor insulator. Its properties can be altered by a control voltage.

Sensitivity A measure of the ability of a receiver to respond to weak signals.

Serial Transmission Communication in which the data is transmitted along a single line.

Series Resistors, cells, switches and batteries etc can be connected in series. see diagram:

Series-Parallel Connection An arrangement where components are connected in series and then many of these modules are connected in parallel to create a series-parallel arrangement. A typical example of this is Christmas-tree lights. Each globe is 24v and 10 are connected in series for the 240v mains. This is repeated 5 times to get a set of say 120 lights.

Series Resonant Circuit A circuit in which the components are connected in series and capable of oscillating at a particular frequency. It exhibits minimum impedance at resonance.

Short-Circuit An un-intended path that conducts electricity. Also called a "bridge" or "short" such as when solder from two tracks touch on a PC board.

Shunt This generally means parallel connection.

Signal Generator A circuit that produces a variable and controllable signal.

Silicon Controlled Rectifier (SCR) A reverse blocking triode thyristor. A pnpn device.

Simplex Operation Operation of a communications channel in one direction only.

Single pole switch A switch in which only one circuit is controlled.

Solenoid A coil of wire that is long compared to its diameter, through which a current will flow and produce a magnetic flux to push or pull a rod (called an armature).

Square Wave A periodic wave that alternately assumes one of two fixed values (high and low) with the transition time between these two levels being negligible.

Solar cell A cell that produces current under sunlight.

Source Code Another name for instructions written in a low-level language such as assembly language (using mnemonics)

Static Memory Data stored in Flip Flops. Memory is lost when power is removed.

Sum Check A binary number, sent at the end of a block to check the accuracy of transmission.

← data →

11000111	10110001	01101100	00001101

13 logic ones 13 in binary

Superheterodyne Receiver The most widely used radio receiver in which the incoming signal is fed into a mixer and mixed with a signal from a local oscillator. The output produces an intermediate frequency that is amplified through an IF strip, detected by a diode and amplified in an audio amplifier.

Surface Acoustic Wave (SAW filter)

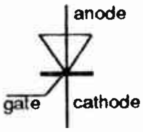
Switch A device for connecting and disconnecting power to a circuit.

Symbolic Code A code which uses mnemonics instead of binary code to give instructions to a computer.

T Flip Flop Toggle flip flop.

Thermistor Resistor that varies in value according to its temperature.

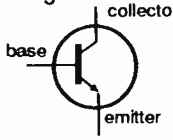
Thyristor A component rather like a diode but will not conduct until a voltage is applied to its third terminal known as the gate.



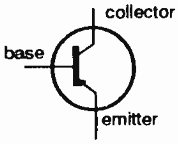
Tolerance The allowable percentage variation of any component from that stated on its body. For instance: red = 2%, gold = 5% and silver = 10%.

Transducer A device that receives energy in one form and supplies an output in another form.

Transistor A three leaded device (Collector, Base, Emitter) used for amplifying or switching. Also called a bi-polar transistor to distinguish it from Field effect transistor etc.



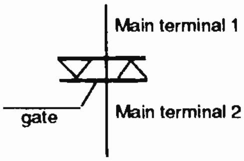
NPN transistor



PNP transistor

Transmitter (Tx) A device that converts audio , video or coded signals into modulated radio frequency signals which can be propagated by electromagnetic waves (radio waves).

Triac Similar to a thyristor but allows current to flow in both directions.



Trimmer - trimmer capacitor A small variable capacitor used in parallel across a larger capacitor to adjust the total capacitance a small amount.

Truth Table A tabular representation of a logic gate showing all the possible combinations.

A	B	C
F	F	F
F	T	T
T	T	T

TTL Transistor-transistor-Logic. Family capable of high speed operation and designed for a rail voltage of 4.5v - 5.5v

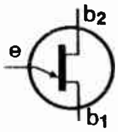
Tuned Circuit A circuit in resonance at a particular frequency.

Tuned Radio Frequency (TRF) An amplitude modulated (AM) receiver with one or more stages of radio frequency before the detector.

UHF Ultra High Frequency

Ultrasonic A frequency above the limits of the human ear - above 20kHz.

Unijunction Transistor A trigger device that has an emitter lead (e) and two bases B_1 and B_2.



p-type emitter Uni-junction transistor

VDU Visual Display Unit.

VLSI Very Large Scale Integration

Volatile Memory Memory that loses its data when power is switched off.

Volt The unit of voltage. One thousand volts = 1kV

Voltage Divider The voltage produced at the join of two components.

Voltage Multiplier A set of components designed to increase the voltage for a particular application.

Voltmeter A meter for reading voltage. It is one of the ranges in a multimeter.

VOX Voice operated Switch.

Watt Symbol W. The unit of power. One watt is the product of one volt and one amp.

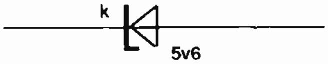
W Band The microwave band from 56 to 100 gigahertz.

Wavelength The distance between two points of corresponding phase in consecutive cycles.

X band The microwave band from 5.2 to 10.9 gigahertz.

Yagi A sharply directional antenna such as a TV antenna.

Zener A diode that has been specially designed to break down at a particular voltage. This is its zener breakdown voltage.



INDEX

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For example: 6 - 10 is Notebook 6, page 10.
Rev - REVEALED.

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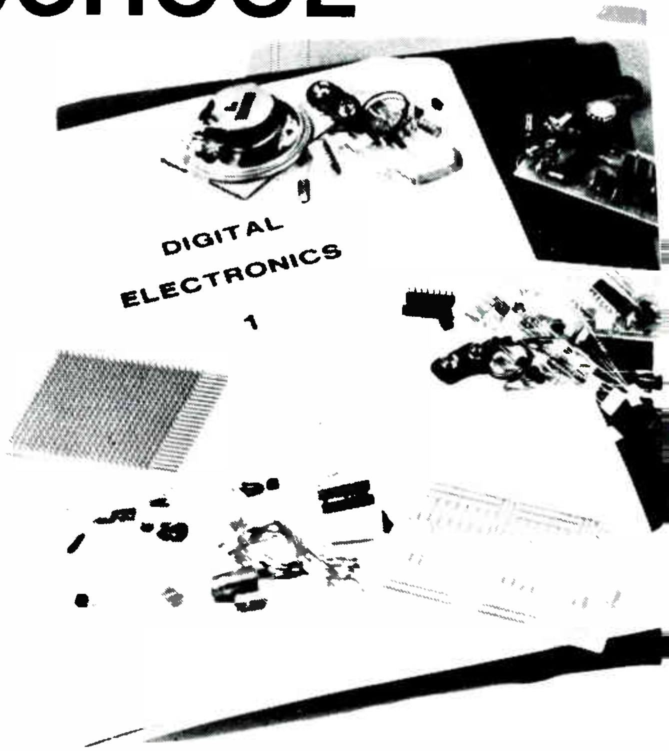

The Australian Digital Electronics School is an offshoot of Talking Electronics and has helped many students to gain a worthwhile career in electronics, and you can be helped too. It specialises in explaining digital electronics at the beginners level and if you would like to make a career in this field, this is where to start.

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