14

(actually about 20)

FM BUGS TO BUILD

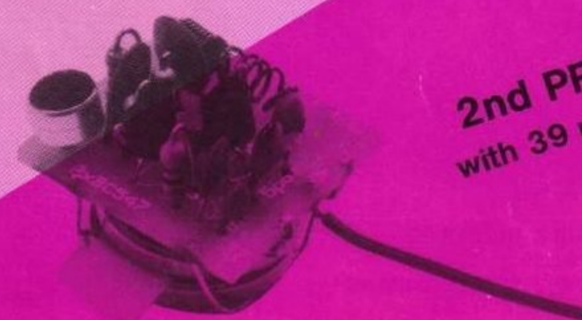
new bugs have been added

by

Colin Mitchell

Learn the secrets and theory behind micro-power FM transmission

2nd PRINTING! with 39 updated pages



Our 600m Cube of Sugar Bug

A TALKING ELECTRONICS PTY LTD PUBLICATION

INTRODUCTION

In this issue we have presented 14 (and 2 extra) of our most popular FM bugs.

The first 2 projects are new, while the remainder have been taken from our first 3 FM bugs books: FM BUGS, MORE FM BUGS, and BUGGING AND ITS PREVENTION. The final project is also new and shows how we are constantly improving our designs to bring you the best possible.

One customer bought 4 FM bug kits from other kit-makers, while he was overseas. We put them together and none of them worked! They had actually left out one or two of the most important components, both in the kit and on the circuit diagram! I don't know how they ever expected the kit to work. Obviously nothing had been tested. When we go overseas we'll swamp the opposition! There's absolutely no competition. The projects in this issue have been tried and proven by over 30,000 successfully built kits and that's your guarantee of success.

The 3 FM bug books mentioned above are now out of print and to satisfy the stream of requests for back copies, we have decided to put all the bugs into one book.

This means you will miss out on some of the lesser articles, as we couldn't include everything.

This is one of the problems of producing such good projects. Even though some of our issues are up to 5 years old, nothing has gone out of date and the circuits are still the best available. We get lots of requests for the bugs and the prices have hardly risen in 5 years. It's always been our intention to produce kits at a competitive price and now that costs have risen all around us, our prices are better value than ever.

To get back to the topic: Many readers are very smart. They buy two copies of everything we produce. They use one in the workshop and keep the other in their library. They know the working copy will get a battering after months of use and have the clean copy to fall back on.

The one thing that's forbidden is to loan any of your copies. You will never get them back. We have had literally hundreds of readers request replacement copies after loaning a copy to a friend. The answer is always the same: "Oh, I loaned it to someone else and they haven't returned it!" or "Oh, I thought I returned it to you a long time ago. Gee, I don't know where it is now!" People are so dishonest - or maybe its a reflection on the quality of the articles.

The answer is not to let anyone borrow. You can take it from me, you will never see it again - or the borrower!

This will be the last printing for "FM Bugs" etc so be warned! Look after your copy.

You will notice the projects have been presented in order of complexity, with the simple bugs at the beginning and working through to more complex designs. If you are just starting in this field, I suggest you build some of the simple circuits first and get to understand how they work. Each project adds a new feature to the design and you can see how the efficiency and range increases as you work though the book.

The projects introduce surface-mount technology as well as a grounding in miniaturisation. FM transmitters are so effective that they have become one of our most popular kits. Providing you don't increase the supply voltage above that specified, or transmit on top of a commercial radio station, you will not interfere with anyone else and you can use the bugs for all kinds of field work, picking up the sounds of the bush, talking between two parties or monitoring your own property.

I know you will have lots of fun so I'll leave it to you to pick out something interesting and clear a space on the workbench.

Colin

Colin.

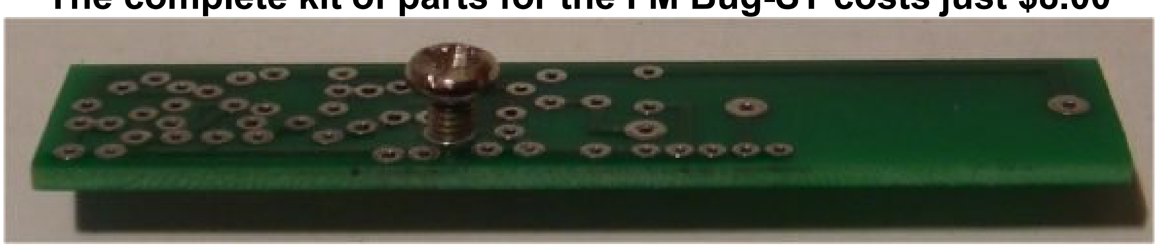
CONTENTS

TALKING ELECTRONICS

talking@tpg.com.au

See complete PRICE LIST at end of this eBook

The complete kit of parts for the FM Bug-ST costs just $8.00



The "screw" is adjusted from the underside of the board to set the frequency.
This "screw" is called a SLUG and the bug is called "SLUG TUNED."

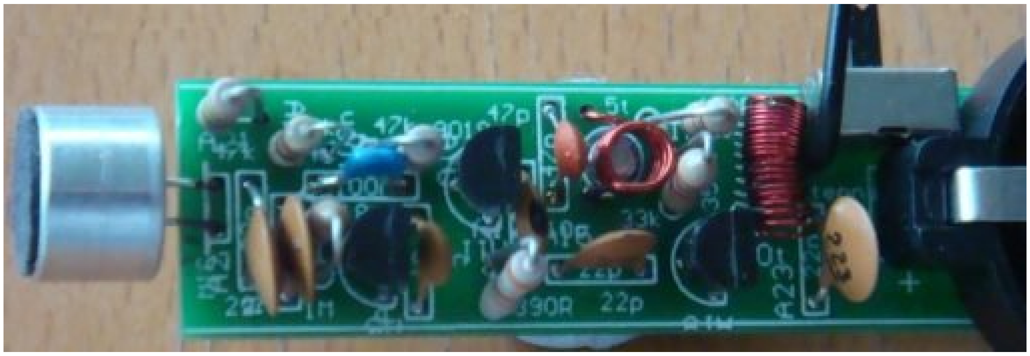
FM BUG (slug tuned)

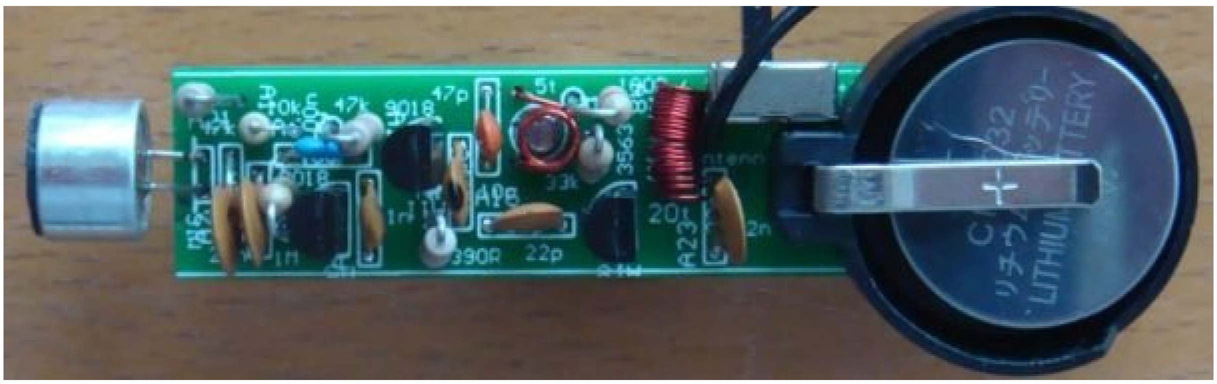
Cost: $8.00 including postage
email:
talking@tpg.com.au
and ask for details on how to pay for the kit.

This project is a great way to learn about FM transmission.
With just a few components you can create your own FM Radio Station !!!

This project has been designed to compete with the low-cost kits on the market. This kit is better than all the rest.
1 and 2 transistor kits are very poor performers and it is pointless getting a kit that does not perform.
You will be disappointed and think all FM transmitters are useless.
But that is not so.
You need 3 transistors to get reliable performance.
The first transistor amplifies the signal from the microphone so you can hear a pin drop.
The second transistor creates the frequency at which the bug transmits and
The third transistor acts as an amplifier (in the form of a BUFFER), to separate the oscillator from the antenna, so the bug does not drift when being held.
The circuit is well-designed and includes an interesting feature: "SLUG TUNING."
We have used a steel bolt or "screw" to adjust the frequency of the circuit and it is screwed through the board and into the coil.
By placing the first two turns close to the board, the end of the bolt will have an effect on changing the frequency.
This is called a SLUG TUNED COIL and is one of the oldest ways to tune a radio or transmitter.
The slug is normally ferrite but if you only insert a small portion, the frequency will shift slightly. If the bolt is fully inserted, it will freeze the oscillator as the coil will pass all its energy into the bolt and the circuit will stop oscillating. But just a small insertion will tune the bug to the frequency you want.
The approximate frequency on the **88MHz to 108MHz band** is set by expanding or compressing the 5 turn coil and then the fine tuning is done by screwing the bold from the underside of the board. As you expand the turns, the frequency increases and compressing the turns takes the frequency from 88MHz to a lower frequency.
Designing a good circuit involves a number of points.
The layout of the board is important as well as the choice of actual component values.
Our is the simplest and best design and has been perfected over the past 25 years from the sales of over 100,000 kits and 20 different designs.
Talking Electronics was the first company in the world to produce a kit and attach a free PC board to the cover of the magazine.
This brought over 30,000 hobbyists into the market of building their own transmitter and experiencing the clarity of FM and the enormous range possible with only a few milliwatts of power.

These kits are very easy to build and result in an enormous achievement with just a few components.
The fun of talking and listening is like having your own radio station and you can transmit music from one location to another or use it to talk over a long distance to lots of listeners.
You can use it as a "Radio Mic" at a gathering or a stage performance.
The clarity is so perfect, you will think the person is actually in the room.



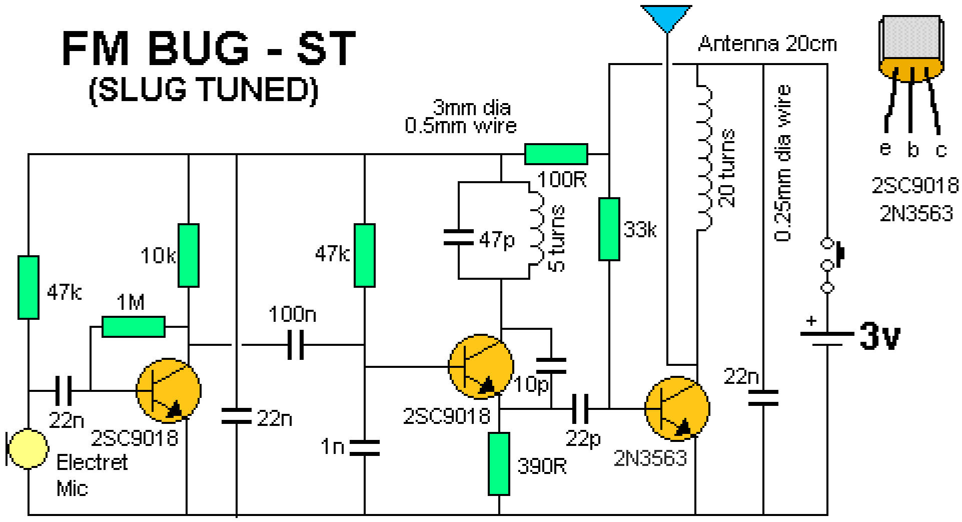


All the parts fit very neatly on the board and the only thing you have to align is the 5 turn oscillator coil. The leads need to be bet so they fit down the holes and the coil sits directly above the screw.
Make sure you tin the leads so the enamel is removed, BEFORE fitting the coil down the holes.
The 20 turn coil is also pre-wound with 0.25mm wire and it is easier to tin and fit to the board.
All the parts are in the same position as on the circuit diagram and this makes it easy to compare the two when trouble-shooting. The prototype-worked as soon as it was built and this is a testament to the designs created by Talking Electronics. Over 50,000 FM Bugs have been sold and TE has 20 different types. This is the cheapest and best and is better than any other $8.00 bug on the market.
The screw tuning is primitive but has been used since the earliest days of radio.
The input is amplified with a stage and the output is buffered with a stage.
The three stages create a very sensitive transmitter that can be handled and it will pick up the sound of a pin dropping on the floor.

This photo shows the coil mounted above the board with the ends down the holes and the coil sitting above the screw. The screw is screwed from the underside of the board and its end enters the coil to reduce the frequency of transmission. The screw is called a SLUG as anything that enters a coil to change the frequency is called a SLUG.

HOW THE CIRCUIT WORKS

The circuit is very simple but you have to use the right-value components and put them in the correct part of the circuit to get the best results.
Many of the circuits on the web contain faults are not very reliable.
The first stage consists of a single component - the electret mic. This is actually a FET (Field Effect Transistor) and it has to have a very small current for it to operate correctly. This current is delivered by the 47k resistor.
The output is only a few millivolts but the signal is very clean and the microphone will pick up a pin dropping on the floor.



The output is connected to the next stage via a 22n capacitor.
This value is easy to obtain as a ceramic capacitor and passes about 20% of the amplitude of the signal. This is sufficient for the first transistor in the circuit.
It amplifies the signal about 70 times to get an output of between 70mV and 700mV.
The 22n across the power rails near the microphone prevents internal feedback in the circuit called "Motor-boating" or squeal and the 100R combines with the capacitor to isolates the first transistors from the third transistor.
The second transistor is the oscillator. It gets its feedback from the 10p capacitor between the collector and emitter.
The transistor turns on via the 47k base resistor and puts a little bit of energy into the coil and capacitor combination on the collector.
This is called a **PARALLEL TUNED CIRCUIT** and the capacitor gets charged first. The coil initially refuses to allow current to flow through it but as the capacitor charges, the coil allows current to flow.
During this time the voltage on the collector falls and this fall passes through the 10p to lower the voltage on the emitter and keep the transistor turned ON.
The 10p charges during this time and the transistor turns off slightly. This reduces the current in the coil and the magnetic field starts to collapse and produce a voltage from the coil that is in the opposite direction.
This puts a higher voltage on the collector and this voltage is passed to the emitter to turn the transistor OFF slightly more.
This continues until the transistor is completely turned off and it is similar to the transistor being removed from the circuit.
The coil continues to produce a voltage and charges the capacitor.
This voltage can be as high as 3v or more, depending on the amount of energy it contains and the amount of energy required to charge the capacitor to 3v.
The end result is a voltage that can be greater than 6v, however we are not using this voltage but tapping off the emitter, where a much smaller voltage is produced.
The emitter waveform passes through the 22p to the output stage.
This a class "A" amplifier and the signal is amplified about 50 times. It could be grater than this due to the effect of the RFC on the collector.
This is called a **RADIO FREQUENCY CHOKE** and it has the effect of storing energy during parts of the cycle and delivering the energy during the remainder of the cycle.

The end result is a larger output waveform.
If you connect the antenna to the collector of the oscillator transistor, it will remove some of the energy and change the frequency at which the circuit works. This is called "drift" and is very annoying as the reception will be lost.
To prevent drift, we have added the 3rd transistor.
It is called a "Buffer Stage" and is designed to separate the antenna from the oscillator.
Finally, the 22n across the power rails is deigned to tighten the rails.
This means the top rail does not move up and down when the transistor is sending audio.
It helps to maintain the frequency at which the circuit works as the oscillator is also called a voltage-controlled oscillator and a change in voltage will produce a slightly different output frequency.

TUNING

Tuning is the capability of changing the frequency of the oscillator so the bug transmits on a clear part of the band.
The FM band is completely filled with radio stations from 88MHz to 108MHz and there is almost nothing available.
The only frequency available in most large cities is 87MHz and some radios will receive as low as 86.5MHz.
The best type of FM radio for picking up our bug is a manually tuned radio.
This allows you to get right on top of the frequency of the bug and achieve the greatest range.
Many of the digitally tuned radios jump in steps of 50kHz or 100kHz and since radio stations have been allocated to these frequencies, you will be competing with a radio station.
The 5-turn coil and the 47p produces a frequency at the lower end of the band and screwing the slug (screw) into the coil will lower the frequency to below 88MHz.
You have to start with the frequency above 88MHz and then carefully reduce it without losing it below 86MHz.
The range of the transmitter is hundreds of metres with the 170cm antenna supplied in the kit and tuning with a manually-tuned radio is simple.
Use the "tuning LED" on the radio to indicate maximum reception. Move the bug further away and retune the radio.

Screwing the slug into the coil reduces the frequency of transmission.

RANGE

How far will this project transmit?
This circuit was placed at the top of a mountain and transmitted 27km to the hobbyists car-radio when he got home.
This was a line-of-sight transmission and was an ideal "set-up."
We have achieved from 200 metres to 400 metres from a house to a hand-held radio while walking down the street when there are no houses blocking the transmission.
Some of the worst conditions are through concrete walls as they contain mesh reinforcing that almost totally prevents the signal passing through.

FM Bug-ST

Parts List

Cost:$8.00 including postage

1 - 100R all 0.25watt
1 - 390R
1 - 10k
1 - 33k
2 - 47k
1 - 1M

1 - 10p ceramic capacitor
1 - 22p ceramic capacitor
1 - 47p ceramic capacitor
1 - 1n ceramic capacitor
3 - 22n ceramic capacitor
1 - 100n monoblock capacitor

2 - 2SC9018 transistors
1 - PN3563 transistor
1 - electret microphone
1 - mini slide switch
1 - 3v lithium coin cell
1 - coin cell holder
1 - 5 turn coil 0.5mm dia wire
1 - 20 turn coil 0.25mm dia wire
1 - bolt
1 - 170cm hook-up wire for antenna
1 - 20cm fine solder

1 - FM BUG - ST PCB

Why do we have so many different FM Transmitter circuits?

Each project has something different to offer.
Some use surface-mount components, some use slug tuning or air trimmer tuning while others allow you to expand the coil to increase the frequency.
By building different circuits you get an understanding of COMPARISON and how different features affect the stability of the circuit and the range.
After all, everything started off with simple, primitive designs.
The first walkie talkies were 27MHz and needed a long antenna to get just a few kilometers.
Now we have mobile phones, WITHOUT an external antenna, with a range of 10km!
Some of our bugs have reached 27km from the top of a mountain to the hobbyists house. The capability of FM transmission is amazing.
Projects start at $8.00 and they provide the best fun and the most learning you will get from such a small number of components.
All of our best projects have been included in this publication and it's just a matter of sitting down and reading the text to learn about this area of electronics.
All the projects have different names, so you can remember them. The boards are not marked: EA-1960-34AeD-2, like our stupid electronics magazine from 50 years ago !!
Over 300,000 kits have been sold so there is a lot of interest in this area and lots of happy hobbyists have been amazed at the performance. . . . . make sure you are one of them.

THE FLY

A very stable BUG.
Can be carried and moved while in use.

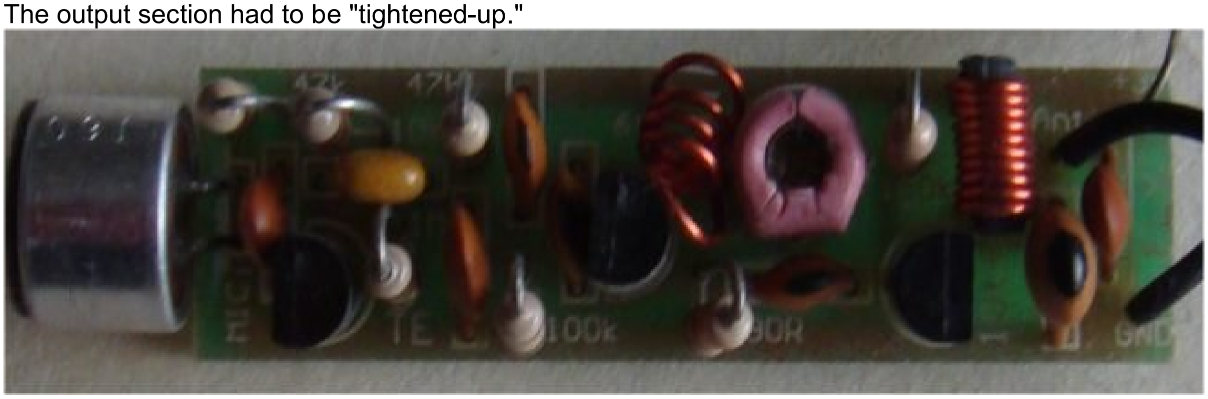
Kit of parts: $10.80 USD
Postage $4.50 USD
pay by PayPal

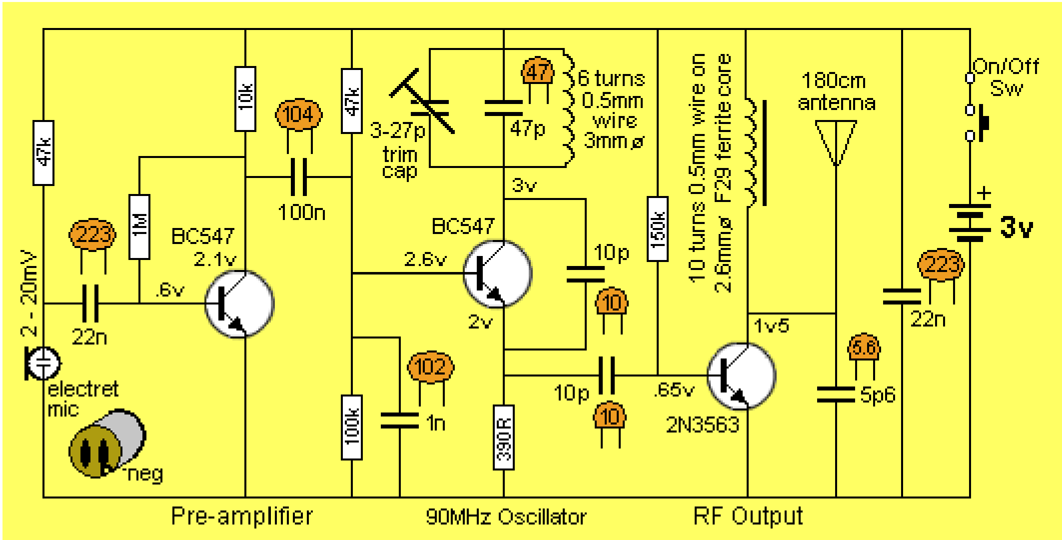
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit

The [LED Power Meter]() can be used to detect the output.
$1.25 extra

Range: 100 to 200 metres.
Frequency: 85MHz to 110MHz - refer to article to set frequency.

At first, the thought of producing a bug that would transmit 400 metres sounded far-fetched. If you consider a circle of radius 400 metres, the area enclosed is quite considerable.
To send a signal over this range is quite an achievement and when we first started designing mini transmitters we had no idea of what we would achieve. Some of the first devices went 50 metres, then 100, and then 200 metres.
We got stuck at 200 metres because, to double the range, the power must be increased four-fold. We were already at the limit of BC 547 transistors and did not want to go into high power designs. So we let it rest for a while.
Some time later the thought arose that the output stage could include a tuned circuit to improve the performance and after some experimenting it was found it did in fact improve the output enormously.
After a few field-tests the range had passed the 300 metre mark and was approaching 400 metres. Thus the AMOEBA was born.
It is an upgraded version of the ANT and although it appears only a few components were added, it represented hundreds of hours of experimenting - working out what was needed and eliminating things that didn't work.
But the Amoeba could not be handled or moved. The circuit was "too active" and allowed the capacitance of the users hand to change the frequency of operation.
So, back to the workbench.
The output section had to be "tightened-up."

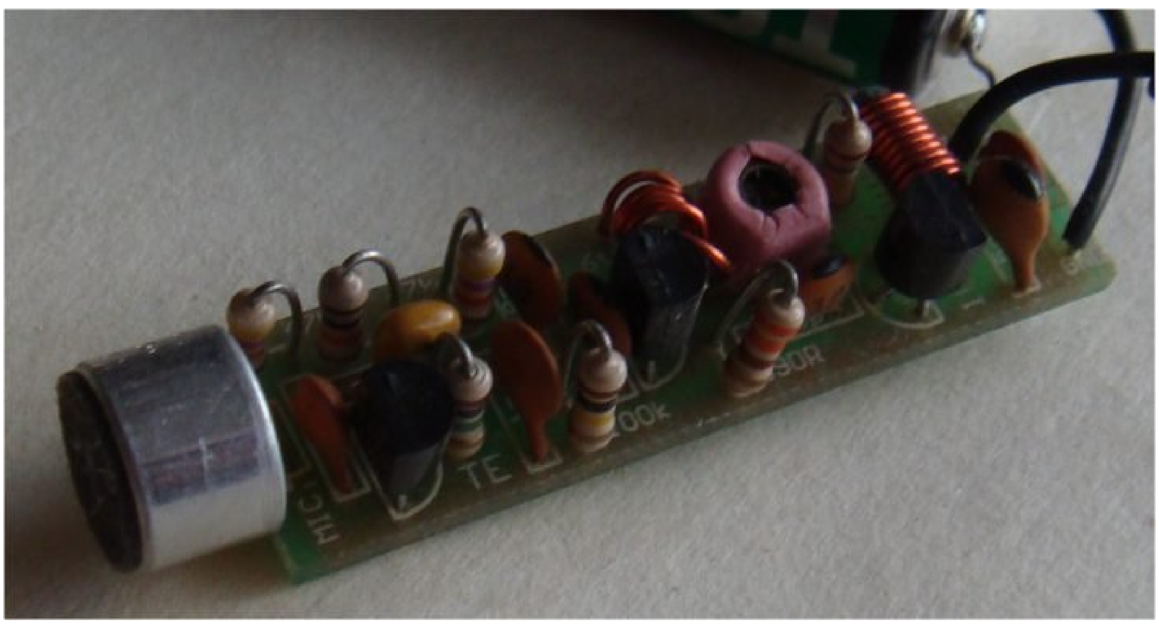




The Fly Circuit Diagram

THE OUTPUT STAGE

To tighten up the output stage we used a linear amplifier and placed an **RFC** (**radio frequency choke** - Radio Frequency Coil) in the output.
The effectiveness of this can be seen by the range we gained over the ANT. Without any increase in current or supply voltage, we have increased the range four-fold.
For the output stage to be effective, it needs a genuine RF transistor and that's why we used a 2N 3563. It's about the only suitable, low-cost, type on the market.



BUYING A KIT

I cannot stress too strongly, the need to purchase a kit. It is almost impossible for you to make your own PC board with tinned track-work and a fully detailed overlay for less than the price we are selling them for. This is because we get them made 1,000 at a time on an automatic 3-head drilling machine and you could never compete with mass-production.
On one of the early CAD boards we placed the RFC around the wrong way and the output was reduced enormously. The simple mistake of having the tank coil and RFC positioned so that the magnetic field of each interacted to oppose each other took quite a while to diagnose.
Also the size and spacing of the coils is critical as the wire gauge as well as coil diameter and the number of the turns.

This has all taken many hundreds of experiments to get the optimum size and shape and it all looks so obvious when it's finished.
If you want your project to work as good as the one we have described, the characteristics of everything must be identical to ours.
If you like experimenting, you should build a kit first, then you can experiment with another set of parts and make all the changes you like.
But let me stress, I think we have achieved the optimum performance and I don't think you will do any better. But don't let that deter you. Winning the lottery is near impossible and yet millions try their luck every week.
But that's getting off the track. First thing's first.
The Amoeba is only slightly more complex than the ANT in construction, but considerably more complex in peaking. The Ant needs no peaking at all but simply an adjustment of the oscillator coil to get the desired frequency. The Amoeba requires additional skill in peaking the tank circuit to get maximum output.
This is done with the aid of a peaking meter (or peaking circuit) we call the LED Power Meter.

PARTS LIST

1 - 390R (orange-white-brown)
1 - 10k (brown-black-orange)
2 - 47k (yellow-purple-orange)
1 - 100k (brown-black-yellow)
1 - 150k (brown-green-yellow)
1 - 1M (brown-black-green)
1 - 2-10p air trimmer
1 - 5p6 ceramic
2 - 10p ceramics
1 - 47p ceramic
1 - 1n ceramic (102)
2 - 22n ceramics (223)
1 - 100n monoblock (monolithic) (104)
2 - BC 547 or 2N 2222 or similar transistors
1 - 2N 3563 transistor
1 - 6 turn 0.5mm enamelled wire (3mm dia) coil
1 - 10cm enamelled wire
1 - Ferrite core F29 material
1 - electret microphone
1 - mini slide switch
2 - AAA cells
1 - 170cm antenna wire
1 - FLY PC BOARD

CONSTRUCTION

If you follow the circuit diagram for the FLY you will see that the audio amplifying stage including the microphone starts on the left. The circuit follows through to the RF oscillator and the output stage and then the power supply.
When we design our CAD PC boards we try to keep the layout as close to how the layout of the circuit diagram is presented. This will help you follow the circuit and understand its operation in a linear fashion especially when it comes to trouble-shooting, (this is when the circuit doesn't work as expected). It is only when you have built and tested the project and had first-hand experience that you will be able to see and understand what each part is doing.
To work on the PC board, rotate it and have the microphone end of the board to your left. Leaving the microphone until last, because it is one of the tallest components. Start with the 47k resistor, place it through the marked holes and bend the leads outwards under the board to hold it in place. Next, fit the 22n capacitor and the BC 547 transistor bending the leads to hold them in place.
When you have fitted 2 or 3 parts, turn the board over and neatly solder the leads to the lands. Snip them as close to the top of the solder joint with a pair of side-cutters. Never cut the leads before soldering.
One constructor cut the leads before soldering and one lead was cut too short. It did not make contact when soldered and it took a long time to find.
Next you can fit the BC 547 transistor, the 100n mono block and the 1M resistor.

Following what you have just done, work from left to right of the board fitting a part as you come to it by following the overlay.
Alternatively you can always fit one component at a time and solder it to the board.
The enameled air coil is pre-wound for your convenience. To tin the leads for the soldering process you can scrape the enamel off the leads with a blade close to the coil so that when the coil is placed on the PC board it is positioned one or two millimeters off the board. When you have scraped the enamel off, lightly tin the leads with some solder and solder it to the pads.
The ferrite-cored coil needs to be wound by you. A length of wire and a small ferrite core is included in the kit.
Taking the wire and coil. Place the middle of the wire on the centre of the core and wind 5 turns to the end of the core and then the other 5 turns. This method allows you to hold the core in your fingers. Make sure the coil is wound is the correct direction so the ends fit down the holes in the PC board.
Tin the leads of the coil, place it down the marked holes and solder it close to the board.
The last part to be fitted is the microphone. It is polarised so there is only one correct way to fit it. One of the leads has a fine track to the case. This is the negative lead and should match the hole on the board marked with a "—" sign.
The batteries included in the kit have to be soldered together. The switch is prepared by feeding an off-cut of tinned copper wire lead through one end-terminal and the centre terminal. Bend to hold it in place, and solder it to the terminals.
With a piece of blu-tack stuck to your workbench stand the two batteries side by side with opposite ends at the same height. Tin the ends with solder. Take the switch and solder the two connected switch tabs to one terminal of a battery and the other tab to the other terminal. Now get another wire off-cut and feed it though the negative hole on the board and solder it in place. Line up the negative terminal and solder the wire. Use a short length of hook-up flex from the antenna to solder the positive terminal to the board.
Solder the antenna wire and the project is complete.

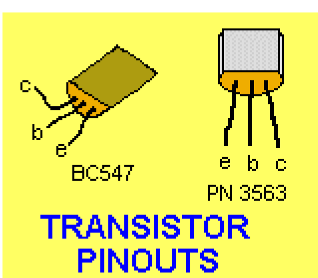
TESTING

You may think our method of testing a transmitter is back-to-front because we start at the output and work towards the front end. But when you look at it more closely, you will see why. Once you have the output stage working, you have a starting point and from there the procedure is fairly straight-forward.
The output of the transmitter consists of two parts. The 'carrier' is a constant frequency. If we are transmitting at 100MHz, it is a 100MHz carrier. Added to this is the audio component and this causes the carrier to increase and decrease by an amount equal to the audio picked up by the microphone.
This audio MODULATES the carrier and this gives the term FM transmission. We use this knowledge to fault-find the project. Our first concern is to be able to detect the carrier. This is picked up on an FM radio as a 'dead spot' or 'clear spot' on the dial when the transmitter is on. When the transmitter is turned off, the background noise appears.
The carrier is produced by the oscillator stage (the BC 547) and the linear amplifier (the 2N 3563) will transfer this frequency to the antenna with increased driving power. When we detect a carrier, we prove that both stages are working. if a dead spot is not heard, you should firstly assume the frequency of transmission is off the FM band.
To adjust the transmitter, all you need do is stretch the turns of the oscillator coil (making sure they do not touch each other if bare tinned copper wire is used). Tune across the entire band on the FM radio, looking for a silent spot.
The bandwidth of the transmitter will be quite narrow and it will be necessary to sweep the band fairly slowly. If nothing is heard, go over some of the simple faults such as making sure the project is ON, the radio is on the correct band (88MHz to 108MHz), the radio has an antenna connected and no metal objects are near the transmitter.
You must detect a carrier before progressing any further. This is the starting point and no other sections can be tested until this is successful. Unless you have a 100MHz CRO, there is no other way to see if the project is transmitting.
This is not exactly true as another solution is to make a second FLY. If the second project works successfully, (and I see no reason why it shouldn't), you can use it to physically check the spacing of the coil, placement of the parts and the position on the FM band, to see why things are not coming through on the first model. When a clear spot is heard, you are half-way home. In fact you are 90% home. The next step is the testing of the audio stage or stages. Although the project contains one audio stage, we can consider the microphone to be a stage since it is an active device containing a FET transistor.
If either the microphone or pre-amplifier stage does not work, you will only get a carrier output.

Make sure the voltage on the microphone is at least 50mV and the collector of the preamplifier is at least .8v. If it is less, the transistor may be saturated and if it is 3v, the transistor will not be conducting. Check the base voltage also. It should be 0.65v. If this fails to locate the fault, you can use almost any CRO to pick up the waveform at a number of locations on the board, around the audio section.
You can also use our Mini Bench Amplifier and it is very handy for testing audio projects.
If you have access to a CRo, by whistling into the microphone and picking up the waveform at the output of the mic (at the point where the load resistor connects to the mic), you will be able to see the output of the microphone. Next, pickup the waveform at the other end of the coupling capacitor and note that some of the amplitude has been lost. This point is also the base of the audio transistor and you can determine the gain of the transistor by comparing the output with the input. The gain should be between 50 and 100.
The output is injected into the base of the oscillator stage via a DC blocking capacitor and this is where the CRO capability finishes. You will need a 100MHz CRO from now on. You should adjust the oscillator coil to a frequency away from a radio station and this is generally at the very bottom of the band. Once the circuit is working successfully, the final part is to peak it by adjusting the coil on the tank circuit.
This will give the range you will be expecting. This is done by connecting the LED Power Meter to the antenna land on the board (without the antenna wire connected). But first we have to build the LED Power Meter.

USING THE LED POWER METER

Connect the 5cm wander lead to the collector of the oscillator transistor on the FLY and turn the project on.
The lead of the LED Power Meter will act as an antenna, so place a radio nearby and tune it to about 88.5MHz or somewhere at the low end of the band. Move the turns of the 6 turn oscillator coil either together or stretch them apart until a feedback whistle is picked up by the radio. This is the frequency of transmission.
When the turns are pushed together the frequency decreases and when moved apart, the frequency increases. Now place the wander lead from the LED Power Meter on the antenna point on the board.
You will not be able "peak" the signal as the output stage does not have any adjustment.
The project is now ready to fit into a Tic Tac box. The ON/OFF switch can be operated by opening the lid and switching the bug on. It does not matter if the lid is open or closed, the microphone will pick up the faintest sounds in a room and transmit them to an FM radio up to 400 metres away. Of course, this will depend on the positioning of the antenna and the quality of the radio. The antenna should be stretched and placed over a high shelf etc so the signal has an opportunity to radiate effectively.
Do a bit of experimenting and you will be very impressed with the performance.



Reading these articles is certainly a starting point, but to really understand how a circuit works, you have to BUILD it.
This eBook contains more variety and information on FM transmission than anywhere else.
The best way to start is with a kit as some of the items in each kit are only available from Talking Electronics.

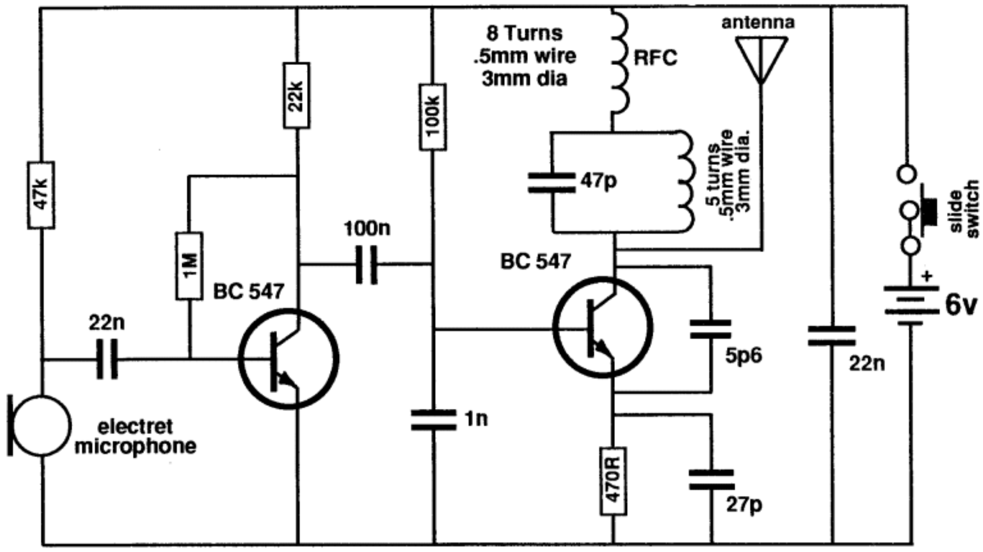
CUBE OF SUGAR BUG

Kit of all parts $14.05 USD

Postage $4.50 USD

email Colin Mitchell to pay by PayPal: talking@tpg.com.au

A Bug about the size of a large cube of sugar



CUBE OF SUGAR CIRCUIT

I have been asked so many times that I thought I should present it . . . I'm talking about the CUBE OF SUGAR BUG.

These bugs were offered to us during our early days of designing FM bugs, for the incredible price of about $200 and we described them in an article some time ago. They came with a sheet of instructions that grossly exaggerated their capability and range.

It was when we were given one for repair that we found out how useless they were. The main problem was they use only a single watch-cell for the supply.

At a voltage of 1.2-1.5v, you cannot expect to get any output at all from the RF stage and this was proven by the fact that the one we tested had a range of about 30 metres instead of an expected 100 metres or so. On top of this the microphone was not very sensitive and the battery lasted only about 20 hours. In all it was a very poor design.

We have changed all that with our CUBE OF SUGAR BUG. Its big advantage is it uses 2 lithium cells to give a 6v supply and this gives it a range of about 500metres. The height of the two cells is only about 1/2cm and with a diameter of about 2cm they take up very little room for the energy they contain. To start with, each cell has a voltage of 3v and this means we only need two cells to produce 6v. The only problem with lithium cells is connecting leads to the positive and negative terminals. This has been the problem with all our bugs as battery holders are usually more expensive than the cells themselves! To keep costs down we have opted for taping the cells together with electrician's tape and placing fine wire between the tape and the cell to make contact. If you are good at soldering you can solder fine leads to the terminals, but you must be very quick as any excess heat will damage the seal around the edge of the cell and they will leak. By using a 6v supply we can get a very good RF output while keeping the project to about the size of half a matchbox.

When completed, it looks like a very large cube of sugar and that's how it got its name.

The circuit is very similar to our VOYAGER project and uses standard components on a small PC board.

If you want to know where it fits in to our line-up, it comes between the Amoeba and Voyager both in complexity and range.

The PC is so compact that we have just been able to put a component overlay on it and you will have to refer to the large layout diagram for assistance when assembling to make sure everything goes in the correct place.

As far as construction is concerned, you should build some of our simpler designs before tackling this one as the soldering needs a fair degree of skill to prevent shorts etc or overheating the components.

If you think you can put it together with a dirty iron and thick solder, you are wasting your time. The first thing you will do is create a short in the trackwork and blame us when the bug fails to work.

PARTS LIST

1 - 470R All 1/4 watt resistors
1 - 22k
1 - 47k
1 - 100k
1 - 1M
1 - 5p6 ceramic
1 - 27p ceramic
1 - 47p ceramic
1 - 1n ceramic
2 - 22n ceramics
1 - 100n monoblock (monolithic)
2 - BC 547 transistors
1 - 5 turn enamelled coil .5mm wire
1 - 8 turn enamelled coil .5mm wire
1 - electret mic insert (small size)
2 - 3v lithium cells
1 - SPDT mini slide switch
1 - 3cm of 2cm heatshrink tubing
1 - 5cm red hook-up wire
1 - 5cm black wire (cut from antenna)
1 - 170cm antenna wire
1 - 30cm fine solder
1 - CUBE OF SUGAR PC BOARD

HOW THE CIRCUIT WORKS

The circuit consists of two transistors and an electret microphone.

The microphone is actually an amplifying stage as it contains a Field Effect Transistor (FET) connected to a thin mylar diaphragm and it amplifies the sounds about 100 times before sending the signal to the first transistor stage - this is why electret microphones have a high output. If you include this, the circuit has 3 active stages.

The waveform at the output of the microphone passes through a 22n coupling capacitor to a common-emitter audio stage. Here it is amplified a further 70 - 100 times and is now large enough to be injected into the RF stage.

The operation of the RF stage has already been described in our other articles and it is sufficient to say that it operates at about 88MHz and is shifted in frequency by the audio injected into it.

It is this frequency shift or Frequency Modulation that produces the transmission called FM.

FM is by far the best way to transmit a signal as it is immune to most forms of interference such as car ignition, storms and other noise producers. All these affect the amplitude of the signal and that's why AM (amplitude modulated) signals are so noisy at the best of times and especially during a storm.

But FM is immune to changes in the amplitude of the signal and that's why it is so clean and clear. With an output as little as 10 milliwatts you can transmit up to a few hundred metres with a perfectly clean signal whereas it requires 200 milliwatts or more of AM to get 100 metres and the signal is very noisy.

RANGE

With any type of transmitter, it is important to generate as much RF as possible to get the best range. It would be nice to generate 200 - 300 milliwatts of RF and reach 10km but this is not the purpose of these projects.

All our bugs are designed to teach you electronics and since they are all powered by batteries we have to keep the output down if we want to use small cells and have them last as long as possible. That's why we have kept the output to 10 milliwatts or so as you can get a surprising distance when you have an efficient circuit and a good radiator (antenna).

To achieve the maximum range with the Sugar Bug, we have improved the Voyager circuit by adding an RFC (Radio Frequency Choke). This is an 8 turn coil between the tank circuit and positive rail.

The RFC couples the output directly to the power rails as far as the current is concerned but allows the tank circuit to produce a higher than normal waveform. It has the effect of separating the tank circuit from the positive rail for the signal.

The other component that has been added to this design is the 27p capacitor across the 470R emitter resistor. This allows the transistor to turn on harder without affecting the DC conditions.

The current taken by our prototype was measured at about 4mA. This makes the consumption about 24 milliwatts. We have not been able to measure the effective radiated power (ERP) from the antenna however by comparison with the Amoeba, we found the output to be about double. The consumption for the Amoeba is 7mA, making the power consumed 21 milliwatts and the reason why we get a higher output from the Sugar Bug is due to the higher supply voltage and the circuit improvements.

The secret to producing a high output is to have a high supply voltage and to keep the circuit very tight. This means keeping the components close to the board and making the PC tracks as short as possible.

This is very important when it comes to the wiring between the capacitor and coil in the tank circuit as the current that passes between these two is very high and losses will occur if the tracks are not kept short.

THE GROUND PLANE

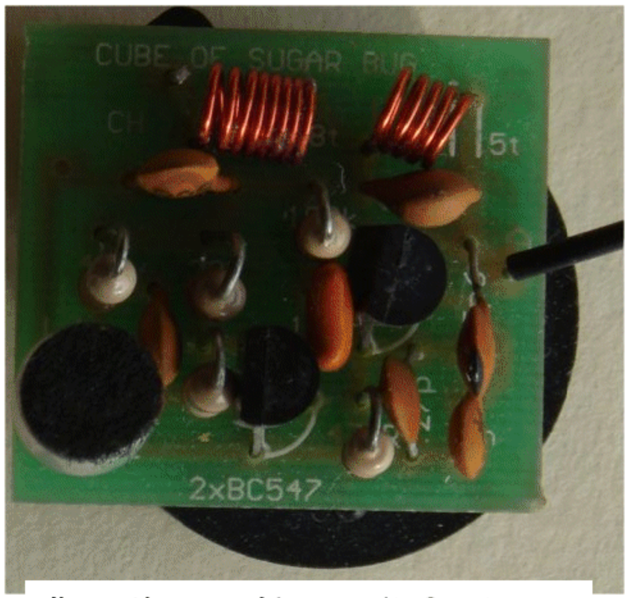
In most of our designs we have relied on the size of the batteries to provide a good ground plane.

A good ground plane is needed by a circuit so that it can push the signal in and out of the antenna. A simple analogy is a trampoline.

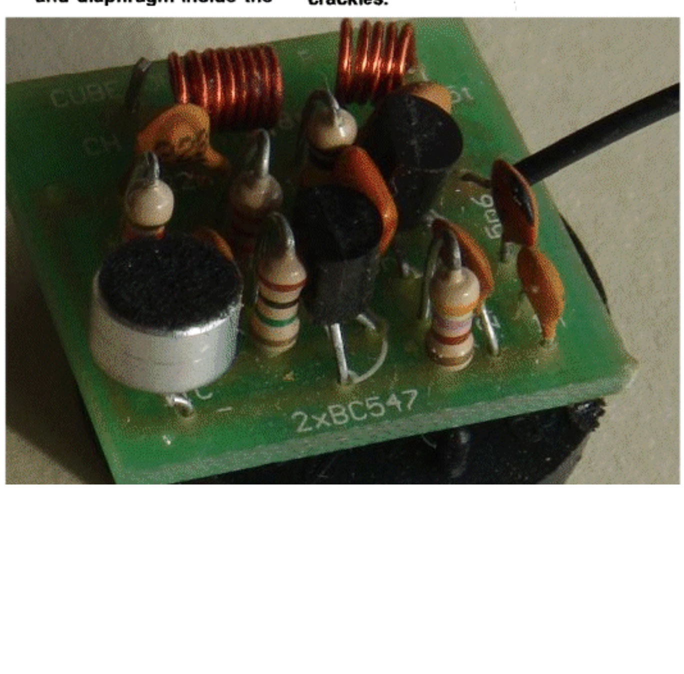
If you sit the legs of a trampoline in soft rubber, the whole frame will move down every time you bounce and it would be difficult to get very high.

The same applies with small batteries. They form a very small ground-plane for the oscillator and the circuit finds it very difficult to push the signal in and out of the antenna. When the cells are larger they provide a much better ground plane and the output of the circuit is much higher - even without any other changes.

The 22n across the power rails also assists the oscillator by keeping the rails from spreading apart or coming together when the oscillator is operating. If the rails are not rigid, the oscillator does not have a firm reference from which to operate.



You must be very careful when soldering the wires to the electret mic to prevent it getting too hot. This will damage the FET and diaphragm inside the case and reduce the sensitivity. Even the slightest amount of overheating will make it become noisy and produce background crackles.



THE MICROPHONE

The "sensitivity" of a bug depends heavily on the quality of the microphone.

We have been supplied with many different types of microphones, ranging from highly sensitive devices to very noisy units, and absolute rubbish.

Even though an electret mic consists of only two components, (a mylar diaphragm and a FET transistor), there is enormous technical know-how required to produce a good quality device. Very few applications require the degree of sensitivity that we need for our bugs and if you buy a microphone "off the shelf" or in a junk pack, you may be disappointed. Some mics are very noisy and as you drive them harder (to pick up faint sounds) the background noise increases and all you hear is a noise like "eggs frying."

Other microphones are as deaf as a post and require a load resistor as low as 4k7 for a 3v supply instead of 47k. All this does is increase the current consumption of the circuit.

We buy microphones in huge quantities and always test a sample before putting them in the kits. If you want to try microphones from other sources, you must use one of our good devices as a reference, so that you can compare one against the other.

THE TRANSISTORS

If you wish to try other transistors in the RF stage, that's fine too. But first build the circuit and measure its output and range before changing the transistor. Some transistors should work better in theory but fail to come up to expectations because of the low supply voltage we are using. They need a higher voltage to get the performance you see in the specification sheets. Others need a higher base current and again, the current consumption goes up in line with the output, so you don't gain anything. If you find anything better than a BC 547, let us know. We have had lots of reports about better transistors but nothing has been proven.

One reader asked why we don't use a 2N 3563 in the oscillator/output, as it is an RF transistor. The reason is outlined above. It does not perform any better than a BC 547 at low voltage/low current so we have opted for the cheaper item.

CERAMIC CAPACITORS

One small point that we haven't mentioned before is the quality of the ceramic capacitors we use in our circuits. There is a wide-held belief that ceramic capacitors are 'junk' and not suitable for high frequency work. This may have been the case many years ago but they have come a long way since then and are now quite suitable for all our applications. The low values we use in the oscillator, such as 5p6, 10p and 47p have an additional characteristic called NPO and this means the value printed on the body does not change if the temperature increases or decreases (within limits). In other words they are very stable.

Again, if you buy capacitors "off the shelf" or in junk packs, you may not get NPO types and you will wonder why the circuit drifts on a hot day or produces crackles in the background, when exposed to hot conditions.

CONSTRUCTION

As we mentioned earlier, all the parts fit onto a small PC board and the location of each part is shown on the overlay. This will make assembly very easy however you should not rush the job. Check with the photos and diagrams before starting.

There are two ways of building the project. One is to add one component at a time and solder it in place.

This is always recommended for beginners as it reduces the possibility of making a mistake. But when you are fairly adept at construction and wish to make the project quickly, you can fit all the parts onto the board, turn it over and solder all the leads.

As you add each component, the leads are splayed slightly to prevent anything falling out.

When we make the bugs for the Security Devices section of our business, we make them 10 or 20 at a time and this is how we do it.

The board has been designed to accept very small components but if a larger components has been included in your kit, you will have to bend the leads slightly to fit the holes.

Be careful with the transistors. They must be fitted as shown on the overlay and pushed close to the board so that they don't stick up higher than any of the other parts. When the leads are being soldered, you must do it quickly so that the transistor does not heat up.

Also, the enamel on the two coils must be scraped off the ends of the wire so that they will accept solder. The coils are pushed onto the board so that they touch the board. The 5 turn coil is the oscillator coil and can be stretched slightly to fit onto the holes. The 8 turn coil is the RFC and is kept closely spaced in this project.

Once all the parts are soldered the leads are cut off and the board is ready for the switch and batteries.

The two lithium cells are placed together and wrapped with electrician's tape so that it stretches and keeps the cells in contact. Prepare red and black lengths of hook-up wire and poke them under the tape to make good contact. Fit heatshrink over the cells and shrink it tightly to make a battery-pack. Take the red (positive) lead to the switch and the negative to the board. Connect the other side of the switch to the board and the project is ready for testing.

TESTING & TUNING

Switch the bug ON and place it near a radio. Tune across the band and you should hear a whistle near the lower end of the band.

If no whistle is detected, remove the antenna and fit the LED Power Meter or Peaker. If the multimeter does not give a reading, go to the If It Doesn't Work section. If a reading is detected, the bug may be transmitting off the FM band. This is most likely to be lower than 88MHz and to bring it higher, separate the turns of the oscillator coil.

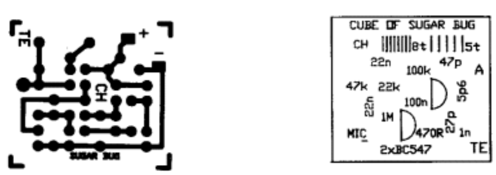
Pick a clear spot on the radio and to move the feedback whistle up the dial, separate the turns of the oscillator coil as we mentioned above. To move the feedback whistle down the band, push the turns together slightly.

Your bug is now ready for many hours of operation.

IF IT DOESN'T WORK

If you have not used one of our kits for this project, don't even begin to look here for assistance. Your fault may be some of the odd parts you are using and we will never be able to cover all these possibilities.

At a quick glance, the Sugar Bug looks very simple but a lot of thought has gone into the layout of the board. For the circuit to work as well as it does, the layout is very important. If you change the wiring to a 'birds-nest,' the frequency will change considerably and the output may fall, or the bug may drift when it is touched or when the temperature changes. Even changing the diameter of the coil will make an enormous difference to the frequency.



Cube of Sugar Bug artwork.

The proximity of the components to one another is also very important and most High Frequency circuits work better when the parts are close together.

When you build one of our kits, all the engineering and layout has been done for you and the project should work first go.

But things can go wrong and when they do, many constructors either trash the project or ring us in desperation. We get calls such as: "Help! My bug doesn't work!" or "It only goes 1 metre! or it whistles! - what's wrong!" As you can appreciate, we can't spend time on the phone diagnosing everyone's project. That's why we have the "If It Doesn't Work" sections. But when we ask the caller if they have done any preliminary testing they say "Oh no, I thought you could fix it for me over the phone!"

Of course we can fix anything but I think these callers have missed the point. All our projects are designed to teach YOU electronics. And when it doesn't work, it provides a perfect opportunity to study the circuit and locate the problem.

Before you start on the bug, replace the two lithium cells with 4 AA or AAA cells so that the circuit is easier to work on.

Then check to see if the bug is producing an output by placing it near a radio and listen for a feedback whistle while tuning across the entire band. If nothing is detected, the bug may be transmitting on a frequency outside the band. The output can be checked another way by removing the antenna lead and connecting the Peaker or Led Power Meter to the antenna point. If no RF is detected the fault will lie in the oscillator section.

Before you make any further tests it's a good idea to make sure the Peaker and multimeter are working by testing them on another bug such as the Amoeba. This way you will know that the test equipment is working and you can get some idea of the reading to expect.

RF is generated by the high frequency section of the bug and if nothing is produced, almost any of the components could be at fault. For instance the 22n across the power rails is essential and any of the components in the oscillator stage will certainly cause the oscillator to mal-function. Some of the faults will be easy to detect but if the 47p capacitor is open circuit or the transistor has been overheated, how are you going to find these minûte faults? The answer is, you can't. The only way to tackle the circuit is to replace the components, one at a time, until it comes to life.

But before you start replacing anything, the first thing to do is to check for obvious faults such as poor soldering or shorts and bridges. Make sure all the component values are correct and the enamel has been scraped off the coil before it was soldered to the board. Simple things like this account for 95% of the faults. The chances of a ceramic going open or a resistor failing is a million-to-one and the only type of low-value capacitor I have found to be open-circuit, in my years of servicing TV's, was a mica capacitor. I have never had any trouble with ceramic capacitors. Oh, yes I have. One capacitor was shorted in a project sent in for repair due to overheating and another had fallen apart due to a very hot iron softening the solder inside the capacitor. They can also crack due to rough handling and this will create a short where the raw edges are exposed to the outside.

In case you are not aware, the leads of these capacitors are soldered to two small discs of metallised ceramic and if you get the capacitor too hot, the leads will fall off.

Next check the current consumption of the project. If it is only about 1 or 2 milliamps, the oscillator stage will not be working at all and a good bet is the oscillator transistor. It could also be a fault in the base bias (such as the 100k not making contact) or a short between base and ground, causing the transistor to be cut-off (not conducting).

If the current is about 4-6mA, the transistor could be damaged due to overheating when soldering (this will damage the crystalline structure and cause the transistor to lose gain). It may be oscillating but at the wrong frequency or have a very small output.

The only other possibility is "a very loose circuit" where the components have not been pushed close to the board. If you don't do this, the extra lead length creates a high impedance path for the signal and reduces the waveform so that the output is only a fraction of that expected. The answer is to push everything close to the board and make sure none of the transistors have been overheated.

If you have any doubt at all, replace the components or build another kit. For the cost of another kit you can make sure you get it right next time and I am sure it will work first go. You can then come back and either replace all the components of the first project, or compare one project against the other and work out where the fault lies. No matter how you do it you are going to learn more than any text book can provide. The main thing is to never let a fault beat you. The satisfaction and reward of finding the fault yourself will give you the encouragement to tackle more difficult problems.

The oscillator section produces the CARRIER and this can be picked up on a radio as a "quiet spot." Once you can detect this you know the oscillator is working and is on or near the correct frequency.

The next step is to make sure the audio from the microphone is being amplified and passed to the oscillator section. The easiest way to test the audio section is to listen for a feedback whistle from the radio. If you don't hear anything, bring the bug closer and turn the volume up. This should produce a feedback whistle and if it doesn't, the audio stage may be at fault.

Check the voltage on the collector of the audio transistor. It should be at mid rail but can be slightly above or below this and still provide the necessary gain. The voltage on the electret mic can be as low as 70mV or as high as 1v and the microphone will (or may) be working correctly. Make sure the case of the microphone goes to the negative rail.

If all this fails to produce audio, reduce the bias resistor to the microphone to 10k and connect the output directly to the base of the oscillator stage via a 22n capacitor. This will bypass the audio stage and you can check the microphone directly.

If you have access to a CRO, you will be able to follow the path of the audio signal and locate the fault very easily. CRO's are ideal for doing this and the most likely cause of poor or absent audio will be a short across the microphone, a short between base and negative rail of the audio transistor or an open coupling capacitor.

The CRO will also detect if you have a faulty microphone such as one that has been damaged by overheating, high reverse voltage or maybe a fault in manufacture. Don't put anything into the hole at the front of the mic as this will damage the diaphragm and it will lose sensitivity.

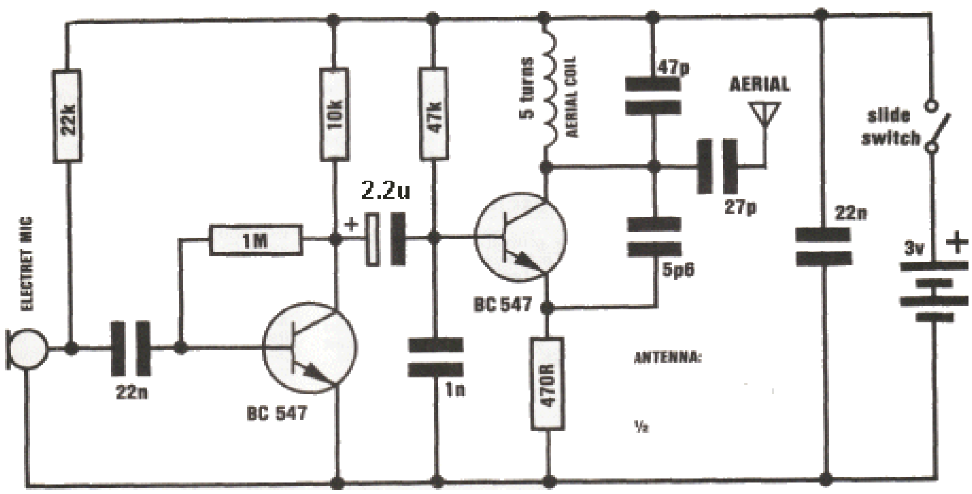
If you don't have a CRO, the front end can be checked by removing the microphone and taking it to another bug or using the microphone from another project as a comparison. The audio stage can be checked by connecting it to an audio amplifier but the best method is to connect the front end of two bugs in parallel and use a slide switch to change from one pre-amplifier to the other. You must remember to disable the RF stage of one bug so that the two do not conflict. This should cover just about all the possible faults and the project should be working by now.

Refit the two lithium cells and look around for a small plastic box to put the project in.

Very soon we hope to produce a small box especially for our range of bugs and if time and money permits, we will stick them to the cover of a forthcoming issue. Look out for it. Until then, keep up the good work.

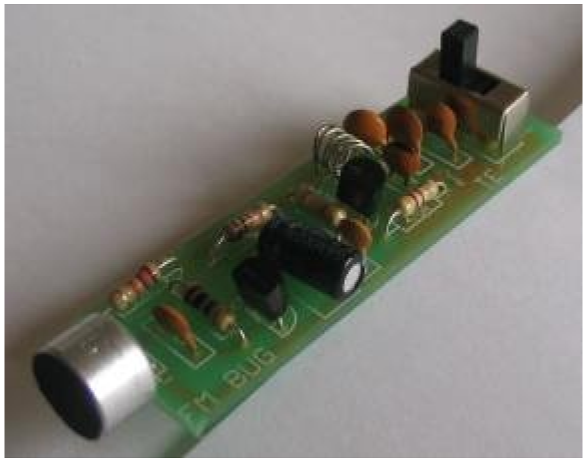
FM BUG

Kit of parts: $11.60 USD
Postage $4.50 USD
pay by PayPal
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit



FM BUG Circuit

Corporate espionage is reaching new heights in sophistication. The latest information to be released shows the depths firms will go to pry into a rival firm's operations.
By using the latest in electronic bugging, they have stolen information, secrets and even formulas known only to the inventors themselves.
Take the example of one firm:
Leaks from Top Management level remained a mystery until, one day, a bug was discovered inside the Managing Director's office.
Sitting prominently on his desk was a gift box of imported cigars!
Cleverly concealed in the lower part of the box was a miniature FM transmitter . . all a gift from a phony sales rep.
This is just one of the many bugging devices available on the eaves-dropping market. The range includes pen and pencil holders, trophies, framed pictures and office furniture with false bottom drawers.
These products are readily sold to fledgling companies, eager to nestle into big brother's market.



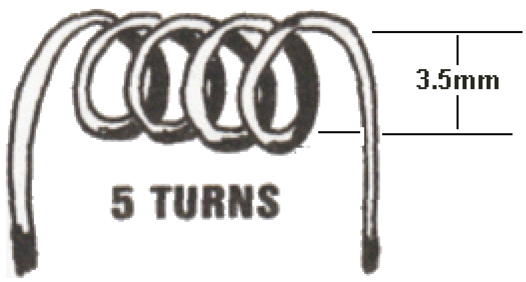
The Complete FM Bug

And for a while these bugging devices worked. Few firms knew of their existence, and even less on how to sniff them out.
But that has all changed now. If a corporation suspects a leak at any level, the first thing they order is an investigation into security. Not only personnel, but information and electronic security.
Debugging has grown into big business. Most large security organisations have a section concentrating on electronic surveillance including bugging and debugging.
They use scanners to detect hidden devices and can locate absolutely anything, anywhere, and on any frequency.
It was only after the firm above had commissioned a scan of the entire floor, that the cigar box was discovered. Its innocence had deceived everyone. And cost them a small fortune!
Bugging of this kind is completely illegal and we don't subscribe to this type of application at all.
But the uses for our SUPER-SNOOP FM WIRELESS MICROPHONE can be harmless, helpful and a lot of fun.
Our unit is both compact and very sensitive and can be used to pick up even the faintest of conversations or noises and transmit them 20 or so metres to any FM receiver.
When you build the FM BUG you will see why we consider the design to be very clever. We have used only low priced components and they are all easy to obtain.
No air trimmer capacitor is required as the coil is squeezed slightly to obtain the desired frequency. This has allowed us to fit the bug into a tooth-brush case so that it can be carried around or placed on a shelf.
If it is set between two books it will be hidden from view or as a supervision accessory it can be placed on a small child, etc. The transmitted signal will over-ride the background noise and the output will be clean. If the child wanders beyond the range of the transmitter, the background noise will come up and signal that the tot is out of range.
As an added bonus, you can listen to the chatterings and squabbles as the children amuse themselves in the back yard.
It is also great for picking up the first signs of a child awakening from his afternoon sleep or it can be used as an indicator from a bed-ridden patient.
The great advantage of the bug is the absence of wires. And since it draws only about 5-10 milliamps, the pair of AAA cells will last for many months.
The success of this FM BUG is the use of TWO transistors in the circuit. To create a good design, like this, each transistor should be required to perform only one task. In any type of transmitter, there is a minimum of two tasks.
One is to amplify the signal from the microphone and the other is to provide a high frequency oscillator.
The amplified microphone signal is injected into the oscillator to modify its frequency and thus produce a FREQUENCY MODULATED oscillator. If an aerial is connected to the output of the oscillator, some of the energy will be radiated into the atmosphere.
To increase the output of our design, an RF amplifier would be needed but this gets into legal technicalities with maximum transmitting power.
It may be of Interest to know that a record distance of 310 miles was achieved with a 350 micro-watt transmitter in the USA, some 15 years ago. This equates to an astounding ONE MILLION miles per watt!
In simple terms, an RF amplifier becomes a LINEAR amplifier.

We have opted for sensitivity and the first transistor is employed as a pre-amplifier. This will enable you to pick up very low-level sounds and transmit them about 20 to 50 metres.

MAKING THE OSCILLATOR COIL

The only critical component in the FM BUG is the oscillator coil. When I say critical, I am referring to its effect on the frequency. Its critical nature only means it must not be touched when the transmitter is in operation as this will detune the circuit completely.
It is the only component which needs to be adjusted or aligned and we will cover its winding and formation in detail.
The oscillator coil is made out of tinned copper wire and does not need any insulation. This is not normal practice but since the coil is small and rigid, the turns are unable to touch each other and short-out.
The coil is made by winding the tinned copper wire over a medium-size Philips screw-driver. The gauge of wire, the diameter of the coil and the spacing between turns is not extremely important and it will be adjusted in the alignment stage. However when the project is fully aligned, it must not be touched at all.
Don't be over-worried at this stage. Just follow the size and shape as shown in the diagram and everything will come out right in the end.



THE DETAILS:

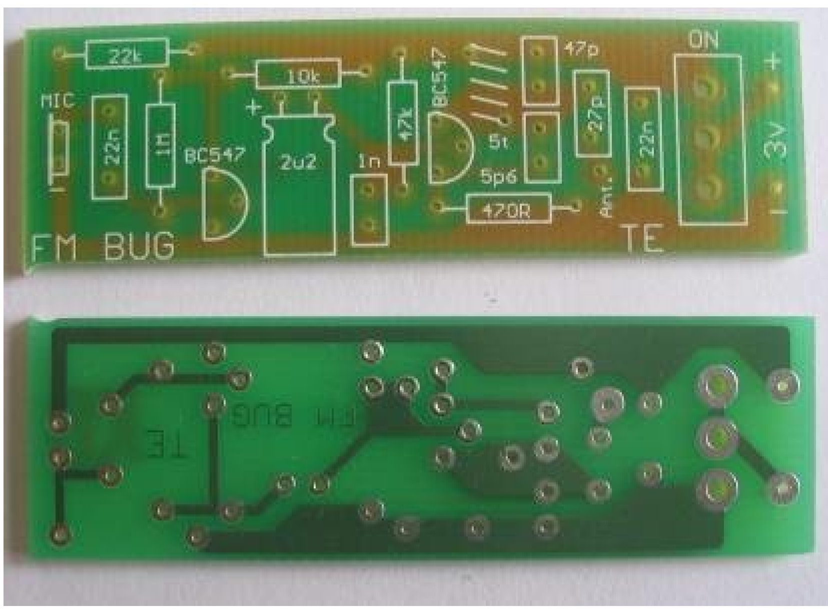
The coil has 5 turns and is wound on a 3.5mm shaft. To be more specific, it has 5 loops of wire at the top and each end terminates at the PC board. The coil must be wound in a clock-wise direction to fit onto the board and if you make a mistake, rewind the coil in the opposite direction.

CONSTRUCTION

Construction is quite straight-forward as everything is mounted on the printed circuit board. The only point to watch is the height of some of the components. The electrolytic must be folded over so that the board will fit into the case.
Positioning of the parts is not as critical as you think as the final frequency is adjusted by squeezing the coil together or stretching it apart.
However it is important to keep the component leads as short as possible and the soldering neat due to the high frequencies involved. The components must be soldered firmly to the board so that they do not move when the transmitter is being carried.
Even the poorest of soldering will work but who wants to see poor soldering on a project? The soldering may not affect the resulting frequency but poor layout of the components certainly will.
All the resistors must be pressed firmly against the PC board before soldering and the two transistors must be pushed so that they are as closes as possible to the board.
Some BC 547 transistors will not work in the circuit. Maybe the frequency is too high. SGS BC 547 transistors did not work at all. The other two types: f BC 547 and Philips BC 547 worked perfectly.
All the small-value capacitors are ceramic as they are not critical in value and do not need to be high stability. But you must be careful when identifying them. It would be a very simple mistake to buy a 56p instead of 5p6 because there is no difference in the size. 22n may be identified with 223 or 22n or .022. A capacitor marked 22k will be a 22p cap and will not be suitable. The 1n capacitor may be marked 1n or .001 or 102. These are all the same value. The value 101 or 103 is NOT 1n so be careful, the caps may be about the same size. The rule is: don't use a capacitor unless its markings are clear and you are sure of the value.

The complete FM BUG

The switch is mounted on the PC board with its three terminals fitted into the large holes. The final items to add to the board are the two AAA cells. These come with the kit and we have chosen them for slenderness so that they can be fitted side-by-side.
It is very difficult to solder to the zinc case but if you roughen the surface with a file and use a large, HOT, soldering iron, the job can be done very quickly. Use a piece of tinned copper wire to join the positive of one to the negative of the other. At the other end, solder longer lengths of wire so that they can be connected directly to the PC board. Make sure the positive terminal connects to the plus on the PC board.



Top and bottom of the FM BUG PC board

AAA cells are also obtainable at photographic shops. The only alternative is an 'N' cell which is nearly as thin as an AAA cell but only half the length.
The terminal marked A on the board is the antenna output. For a frequency of 90MHz, the antenna should be 165cm long. This is classified as a half-wave antenna and provides one of the most effective radiators. If you find the antenna gets in the way you can opt for a quarter-wave antenna and this will be 83cm long. If you only require to transmit 10 to 20 metres the antenna can be as short as 42cm or even as low as 5 or 10 cm.
The most suitable length will depend on the sensitivity of the FM radio used to pick up the signal and the obstructions between the transmitter and receiver. It will be a good experiment for you to 'cut' your own antenna and determine which is the most suitable for your application.

HOW THE CIRCUIT WORKS

The circuit consists of two separate stages. The first is an audio pre-amplifier and the second is a 90MHz oscillator.

The first stage is very simple to explain. It is a self-biasing common-emitter amplifier capable of amplifying minute signals picked up by the electret microphone. It delivers these to the oscillator stage. The amplification of the first stage is about 70 and it only operates at audio frequencies. The 22n capacitor isolates the microphone from the base voltage of the transistor and allows only AC signals to pass through. The transistor is automatically biased via the 1M resistor which is fed from the voltage appearing at the collector. This is a simple yet very effective circuit. The output from the transistor passes through a 2.2u electrolytic. This value is not critical as its sole purpose is to couple the two stages.

The 47k, 1n, 470R and 22n components are not critical either. So, what are the critical components in this circuit?

The critical components are the coil and 47p capacitor. These determine the frequency at which the bug will transmit. In addition, the effective capacitance of the transistor plays a deciding factor in the resulting frequency.

This stage is basically a free-running 90MHz oscillator in which the feedback path is the 5p6 capacitor.

When the circuit is turned on, a pulse of electricity passes through the collector-emitter circuit and this also includes the parallel tuned circuit made up of the oscillator coil and the 47p capacitor. This pulse of electricity is due to the transistor being turned on via the 47k resistor in the base circuit.

When ever energy is injected into a tuned circuit, the energy is firstly absorbed by the capacitor. The electricity will then flow out to the coil where it is converted to magnetic flux. The magnetic flux will cut the turns of wire in the coil and produce current and voltage which will be passed to the capacitor.

In theory, this current will flow back and forth indefinitely, however in practice, there are a number of losses which will cause the oscillations to die down fairly quickly.

If a feedback circuit is provided for the stage, the natural RESONANT frequency of the coil/capacitor combination will be maintained. The 5p6 provides this feedback path and keeps the transistor oscillating.

The 5p6 feeds a small sample of the voltage appearing at the collector, to the emitter and modifies the emitter voltage. The transistor sees its base-to-emitter voltage altering in harmony with the resonant frequency of the tuned circuit and turns the collector on and off at the same frequency.

Thus there is a degree of stability in the oscillator frequency.

The actual frequency of the stage is dependent upon the total capacitance of the circuit and this includes all the other components to a minor extent.

Once the basic frequency of 90MHz is set, the variations in frequency are produced by the changes in effective capacitance of the transistor. This occurs when its base voltage is increased and reduced. The electret microphone picks up the sound waves which are amplified by the first transistor and the resulting frequency is passed to the base of Q2 via the 2.2u electrolytic.

This alters the gain of the transistor and changes its internal capacitance. This junction capacitance modifies the oscillator with a frequency equal to the sound entering the microphone thus FREQUENCY MODULATING the circuit. A short length of antenna wire is connected to the collector of the oscillator via a coupling capacitor and some of the energy of the circuit will be radiated to the surroundings.

Any FM receiver will pick up this energy and decode the audio portion of the signal.

SETTING UP THE TRANSMITTER

When the FM BUG is complete, checked and ready for insertion into its case, there is one slight adjustment which must be made to align it to the correct frequency.

As we have said, the only critical component is the oscillator coil. It is the only item which is adjustable.

Since we are working with a very high frequency, the proximity of your hand or even a metal screw-driver will tend to de-tune the oscillator appreciably.

For this reason you must use a plastic aligning stick to make the adjustment. Any piece of plastic will do. A knitting needle, pen barrel or plastic stirring stick can be used.

Place the bug about a metre from the FM radio and switch both units on. Tune the radio to an unused portion of the band and use the alignment stick to push the turns of the coil together. Make sure none of the turns touch each other as this will short out the operation of the oscillator.

All of a sudden you will hear the background noise diminish and you may even get feed back. This amount of adjustment is sufficient. Place the BUG in its case and tape up the two halves.

The fine tuning between radio and transmitter is done on the radio. Peak the reception and move the BUG further away. Peak the fine tune again and move the BUG into another part of the house and see how far it will transmit.

IF THE BUG FAILS

If the bug fails to operate, you have a problem. Simple digital tests will not fix it nor will ordinary audio procedures. The frequency at which the BUG operates is too high.
You have to use a new method called comparison.
This involves the comparing of a unit which works, with the faulty unit.
This means it is ideal for a group of constructors to build a number of units and compare one against the other.
This will not be possible with individual constructors and they will have to adapt this fault-finding section.
The first fact you have to establish is the correct operation of the FM receiver.
If you have another BUG and it is capable of transmitting through the radio you know the radio is tuned to the correct frequency. Otherwise you will have to double-check the tuning of the dial and make sure the radio is switched to the correct setting.
The next stage is to determine if the BUG is functioning AT ALL. The only voltage measurements you can make are across the collector-emitter terminals of the first transistor (1 v to 1.5v) and across the collector-emitter terminals of the second transistor (1.3v to 1.5v)
These values won't tell you much, except that the battery voltage is reaching the component.
Tune the radio to about 90MHz and lay the radio antenna very close to the antenna of the BUG. Switch the BUG on and off via the slide switch. You should hear a click in the radio if the BUG is on a frequency NEAR 90MHz. Move the turns of the aerial coil together or apart with a plastic stick as you switch the unit ON and OFF.
If a click is heard but no feed-back, the oscillator will be operating but not the pre-amp stage. This could be due to the electret microphone being around the wrong way, the transistor around the wrong way, a missing component or an open 2.2u electro.
If the fault cannot be located, compare your unit with a friend's. You may have made a solder bridge, connected the batteries around the wrong way, made the coil too big or used the wrong value capacitor for one of the values.
If all this fails, put the unit aside and start again.

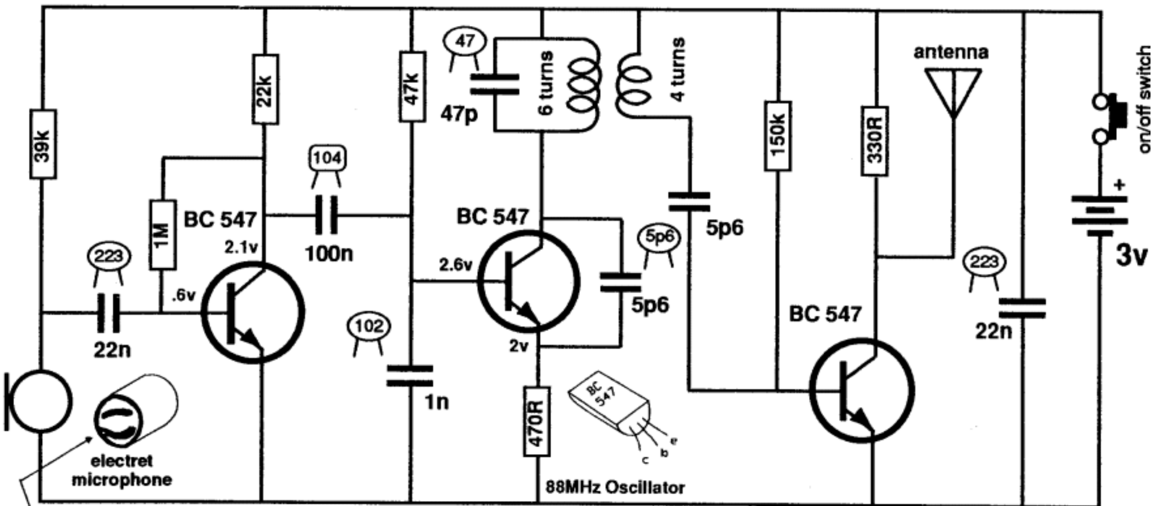
PARTS LIST

1 - 470R
1 - 10k
1 - 22k
1 - 47k
1 - 1M
1 - 5.6p ceramic = 5p6
1 - 22p ceramic or 27p or 33p
1 - 47p ceramic
1 - 1n ceramic = 1,000p or 102
1 - 22n ceramic = .022 or 223
1 - 2.2u 16v or 25v
2 - BC 547 transistors
1 - mini slide switch spdt.
1 - electret microphone (insert)
2 - AAA cells
10cm tinned copper wire
2 - metres aerial wire

1 - FM BUG PC board

THE ANT

A very stable BUG. Can be carried and moved while in use.



ANT CIRCUIT

All the projects in this book have been given a name. An insect name. During their design, we called them all 'bugs' and it was difficult to differentiate one from another.

Then Ross suggested we give them names corresponding to their size or function. Thus we called this one the ANT. It's small (but not as small as the mini bug described later in this book) and the name ANT fits perfectly.

Before settling on a particular project, you should read the notes on all the projects as each has something different to offer. The theory behind a simple FM transmitter is considerable and we have tried to present as many facts as possible, but split between each of the projects.

One of the features of this is project is the fact that is it frequency stable due to the resistive output. This enables it to be carried aound without drifting off the band. It is also very compact and has a good range. It has been primarily designed for this type of application, such as minister or lecturer, where the talker must move around while talking.

It can be made even more compact by using button cells for the supply. We have opted for AAA cells in our discussion as their size provides a considerable duration of operation and they can be soldered in place to fit inside a Tic Tac box.

You could just as easily use two button cells if you are careful with a soldering iron. But is not advisable to solder them and you should bend up some clips to hold them in place. Some of the commercial lapel FM microphones are beautifully designed and we have included a photo of one of these in this article to show you what to aim for.

But their range was considerably less than we had hoped for and so you cannot compare the two. Its another one of those things that look nice but fall short in performance.

A brief outline of the ability of the 'ANT' will help you compare it with our other designs. The ANT will transmit up to about 200 metres under fairly favourable conditions but when you carry it around, the range is reduced to 20 - 50 metres.

It transmits on the 88 - l08MHz FM band and must be tuned to an unused portion of the band so that it does not interfere with local radio stations.

Frequency range and fidelity is superb on FM and the reproduction is crystal clear. You can use this project for listening to wild-life, animal tracking and husbandry, remote listening for security purposes, as an early warning alarm or for transferring TV sound from one room to another. Its uses are limitless and it is especially useful for situations where it is required to be moved or carried, such as for stage-work.

We will leave the ideas up to you. Kits for the ANT (and also all the other projects are available by mail-order from Talking Elelctronics and by using the step-by-step notes on the following pages. you can't go wrong.

Without any more discussion, let's start.

PARTS LIST

1 - 330R (orange-orange-brown)
1 - 470R (yellow-purple-brown)
1 - 22k (red-red-orange)
1 - 39k (orange-white-orange)
1 - 47k (yellow-purple-orange)
1 - 150k (brown-green-yellow)
1 - 1M (brown-black-green)

2 - 5p6 ceramics
1 - 47p ceramic
1 - 1n ceramic (102)
2 - 22n ceramics (223)
1 - 100n monoblock (monolithic) (104)

3 - BC 547 transistors
1 - 6 turn .61mm tinned copper wire 3mm dia coil
1 - 4 turn .5mm enamelled wire 3mm dia coil
1 - electret microphone
1 - mini slide switch
2 - AAA cells
1 - 170cm antenna wire

1 - ANT PC BOARD

HOW THE CIRCUIT WORKS:

There is a lot more to the circuit than first meets the eye.

Some components perform one task, others perform more than one task and everything is fairly critical.

The value of some of the parts is more critical than others and also the placing and spacing of the components is important. This is because the circuit is operating at a high frequency and we want it to operate at peak performance.

Starting at the left hand end of the circuit, we have an electret microphone. As we have mentioned before, this microphone houses an FET (Field Effect Transistor) in which the lead equivalent to the base of a normal transistor, the GATE. The gate is connected to a small metallised diaphragm that is charged with a high potential during manufacture and it holds this charge for the life of the unit.

The diaphragm forms a miniature capacitor or condenser (and this gives rise to its name 'condenser microphone'). When sound waves touch the diaphragm, the charge on the gate of the FET alters. The FET amplifies this and the result appears on the output lead.

These microphones are very sensitive and produce a very good output swing with normal levels of speech.

The 22k resistor is the load resistor and supplies the microphone with a potential. When the microphone picks up signals, the varying voltage across the field effect transistor is passed to the first BC 547 via a 22n capacitor. This value is not critical and has been chosen as it is the largest value ceramic having a small size.

The BC 547 is a self-biasing audio amplifier and is used as a pre-amplifier to boost the output of the microphone to a level suitable for injecting into the oscillator stage.

The transitor is biased via the 1M base resistor and provides a gain of about 100.

The main purpose of the stage is to provide microphone gain so that the circuit will pick up faint sounds (it can be made more sensitive by lowering the value of the load resistor to the electret to 10k or 4k7) and the result is the wireless microphone is nearly as sensitive as the human ear. If this stage is removed, it will be necessary to talk directly into the microphone and the unit will only pick up direct speech.

The output 100n can be any type of capacitor and we have used a mono block mainly for its small size.

The second BC 547 is wired as an oscillator operating at about 100MHz. The frequency has been set by the value of the components in the collector and emitter circuits and also those in the base and coupling circuits.

In other words, the frequency is set by nearly everything in the circuit, including the battery voltage and 22n battery-decoupler. The only components that do not affect the frequency are the pre-amp parts and microphone.

The oscillator stage is turned on via the 47k and this causes a current to flow in the collector-emitter circuit. Connected to the collector of the transistor is a parallel tuned circuit made up of a capacitor and coil.

When a pulse of energy is passed through an arrangement such as this, the capacitor initially stores a charge and this energy is then passed to the coil. The energy is converted to magnetic flux and a very short time later, the magnetic flux cuts adjacent turns and this produces electrical energy that flows back into the capacitor. This phenomenon is called RESONANCE.
In theory this action will go back and forth indefinitely however in practice there are a number of losses in the capacitor and coil and gradually the packet of energy will decrease.

This is where the transistor comes in. It is designed to supply a small amount of energy at each cycle to keep the oscillations at a maximum.

This is done by picking off a small amount of voltage from the collector and feeding it to the emitter. This is done via the 5p6 and the low value of this capacitor has been chosen so that it does not dampen the oscillations too much.

The third transistor is inductively coupled to the oscillator by interleaving 4 turns (called the secondary) with the main coil. The 'pick-off' 5p6 capacitor is a low value and means only a very small sample is picked off. This prevents any loading effect on the oscillator.

The output transistor is turned on slightly by the 150k base resistor and the waveform picked off by the secondary of the air-cored transformer is passed to the base.

The function of the 5p6 is two-fold. Firstly it allows a turn-on voltage to be applied to the base via the 150k and secondly it transforms the package of energy from the secondary of the transformer into a form suitable for the transistor.

The energy output of the transformer comes in a form that is high voltage and low current. The transistor requires low voltage and high current. The capacitor converts the package of energy into this form.

The transistor amplifies this waveform and the current through the collector-emitter is modified to produce a carrier wave.

The carrier is picked up by an FM receiver and when the 'ANT' is tuned in, the background noise reduces to almost zero. When speech is picked up by the microphone, the output frequency is modulated and the receiver converts this back into speech.

This frequency modulation is performed in the oscillator stage. Signals picked up by the electret micrpohone are amplified by the first transistor and appear on the base of the oscillator stage. The 1n capacitor plays an important part in the process. This is how it works:

The base of the transistor is trying to move up and down in sympathy with the emitter. But at 90MHz, the 1n provides a restraint and the result is the base is held firm (at a voltage level of about 1.3v) and this permits the oscillator to function.

Along comes the audio waveform and because it is a much lower frequency, the 1n does not have any hold on the voltage and the base is allowed to rise and fall.

This alters the gain of the transistor and alters its internal capacitance. Thus the frequency of the oscillator changes an amount equal to the waveform entering it. This is called FREQUENCY MODULATION and produces a very clean transmitting signal that is distortion-free.

The circuit is tuned by adjusting the spacing of the oscillator coil. A common alternate approach is to include a variable capacitor across the coil so that it can be adjusted. These trimmers are difficult to obtain and are quite expensive. They also take up more space.

Ours is the better approach as once the frequency is set, it does not require any further adjustment.

Moving the coils apart or together alters the frequency quite appreciably and this must be done carefully so as not to shift the frequency off the band.

The main coil has 6 turns and secondary 4 turns. This means a turns ratio applies between the windings and because the secondary feeds into a 5p6 only a fraction of the energy of the tuned circuit is picked off.

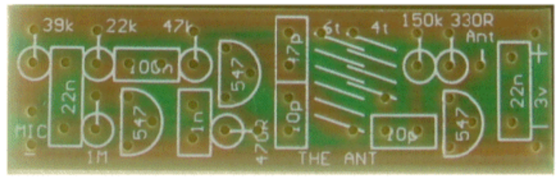
The purpose of the linear amplifier output stage is to reduce the effect of external capacitance on the circuit. This is important if you want to move the unit around or wear it as a lapel mic.

The output stage reduces the loading effect of the aerial and also 'tightens up' the whole circuit so that it is not sensitive to outside capacitive effects.

The final component is the 22n across the battery. This is necessary to reduce the internal impedance of the power supply. The capacitor stabilises the supply rails and allows peak amounts of current to be drawn without affecting the rest of the circuit. This capacitor is also called a 'supply decoupler' and at 90MHz it is very effective.

CONSTRUCTING THE 'ANT'

The PCB has been updated with each component clearly identified on the board.



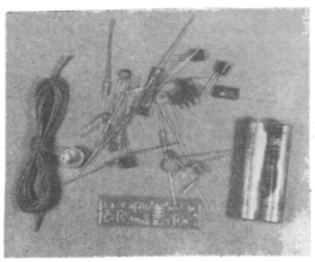
The following step-by-step construction notes show how and when each component is added to the board. And by following this, you are almost guaranteed success.

Lay out all the parts on a clear portion of the work-bench and identify everything.

You should be able to read the value of each component and know that some of them must be inserted around a certain way.

The soldering iron should be clean and you should have a pair of side cutters for clipping the leads after each component has been soldered.

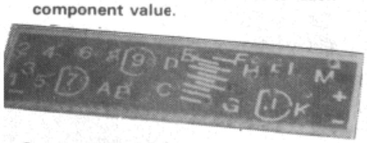
Here we go:



Lay out all the parts similar to this photo. Make sure everything is present by comparing with the parts list. If a component is not marked as stated in the list, it may be the nearest value or a slightly better value. Don't worry too much at this stage unless you are sure it is wrong.

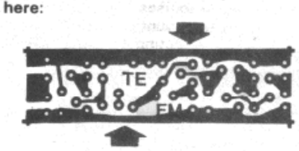
There is one extra resistor in the kit. It is a 10k and should be used as the mic load resistor if you want the ANT to have super-sensitive pick-up.

Inspect the board. It has numbers and letters on it in place of component values. This was necessary as the board was too small to write each component value.

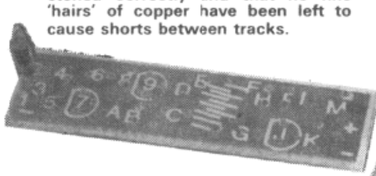


Construction does not follow the numbering but goes across the board in a linear mode so that you have plenty of room when fitting each component.

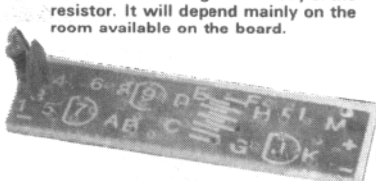
Check the underside of the board for damaged tracks, especially here and here:



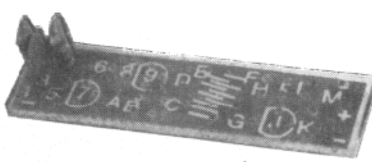
Make sure the legend is readable and that all holes have been drilled. Check the underside of the board for correct track-work and see that all tracks are etched correctly and that no fine 'hairs' of copper have been left to cause shorts between tracks.



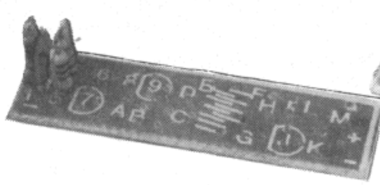
The first component to be mounted is a 22k resistor (red red orange). Bend one lead over close to the body of the resistor and fit the two leads down the holes marked '2', so that the resistor touches the board. Solder it in position and cut the two leads close to the board. This applies to all the resistors in this project and they can be placed either way around as it does not matter which hole gets the body of the resistor. It will depend mainly on the room available on the board.



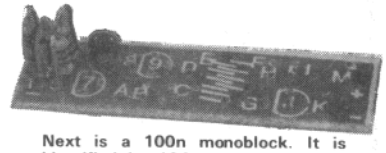
The next component is a 22n ceramic capacitor (marked 223 on the body). It fits down the holes marked '3' and touches the board. It can be placed either way around and soldered quickly so that it doesn't get too hot. Cut the leads close to the board to make a neat job.



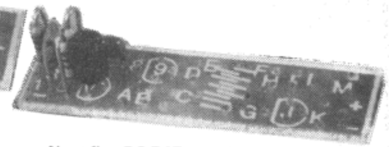
The third component to be added to the board is a 22k (red red orange) resistor. It is fitted over the '4' on the PC board and like the first resistor, the leads are cut off close to the board, after it has been soldered.



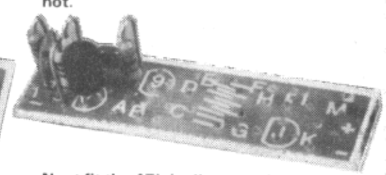
Next fit a 1M (brown black green) resistor over the holes identified by the number '5'. Solder it and cut the leads as before.



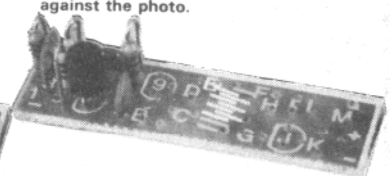
Next is a 100n monoblock. It is identified by 104 on the body and these numbers will be very small and hard to see. It can be placed either way around on the board and goes down holes marked '6'. It is soldered quickly to prevent it overheating. Clip the leads close to the board.



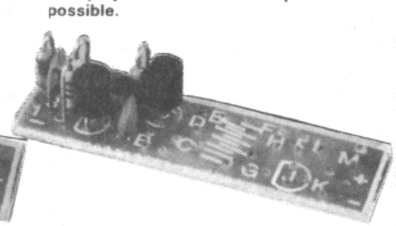
Next fit a BC 547 transistor so that it is level with the top of the 1M resistor. It goes down the three holes marked '7' and the flat on the side of the transistor matches up with the flat on the overlay. Solder the leads quickly as the transistor does not like to be overheated. You can hold the transistor in place with a finger and this will act as heatsink to let you know if the transistor is getting too hot.



Next fit the 47k (yellow purple orange) resistor down the holes marked '8' and keep it nicely upright with one hand while soldering with the other. Clip the leads and check your board against the photo.

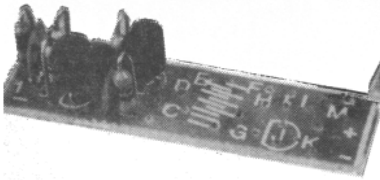


Next the 1n ceramic (marked 102 on the body). This goes down the holes marked 'A' and touches the board both before and after soldering so that the project looks as compact as possible.

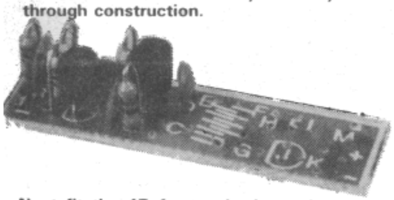


The second BC 547 transistor is now added to the board. This fits down the holes marked '9' and as before, solder it quickly to prevent it getting too hot.

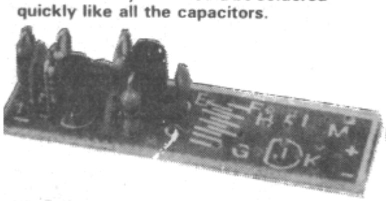
There are no faults or mistakes with the new PCB's. Our new supplier doesn't make any mistakes !!



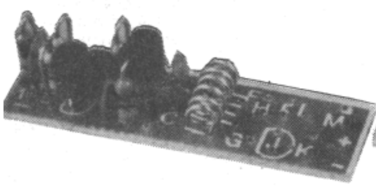
The 470R (yellow purple brown) resistor is fitted down the holes marked 'B' and soldered like the other resistors. Clip the leads close to the board and we are nearly halfway through construction.



Next fit the 47pf ceramic down the holes marked 'D', as shown in the photo. This capacitor will be marked 47 on the body and should be soldered quickly like all the capacitors.

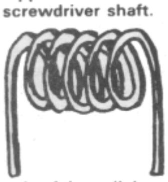


The next component is a 5p6 ceramic and fits down holes marked 'C' on the board. It can be marked 5.6 or 5p6 and can be fitted either way around.



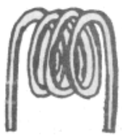
Now comes the most critical part. The main oscillator coil determines the frequency of operation and its size and shape is very important. It must look exactly like that shown in the photo to get the ANT to transmit on the 88 - 108MHz band. The kit contains a pre-wound coil but if it has been squashed or damaged, it must be rewound.

The coil consists of 6 turns of .71mm tinned copper wire wound on a 3mm Philips screwdriver shaft.

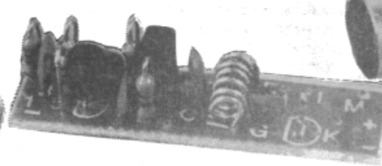


Fit the ends of the coil down the holes as show in the photo and this will create the corect spacing between turns. Solder the ends and cut the excess off close to the board.

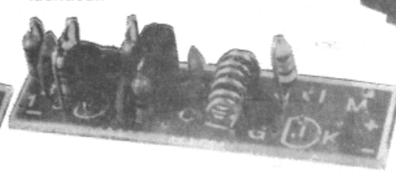
The secondary winding consists of 4 turns of .61mm enamelled wire wound on a 3mm shaft. Bare the ends by scraping them with a nail file or sand paper so that the enamel is completely removed and fit the ends down the holes on the PC board as shown.



Interleave the turns with those of the tinned copper wire coil. Start at the top and you will find the other end will fit down the appropriate hole on the board. Solder the ends and clip the surplus close to the board.

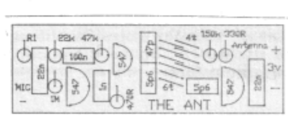


Next fit a 5p6 ceramic down holes marked 'G' on the board. Solder the leads and clip them the same as the other parts. Check your model with the photo to make sure everything is identical.

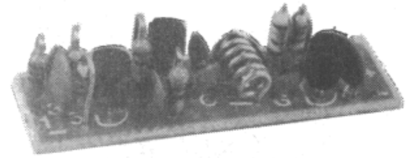


The next item is a 150k (brown green yellow) resistor and this goes down holes marked 'H'.

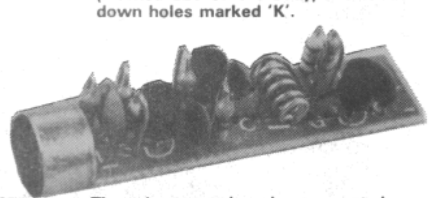
The 330R (orange orange brown) resistor fits down holes marked 'I' and solder it as neatly as the other resistors.



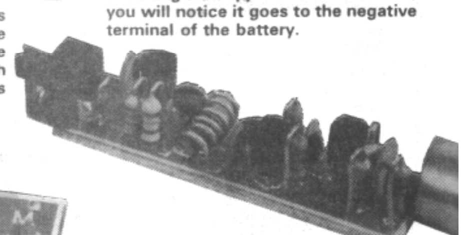
The third and final transistor is now fitted and this BC 547 fits down the three holes marked 'J'. Don't let the transistor project higher than the top of the resistors.



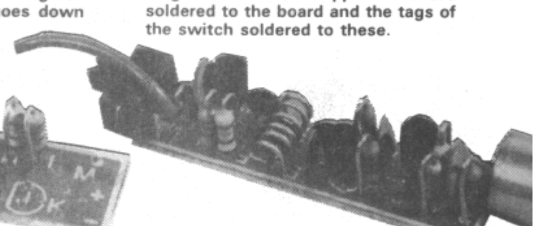
The last capacitor to add is a 22n (marked 223 on the body) and it fits down holes marked 'K'.



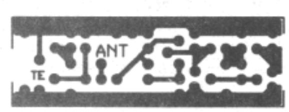
The electret microphone must be fitted so that the lead going to the outside of the case goes down the hole marked negative '-' on the board. By checking the copper side of the board, you will notice it goes to the negative terminal of the battery.



The photo shows how the switch is added to the top of the board. Short lengths of tinned copper wire are soldered to the board and the tags of the switch soldered to these.



The aerial wire is taken to the hole shown and soldered in place.
It should be cut to 156cm for ½wave or 83cm for ¼wave. Try a half wave antenna first and if the range is not required, go to ¼ wave.



The two AAA cells are connected together by soldering the switch between the positive of one cell and the negative of the other. Refer to the photos to see how a link is required between two terminals of the switch so that it will operate correctly.

At the other end, a short length of tinned copper wire is soldered between the negative of one cell and the negative hole on the PC board. A short length of insulated hook-up wire is soldered to the positive of the other cell and the positive hole on the PC board.

The project is now complete. Check your model against the photos and it is ready for testing.

SENSITIVITY

The sensitivity of the ANT depends to a large extent on the value of the load resistor for the electret microphone. We have used 39k in the kit as the microphone we have supplied is a very sensitive type. If you wish to increase the sensitivity to super-performance, the resistor can be decreased to 22k but don't go any lower otherwise the circuit will 'oscillate' or 'motor-boat.'

NOTES ON THE ELECTRET MICROPHONE

There are a number of electret microphones on the market and the difference between them is considerable. Some have high sensitivity while others are low sensitivity.

All our circuits call for a high sensitivity two-leaded type and this is where the problem arises. Some look like three-leaded devices but are really two. They have two short leads and a thick earth tag next to one of the leads.

These are two-leaded types and you have to connect the closest lead to the earth tag to make it into an obvious two-leaded type otherwise only a buzz will be produced.

Three leaded microphones are a bit different. They have a low-value resistor (about 220R to 1k) built into them so that they can be connected directly to a 1.5v to 3v circuit without the need for any additional resistor.

But if you want to operate them on more than 3v, an external load resistor must be added. The resistance of this should be between 10k and 47k.

Three-leaded microphones can be used in our circuits by connecting the earth lead to the negative rail and the centre lead to the load resistor on the PC board. This means the resistor inside the microphone is not used and thus the third lead is not used.

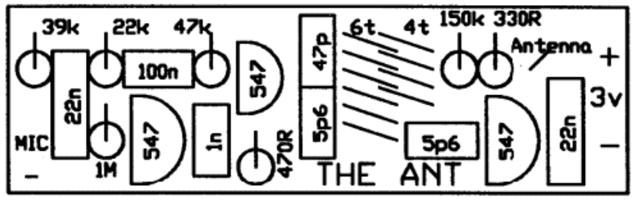
will not work satisfactorily on re-assembly.

Some electret microphones are larger than others. Both work on the same principle and have the same output waveform when supplied with a voltage if they have the same sensitivity.

But some produce a very high output

Electret microphones do not produce a voltage or current but rather modify a voltage across a load resistor.

They are an active device (due to the presence of a transistor) and must be placed in a circuit around the correct way.



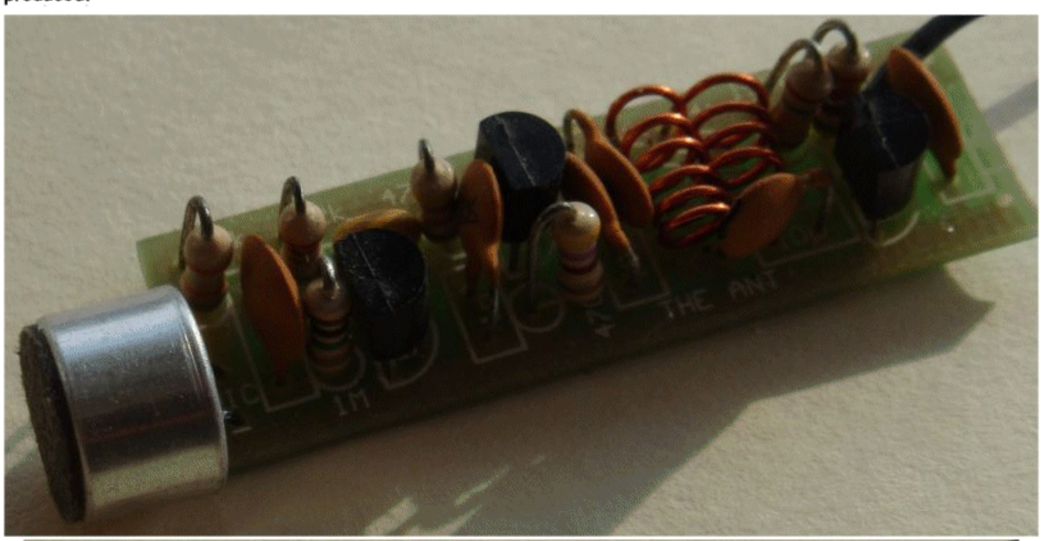
An enlarged view of the ANT overlay

You must not put a voltage directly across them as this may damage the transistor. They must be placed in series with a resistor.

Some microphones come with long leads and can be soldered directly to the board. Others will need leads applied and when doing this, do not overheat the microphone as the diaphragm is very easily damaged.

If the microphone produces a lot of background noise, like bacon and eggs frying, the microphone is damaged.

A close-up of the ANT board showing the 6 turn coil and 4 turn coil interlaced



TESTING

At first you may think the method of testing a transmitter is around the wrong way. This is because we start at the output stage and work towards the front end.

But when you look at it more closely, you will see the reason for this.

Once you have the output stage working, you have a starting point and from there the procedure is fairly straight-forward.

Once you have read the 'How it works section', you will realise the output waveform of the transmitter consists of two parts. The base part is called the 'carrier' and this is a constant frequency. If we are transmitting at 100MHz, it is a 100MHz frequency. Added to this is the audio component and this causes the 100MHz to increase an amount equal to the audio frequency being picked up by the microphone.

The audio tone FREQUENCY MODULATES the carrier and this gives us the term FM transmission.

We use this knowledge to fault-find the project. Our first concern is to be able to detect the carrier. This is picked up on an FM radio as a 'dead spot' and by turning the transmitter off, the background noise will appear.

The carrier is produced by the oscillator stage and if a linear amplifier is present, it will pass the carrier to the aerial. When we detect a carrier, we prove that both stages are working.

If a dead spot is not heard, we can firstly assume that the frequency of transmission is off the FM band.

To adjust the transmitter, all you need do is close up the turns of the oscillator coil (making sure the turns do not touch each other if bare tinned copper wire is used).

Sweep the entire FM band on the radio, looking for a silent spot. The bandwidth of the transmitter will be quite narrow and it will be necessary to sweep the band fairly slowly.

If nothing is heard, go over some of the simple faults such as making sure the project is turned on, the radio is on the correct band (88MHz to 108MHz), the radio has an antenna connected and no metal objects are near the transmitter etc.

You must detect a carrier before progressing any further. This is the starting point and no other sections can be tested until this is successful.

Unless you have a 100MHz CRO, there is no other way to see if the project is transmitting. This is not entirely true as another solution is to make a second model.

If the second model works successfully (and I see no reason why it shouldn't), you can use it to physically check the spacing of the coil, placement of parts and the position on the FM band, to see why things are not coming through on the first.

When a dip is heard, you are half-way home. In fact you are 90% home. The rest is down-hill.

The next step is the testing of the audio stage or stages. Even though the project contains one audio stage, we can consider the microphone to be a stage since it is an active device containing an FET transistor.

If either the microphone or pre-amplifier stage does not work, you will not get any more than a carrier output.

The testing of these two stages is covered in the section 'More Tips on Fixing The Projects' and you should read this and follow it through.

Testing is done a little differently than you expect.

You don't need any elaborate test gear - just an FM radio.

If this fails to locate the fault, you can use almost any CRO to pick up the waveform at any one of a number of points on the board. It is important to note that you will not be able to transmit when making these tests but this is not necessary as we have already proven the oscillator is producing a carrier.

By whistling into the microphone and picking up the waveform at the output of the mic, (at the point where the load resistor connects to the microphone), you will be able to see the peak-to-peak performance of the microphone.

Next, pick up the waveform at the other end of the coupling capacitor and note that some of the amplitude has been lost.

This point is also the base lead of the audio transistor and it is handy to make a calculation of the gain of this stage.

This is done by whistling at a set distance from the microphone to get say a 5mV p-p waveform. By going to the collector of this stage, (and adjusting the vertical amplifier of the CRO), you will be able to read the peak-to-peak value after amplification.

It should be at least 500mV, giving a gain of 100.

This waveform is injected into the base of the oscillator stage via a DC blocking capacitor and causes it to change frequency as mentioned before. Finally you will be able to detect the audio waveform at the emitter of the oscillator stage and this will prove the audio component is flowing through the circuit.

If the gain of the audio amp stage is less than 100, the transistor should be replaced as it may be leaky or faulty in some way. The only other cause of low gain is the two biasing components being incorrect.

Once the circuit is working successfully, the final stage is peaking the transmitter so that it achieves the range we have stated. If you require only a short range, the project need not be peaked at all. The aerial can be almost any length and providing you have picked a spot on the band that is away from any other radio station, the job is done.

If you want more than a few metres range, you will have to trim the aerial to ½ or ¼ wave and set the frequency to approx mid band. Adjust the position of the two cells and and set everything exactly as it will be placed in the final rest position. Move the transmitter to the next room. Fine tune the radio and listen for such things as a ticking clock.

If the background snow level comes up, you may have to provide an antenna for the FM radio. They are usually a folded dipole, looking very much like the letter 'T' and when this is added to the radio, its range increases enormously. Also the transmitter gives the best range when the aerial is allowed to fall vertically.

Our prototype had a range in excess of 200 metres when carried about in a built-up area.

This is how we tested it: Paul went down to the fish and chip shop with the transmitter placed in his top pocket and the antenna dangling inside his jumper. We could hear him cross the main road some 150 metres away, enter the shop, place the order and hear the ding of the cash register.

Between the shop and our receiver was two layers of glass, two houses and a span of back yards. This is the range to be expected when the unit is peaked and a 9v battery fitted. The 9v supply did not achieve a greatly increased distance, and may be not worth the extra cost. With 3v, the transmitter started to fade out just before entering the shop. Nine volts allowed us to pick up conversation inside the shop and this represents only about 20% improvement.

When peaking up the 'ANT', the air cored transformer plays a very important role. It can be peaked by moving the secondary winding into the main coil or detuned by withdrawing it. This way you can create the range you require.

SETTING UP THE 'ANT'.

This is how it is done: Place the 'ANT' about 1 metre from an FM radio and switch them both ON.

Tune the radio from one end of the band to the other and listen for a feedback whistle. When this is heard, switch the transmitter off and tune the receiver to the closest radio station, either side of the transmitter frequency.

The transmitter must be operated on an unused portion of the band and must not interfere with any other radio station.

If a station is very close, the transmitter will have to be moved along the band. This is done by pushing the turns of the main coil together slightly and repeating the above to see how far the frequency has shifted. These turns can also be spread out to shift the frequency in the other direction.

Once a clear channel has been found in the middle of the band, the coil is not touched again.

If the background hiss dies down from the receiver but no feedback whistle is heard, it indicates the carrier section is working but not the pre-amp or microphone stages.

To fix this, you will have to read the next section on fault finding.

The fine tuning between the transmitter and receiver is done at the receiver end. Move the transmitter away about 10 metres or so (preferably into another room) and fine-tune the receiver slightly to pick up the transmitter as strongly as possible.

Once you are satisfied that the circuit is working equally as good as our description, you can fit it into a TIC TAC container.

If you prefer to use another case remember it is preferable to use a plastic case so that it doesn't have any effect on the performance. A metal case may shift the frequency or deaden the oscillator and reduce the range.

After fitting, the only part you will have to hide is the aerial and at the cost of reducing the range, it can be cut down to 5 or 10cm.

In our field tests, the range was 200 metres in a built-up area and 250 metres in a line-of-sight operation. All these tests were done with an 83cm ¼wave antenna.

This range makes the ANT ideal for large halls or for sporting events where a 100 metre range is required.

On 3v, the circuit comsumes about 5mA and the life of the battery will be about 100 hours.

The transmitter can also be operated on 9v and our tests showed the range to be about 250metres in a built-up area and 300metres in a line-of-sight operation.

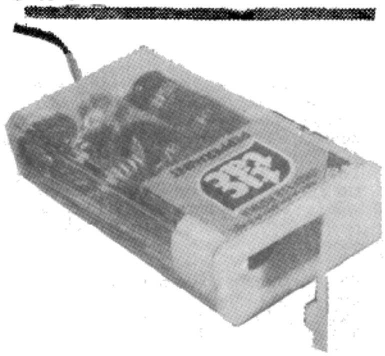
In other words. 9v did not increase the range very much and we consider 3v is the best choice.

By now I hope everything is working perfectly and you are ready to test the range.

This commercial FM mic looks beautiful but it doesn't perform very well. We got only about 5metres out of it. It's only a single transistor model and the microphone is not very sensitive.

FITTING THE 'ANT' INTO A CASE

The 'ANT' is designed to be fitted into a TIC TAC box and the photo shows how this is done.



A cut-out is made in the bottom of the box for the slide switch with a hot soldering iron and a small file.

The flip-top lid hides the microphone and it can either be left open, removed or a hole drilled to allow the sound to enter. A small hole will not produce as much clarity as an exposed microphone and you will have to accept a balance between appearance and performance.

Once the case arrangements have been made it will be necessary to 'SET UP' the transmitter and make sure it is working correctly.

MORE TIPS ON FIXING THE PROJECTS:

These notes apply to all the circuits in this book and only slight differences apply to each design.

If any circuit does not work exactly as described, don't despair. It's now that you will pick up a lot of servicing tips.

The equipment you will need is a multimeter, soldering iron and tools, an uncluttered bench and an FM radio.

All the circuits have been tested and are guaranteed to work. But if one doesn't, there could be one of a thousand reasons. Most of the time it will be due to a simple mistake such as two resistors or capacitors swapped over or a connection that has not been properly soldered.

These are very hard to locate and quite often someone as remote from electronics as your sister, mother or wife can spot a simple mistake as they will see the project with new eyes.

Don't over estimate yourself. It's the simple mistakes that can be so easily made - and so hard to fix!

Talking Electronics provides a repair service but, as you can imagine, the cost of repairing a low-priced project can be more than the inital cost of the kit!

That's why we don't expect these kits to be sent in. We want them to be fixed by you and that's why so much of the book is devoted to getting them going.

There are two ways of going about this. One is to fiddle around making a few voltage checks along the way and somehow, eventually, the thing gets fixed. The other is to make up a second kit and using this as a foundation, repair the first.

This may be an expensive way of going about it as you could finish up with two non-working models. But look on the bright side, you should finish up with two working models and have learned a lot in the meantime.

The idea is to use the second kit to fix the first by swapping one part at a time. You must remember which model is which!

When the second fails to work and the first springs into life, you know the fault has been located.

If, on the other hand, both models become non-operational, you may have located one of the faults and at this point you should swap the components back again to get unit two working. Put a new component in model one and keep going.

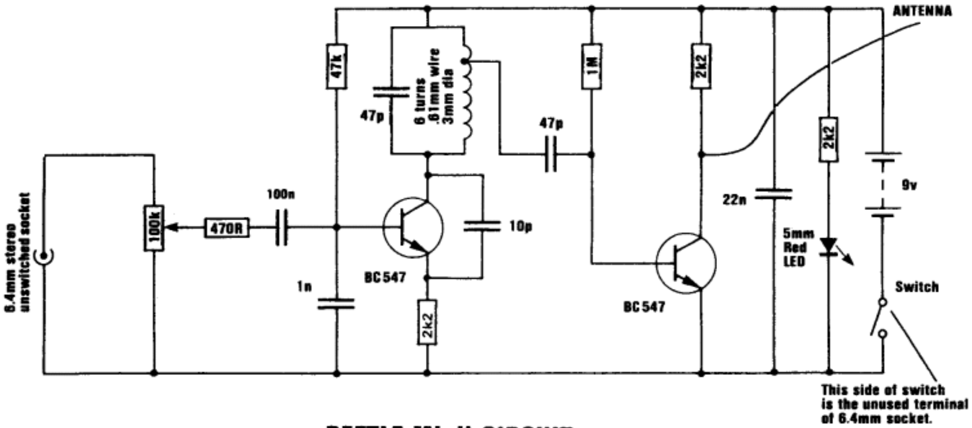
Eventually every component will be transferred and both projects must fire-up. This might be slow and expensive but how else would you be able to locate an open 5p6 capacitor or a dry 2.2mfd electrolytic? (These could have been damaged during assembly or soldering).

BEETLE Mk II

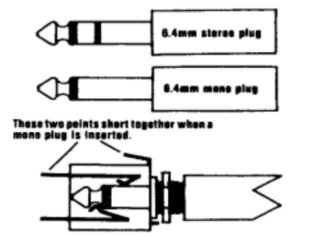
TRANSMITS YOUR GUITAR TO AN FM TUNER

Kit of parts $16.25 USD
Post: $6.50 USD

email Colin: talking@tpg.com.au for paypal details



BEETLE Mk II CIRCUIT



Using a mono plug in a stereo socket to act as a switch as well as an input.

The Beetle Mk II is also known as AIR LINK Mk I when made up in completed form. We have it in kit form as well as completely made up. See the list of products at the back of this book for ready-made units.

Beetle Mk II is an improved version of the Beetle project described in FM BUG book number 1 and has a number of changes to allow it to operate on 9v.

The circuit is designed to switch ON when the 6.4mm plug is plugged into the socket and it connects to the output of a guitar via a short patch cord.

The kit comes complete with socket, box, led mount and 9v battery. All you have to do is put it together.

The main difference with this design is the input attenuation. It can be adjusted to allow the circuit to match almost any guitar.

The output from a guitar can range from a very low level to hundreds of millivolts and to prevent overloading the input circuit, a preset pot is included. This pot can be adjusted through a hole in the side of the case.

The main requirement for a guitar transmitter is stability. It must not drift when a player moves around. This has been achieved with the ANT circuit (converted for 9v operation) and with a few changes including a tapped oscillator coil.

The project needs a reasonable degree of skill to put together and you should have built some of our other designs to understand what is required. If you've done this, let's go:

CONSTRUCTION

All the components are fitted onto the "BEETLE" PC board and due to the compact nature of the layout, a lettering and numbering system has been used to identify each component.

Refer to the large layout for the value of each part and everything is straight-forward until you come to the tapping on the oscillator coil. This is made on the 3/4 turn from the positive end. You can refer to the Amoeba project for assistance with this and the ANT project for identifying each of the components.

The board fits down the slots of a small jiffy box and a hole is drilled in the side of the case so that the mini trim pot can be adjusted with a miniature screw driver during the set-up procedure.

Two leads are required for the 'Power-ON' LED and three for the input socket as well as two for the battery and you should refer to the wiring diagram to see how to connect these together.

When everything is wired up, the project can be set to the desired frequency by adjusting the oscillator coil. The best frequency is about 88.1MHz to 88.5MHz.

PARTS LIST

1 - 470R (yellow-purple-brown)
3 - 2k2 (red-red-red)
1 - 47k (yellow-purple-orange)
1 - 1M (brown-black-green)

1 - 100k mini trim pot

1 - 10p ceramic
2 - 47p ceramics
1 - 1n ceramic
1 - 22n ceramic
1 - 100n monoblock

1 - 5mm red LED
2 - BC 547 transistors

1 - 9v battery snap
1 - 9v battery

1 - 6 turn coil .61mm wire 3mm dia
1 - 160cm hook-up wire for antenna
1 - LED mount
1 - 6.4mm stereo socket unswitched
1 - H 0205 jiffy box with plastic lid

1 - **BEETLE Mk II PC BOARD**

FITTING THE PARTS INTO THE CASE

Everything is a tight squeeze but firstly 4 holes have to be drilled: one to take the LED mount, one for the 6.4mm socket, one for the antenna and one for the mini trim pot adjustment.

The quickest way to make the holes is with a hot soldering iron and finish off with a tapered reamer but this is not as good as the right size drill taken carefully through the plastic.

The socket should be mounted between the guides so that it fits flat against the side of the case.

The LED mount fits together from both sides and the leads of the LED can be soldered to the circuit, remembering the short lead goes to the negative rail on the PC.

Feed the antenna through the hole and mount all the items in the box.

The plastic lid can now be screwed on but firstly the guitar strap is fitted between the lid and case, and the 4 screws tightened up. This will clamp the strap in place and hold the case just where you want it. Use a patch lead (about 60cm long) between guitar and case and fit the antenna on top of the strap and hold it in place.

The unit is now ready for use and when a 6.4mm plug is inserted into the socket, the circuit is supplied with current. The socket has contacts that short together when the plug is inserted and this acts as a switch.

You will need an FM tuner (88 - 108MHz) or FM radio with output socket and this is taken to the input of a power amplifier to complete the system.

Connect a patch lead between guitar and Beetle and you are ready for testing.

TESTING

Turn the volume of your amplifier to a low setting so as not to blast you out of the room. Turn the guitar volume to about 7 or 8 and adjust the pre-set pot to give a clear, undistorted, output.

Adjust the trim pot fully clockwise and anticlockwise to hear distortion and zero output so that you are familiar with these and make sure the final setting is not near the unwanted levels.

The range for the Beetle will be about 30 to 50 metres and most important the frequency will be very stable.

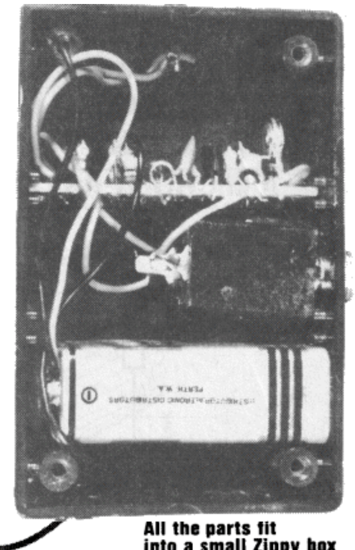
We tried the Air Link in a shopping centre and it went down the Mall and around the corner without fading out.

You should pick a low frequency that is free from interference such as 2-way couriers etc. About 88.1MHz to 88.5MHz will be suitable for one unit and if you want another in close proximity, it should be between 88.6MHz and 88.9MHz to prevent interference.

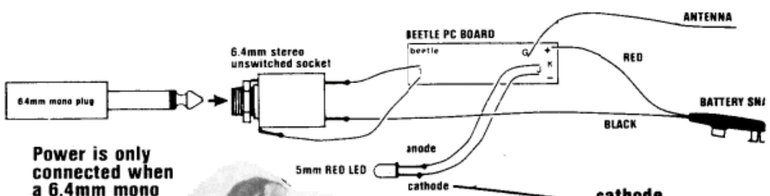
Obviously you don't want them on the same frequency as you need to mix the signals. Don't forget to remove the plug when not using the transmitter, to save power.

When you get your Air Link operational, you will never go back to coily cords!

It'll be the best investment you ever made.

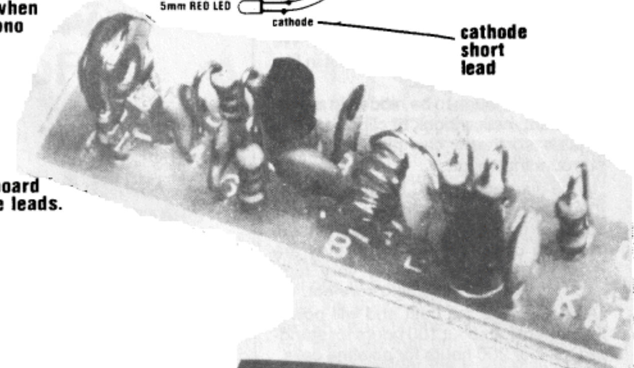


All the parts fit into a small Zippy box size: UB-5.

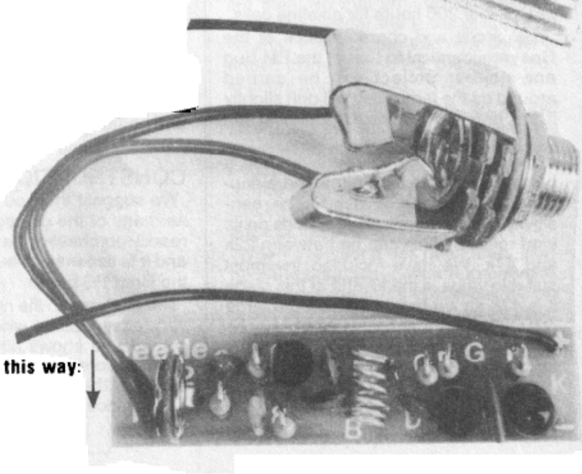


Power is only connected when a 6.4mm mono plug is inserted.

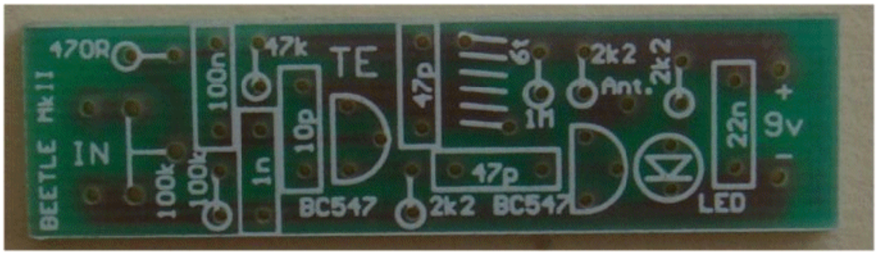
cathode short lead



The fully assembled board ready for the leads.



Cathode this way: LED

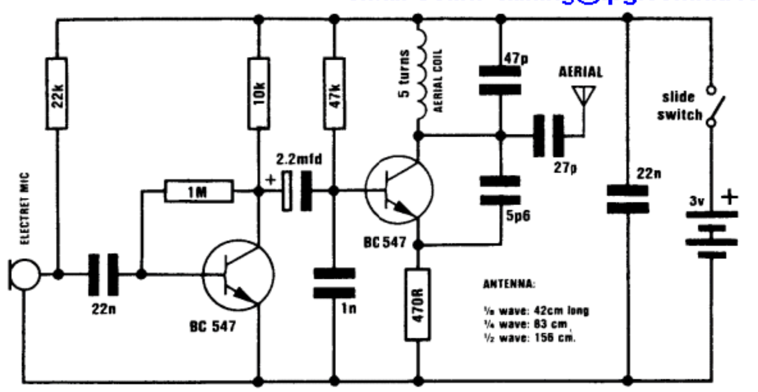


THE GNAT

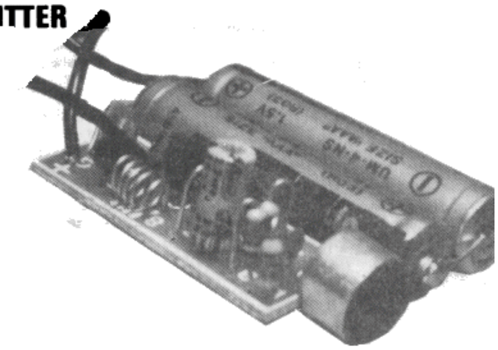
Kit of parts: $10.50 USD
Postage: $4.50 USD

A MICRO VERSION OF THE FM BUG

email Colin: talking@tpg.com.au for paypal details



GNAT FM TRANSMITTER



This is one of our smallest bugs in the series and is designed to be placed in an inconspicuous place and left there. We have called it the GNAT to keep it in line with our series of bugs.

It is small enough to be hidden in a desk ornament, hollow book or clipped under a table so that it can pick up all the surrounding sounds.

In the diagram, the PC board is smaller than the batteries but if you use small cells, the operating time will be reduced. You can use button cells but they are expensive, do not have a very high capacity and are difficult to connect.

AAA cells are the best and will power the project for about 100 hours for standard cells or 200 hours for alkaline cells.

The circuit and characteristics of the Gnat are identical to that of the FM Bug and neither project can be carried around as the frequency will drift slightly if the antenna is near or touching the body.

The circuit is extremely sensitive and is better than the human ear when a sensitive microphone is used. The sensitivity of the microphone depends on its load resistor. This can be between 22k and 47k. We have included the most suitable value in the kit and at this stage it is 47k as we have purchased a large quantity of very sensitive microphones and these require on a very small current for their operation.

The range of the Gnat will depend mainly on the length of the antenna and it can be as short as 5cm. At this length the range will only be a few metres, so if you want the full range, you should use the 170cm antenna and stretch it out fully.

The project is small enough to be placed inside a matchbox if the switch and board are moved around slightly.

Now for construction:

CONSTRUCTION

We suggest that you buy a kit of parts as many of the components cannot be readily purchased, the coil is pre-wound and it is essential to build the project on the Gnat PC board.

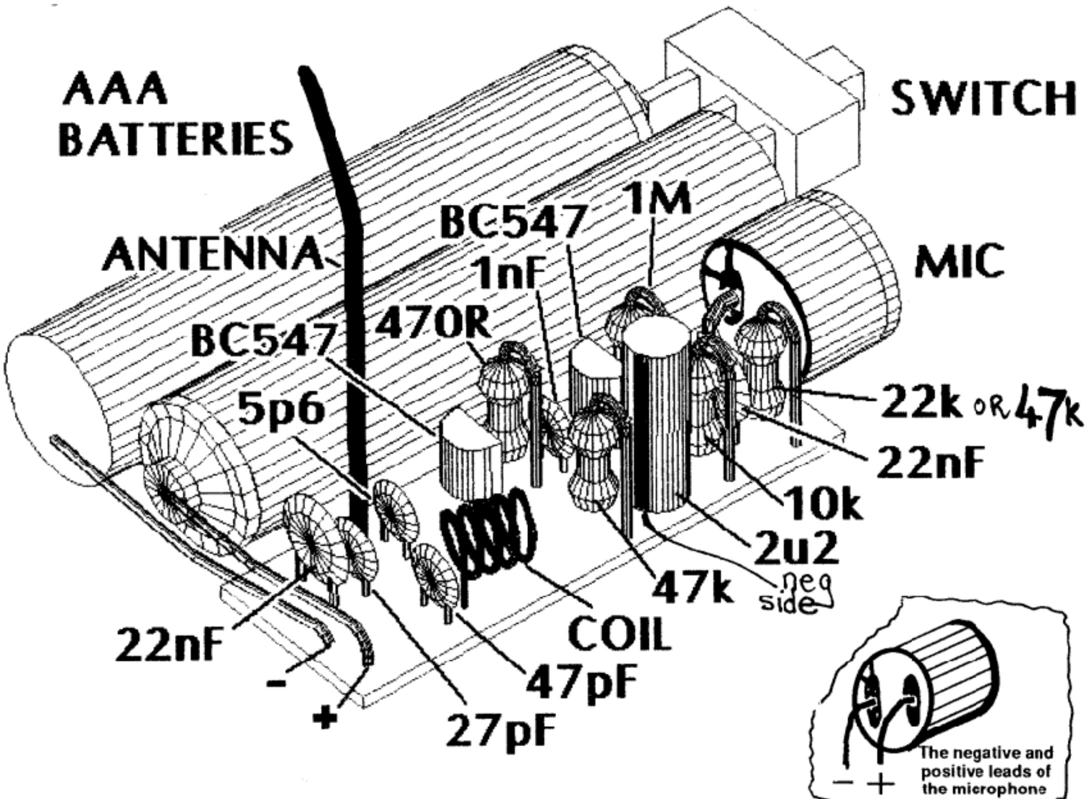
The diagram on the next page makes it very easy to see where the parts are placed and shows how the capacitors and resistors are kept close to the board so that the leads do not alter the capacitance and impedance of the circuit.

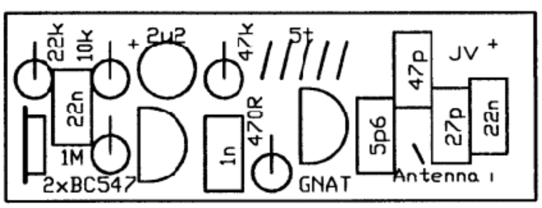
PARTS LIST

1 - 470R (yellow-purple-brown-gold)
1 - 10k (brown-black-orange-gold)
1 - 22k (red-red-orange-gold)
2 - 47k (yellow-purple-orange-gold)
1 - 1M (brown-black-green-gold)

1 - 5p6 ceramic marked as 5.6
1 - 27p ceramic marked as 27
1 - 47p ceramic marked as 47
1 - 1n ceramic marked as 102
2 - 22n ceramic marked as 223
1 - 2u2 PC mount electrolytic

2 - BC 547 transistors
1 - mini slide switch SPDT
1 - electret mic insert
2 - AAA cells
1 - 5 turn tinned copper wire coil
1 - 170cm antenna wire
1 - GNAT PC BOARD





Before starting, you should put the parts on the layout diagram opposite and make sure everything is included. Use the 47k for the microphone we have supplied.. If you want greater sensitivity, use 22k.

Fit one part at a time and push it firmly onto the board. Bend the leads slightly so that the component stays in place and cut them so that 2mm is available for soldering. Solder the leads quickly and cleanly, making sure that new solder is added to the joint so that the connection is bright and shiny.

The transistors must be fitted so that they cover the outline on the board, the electrolytic must be fitted so that the negative stripe on the side is as shown on the diagram and the microphone is placed with the negative lead near the edge of the board.

When everything has been fitted, connect the batteries, switch and antenna. Make sure the turns of the coil do not touch each other and you are ready to try it on a radio. Switch the unit on and tune your FM receiver to the low end of the band. It should come through loud and clear.

Fit it into a matchbox or other similar case and the project is complete.

The 3D artwork above was designed and drawn by Ken Stone as a 3D side-elevation and rotated with the aid of a new program. It took 4 hours to produce the image we have used above. That's how slow and inefficient computers were at the time. In fact, computers had just become available for less than $4,000. And the hard drive was 10 Meg !!
This image could be re-drawn now in less than 1/100th of a second.

THE AMOEBA

Kit of Parts: $11.60 USD

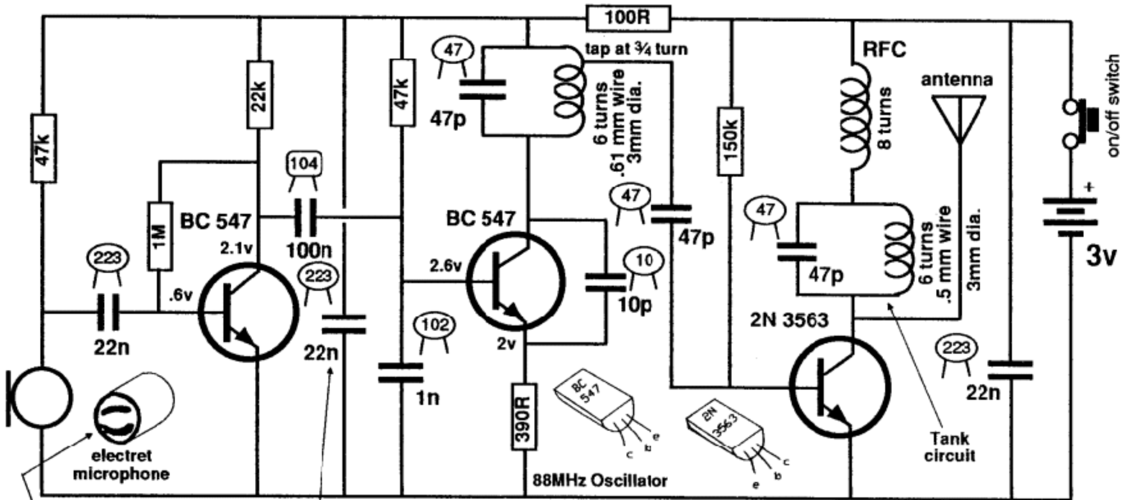
Postage: $4.50 USD

Our 400 metre BUG. How far can you transmit on 10 milliwatts!

PayPal details email: talking@tpg.com.au

The LED Power Meter is needed to peak the output of this bug

$1.25 extra



AMOEBA CIRCUIT

At first, the thought of producing a bug that would transmit 400 metres sounded far fetched. If you consider a circle of radius 400 metres, the area enclosed is quite considerable.

To send a signal over this range is quite an achievement and when we first started designing mini transmitters, we had no idea of what we would achieve. Some of the first devices went 50 metres, then 100, and then 200 metres.

We got stuck at 200 metres because, to double the range, the power must be increased four-fold. We were already at the limit of BC 547 transistors and did not want to go into high power designs.

So we let it rest for a while.

Some time later the thought arose that the output stage could include a tuned circuit to improve the performance and after some experimenting it was found it did in fact improve the output enormously.

After a few field tests the range had past the 300 metre mark and was approaching 400 metres.

Thus the AMOEBA was born.

It is an upgraded version of the ANT and although it appears that only a few components have been changed, it represents hundreds of hours of experimenting - working out what was needed and eliminating things that didn't work.

THE TUNED CIRCUIT

The effectiveness of the tuned circuit can be seen by the range we gained over the ANT or original FM Bug. Without any increase in current or supply voltage, we have increased the range four-fold. The only cost we had to pay was the stability of the output. The Amoeba is not as stable as the Ant and it cannot be handled or moved without affecting the frequency slightly.

It's designed to be placed in a location and left to transmit. To get the maximum energy out of the circuit, the TANK CIRCUIT must be tuned (peaked) to exactly the same frequency as the oscillator and the output transistor should be an RF type. That's why we have chosen a 2N 3563. It's about the only suitable, low-cost, type on the market.

On top of this, it is an advantage to include an RFC in the output to improve the narrowness of the transmission. (All the units we sell in made-up form have this included and are available for $50.00. Refer to the list at the back of this issue.) It's an interesting exercise to compare the Amoeba with the Ant and determine where the extra output energy is coming from.

You can see the difference between the two circuits and when you read the accompanying notes, you will see how and why the tank circuit is more efficient than a load resistor. Although the tank circuit consists of only two components, we have written more than three pages on its operation. It's so brilliant that it would take even more than this to explain fully and when you visualise how the two

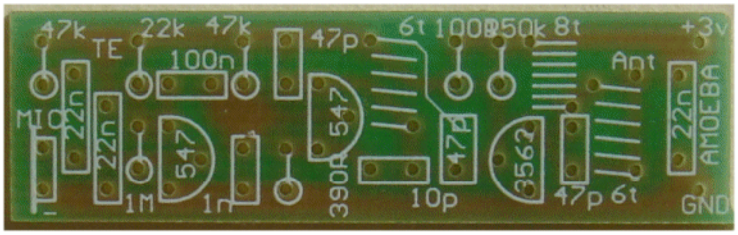
PARTS LIST

1 - 100R (brown-black-brown)
1 - 390R (orange-white-brown)
1 - 22k (red-red-orange)
2 - 47k (yellow-purple-orange)
1 - 150k (brown-green-yellow)
1 - 1M (brown-black-green)

1 - 10p ceramic
3 - 47p ceramics
1 - 1n ceramic (102)
3 - 22n ceramics (223)
1 - 100n monoblock (monolithic) (104)

2 - BC 547 transistors
1 - 2N 3563 transistor
1 - 6 turn .61mm tinned copper wire 3mm dia coil
1 - 6 turn .5mm enamelled wire 3mm dia coil
1 - 8 turn .5mm enamelled wire 3mm dia coil
1 - electret microphone
1 - mini slide switch
2 - AAA cells
1 - 170cm antenna wire

1 - AMOEBA PC BOARD



items work when placed together, you can appreciate the magic of electronics.

To us, the construction is fairly simple and straight-forward but if this is your first project in this field, I suggest you try the ANT as it is considerably simpler to construct and tune.

Some of the aspects of construction will be new to many readers, especially the tapped coil and the close parts layout but this is the sign of a professionally laid-out board and you must keep the circuit as tight as possible when you are working in the Mega-hertz range.

The tapped coil is common in radio work and is a very effective way of coupling two stages. It turns the coil into an auto-transformer in which the turns ratio of the whole coil compared to the single output turn provides a current gain of more than 6:1.

BUYING A KIT

I cannot stress too strongly, the need to purchase a kit. It is almost impossible for you to make your own PC board with tinned trackwork and a fully detailed overlay for less than the price we are selling them for. This is because we get them made 1,000 at a time on an automatic 3-head drilling machine and you could never compete with mass-production.

On one of the early CAD boards we placed the RFC around the wrong way and the output was reduced enormously. The simple mistake of having the tank coil and RFC positioned so that the magnetic field of each interacted to oppose each other took quite a while to diagnose.

Also the size and spacing of the coils is critical as is the wire gauge as well as the coil diameter and the number of turns.

This has all taken many hundreds of experiments to get the optimum size and shape and it all looks so obvious when it's finished.

If you want your project to work as good as the one we have described, the characteristics of everything must be identical to ours.

If you like experimenting, you should build a kit first, then you can experiment with another set of parts and make all the changes you like.

But let me stress, I think we have achieved the optimum performance and I don't think you will do any better. But don't let that deter you. Winning the lottery is nigh impossible and yet millions try their luck every week.

But that's getting off the track. First things first.

The Amoeba is only slightly more complex than the ANT in construction, but considerably more complex in peaking. The Ant needs no peaking at all but simply an adjustment of the oscillator coil to get the desired frequency. The Amoeba requires additional skill in peaking the tank circuit to get maximum output.

This is done with the aid of a peaking meter (or peaking circuit) we call the LED Power Meter. It is made up of two diodes, two capacitors and a LED with resistor, connected to a multimeter set to a low voltage range. It is a very simple circuit that can be made in a couple of minutes and connected to almost any multimeter, in place of the leads.

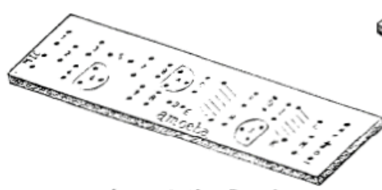
It's so simple yet so necessary in RF work. It's an RF power meter for very low outputs and although it is not calibrated, it works very well.

You will learn that the output of a transmitter is dependent on the effectiveness of the antenna and unless it is long and straight and away from any metal objects, the output will not be as good as expected.

CONSTRUCTION

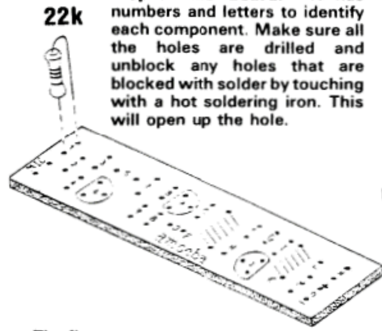
The PC board shown in the step-by-step guide on the following pages is our original board. We now have a CAD board with everything clearly identified on the top and you will have no trouble fitting the components.

JUST USE THESE INSTRUCTIONS AS A GUIDE as everything is correct up to the RFC coil. The original board did not have an RFC but the CAD board has it included near the end of the board, beside the 22n.



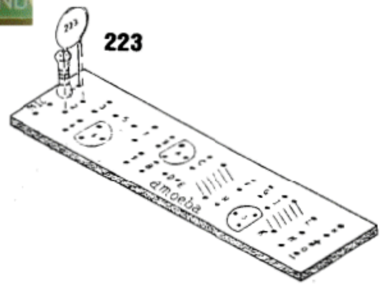
Inspect the Board. It has numbers and letters to identify each component. Make sure all the holes are drilled and unblock any holes that are blocked with solder by touching with a hot soldering iron. This will open up the hole.

22k



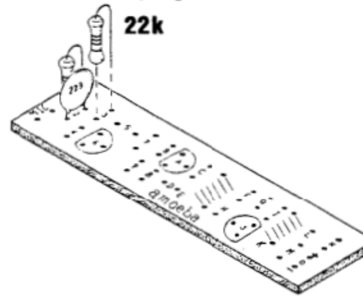
The first component to add is a 22k (red-red-orange) resistor. Bend one lead over and fit the two leads down the holes marked '1' so that the resistor touches the board. Solder it quickly in position.

223



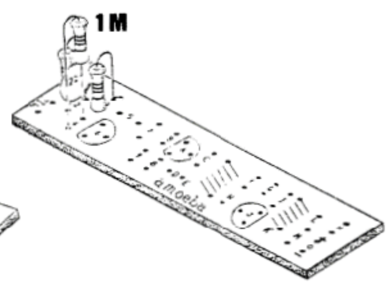
The next component is a 22n ceramic (223 marked on the body). It fits down holes marked '2' on the PC. It can be placed either way around and is soldered quickly so that it doesn't get too hot. Clip the leads as you go.

22k



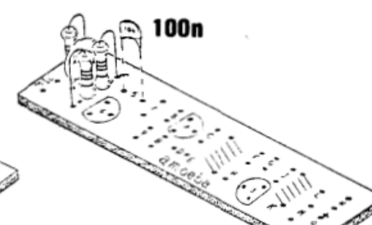
Next is a 22k (red-red-orange) resistor. It fits down holes marked '3' and soldered quickly. The leads are cut off close to the board after it has been soldered.

1M

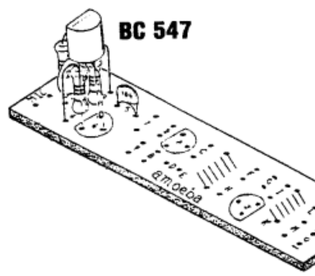


The next component is a 1M (brown-black-green) resistor and is fitted as shown, into holes marked '4'. Solder quickly and cut the leads as before.

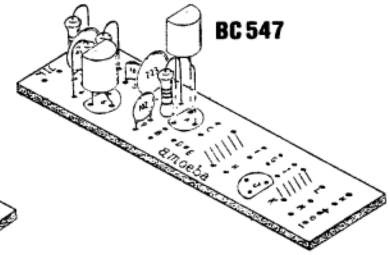
100n



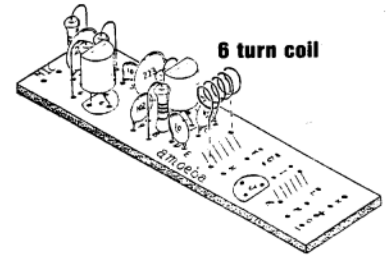
Next is a 100n monoblock. It is identified by 104 on the body. It is very small and goes down holes marked '5' on the PC.



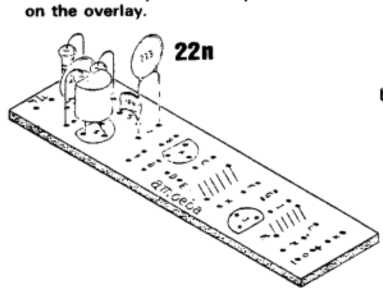
Next fit a BC 547 transistor so that it is level with the top of the 1M resistor. It goes down holes marked '6' so that the flat on the body matches up with the flat on the overlay.



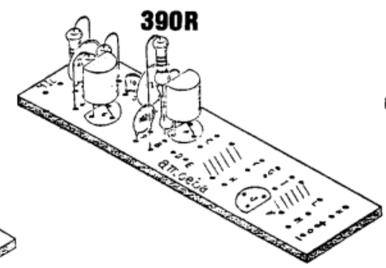
The second BC 547 transistor is now added to the board. It fits down holes marked 'A' and soldered quickly as before so that it doesn't get too hot.



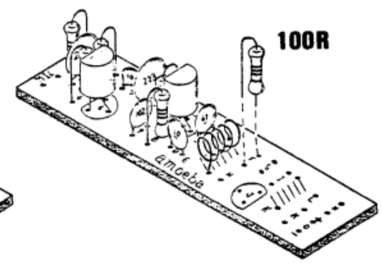
The 6 turn tinned copper wire coil is next and is fitted down holes marked 'E.' The turns should be evenly spaced. Solder the leads and trim off neatly against the board.



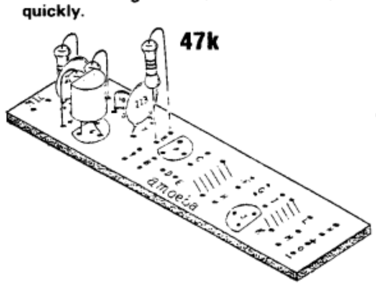
Next fit a 22n ceramic into holes marked '7.' Press it against the board and solder quickly.



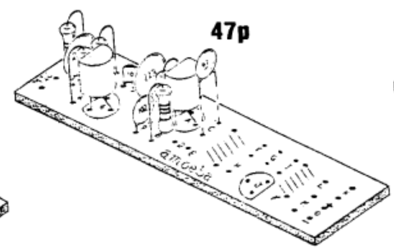
The 390R (orange-white-brown) resistor is next and fits down holes marked 'B'. Keep it pressed against the board as before and solder neatly. Cut the leads off.



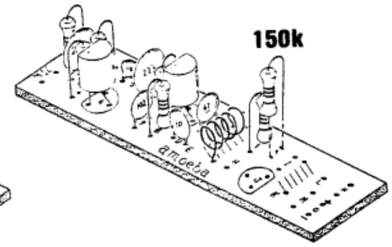
Next fit the 100R (brown-black-brown) resistor into holes marked 'F' and solder as before.



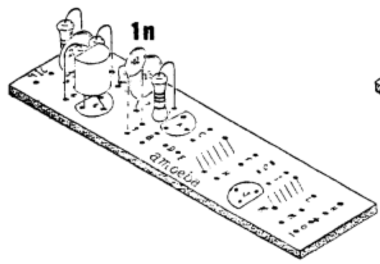
Next fit a 47k (yellow-purple-orange) resistor down holes marked '8' and solder quickly as before.



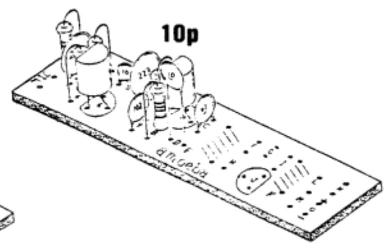
Next fit a 47p ceramic into holes marked 'C.' The capacitor will be marked 47 on the body and solder quickly to prevent overheating.



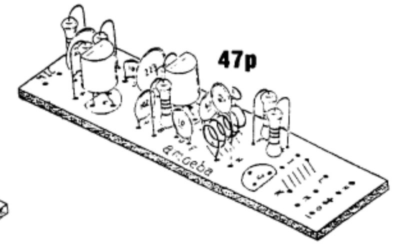
The 150k (brown-green-yellow) resistor is next. It is soldered into holes marked 'G' and the leads cut off.



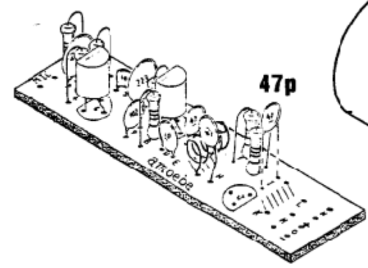
The next component is a 1n (marked as 102) ceramic capacitor. It fits down holes marked '9' and soldered quickly.



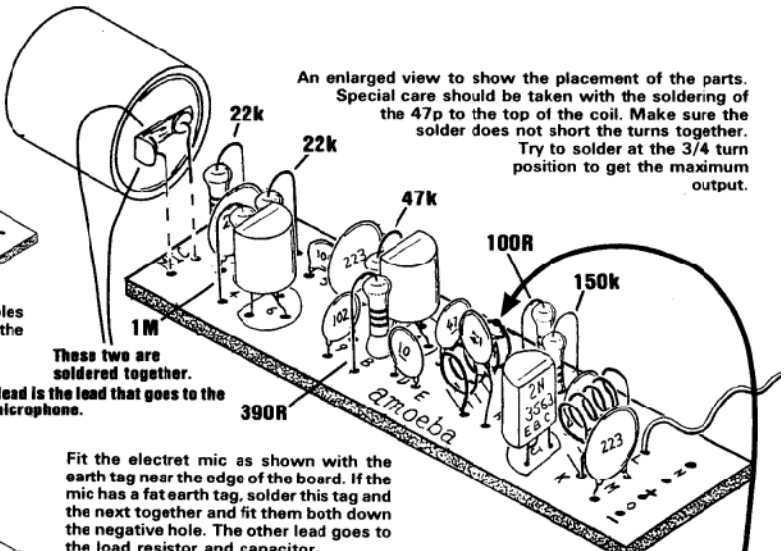
The 10p ceramic fits down holes marked 'D' and should be kept away from the area allocated to the coil.



The next component is a 47p capacitor. One end is soldered to the top of the first turn of the coil and the other end fits down hole 'H.' If possible, try to connect to the 3/4 turn of the coil as this will give better output. See photo on next page.



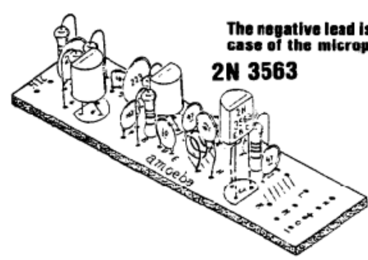
Next is a 47p capacitor that fits into holes marked 'I.' Push it firmly against the board and solder quickly.



An enlarged view to show the placement of the parts. Special care should be taken with the soldering of the 47p to the top of the coil. Make sure the solder does not short the turns together. Try to solder at the 3/4 turn position to get the maximum output.

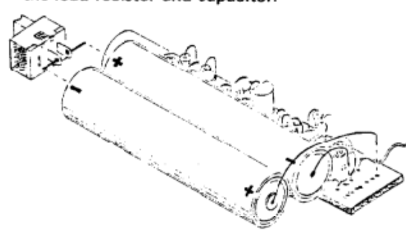
These two are soldered together.

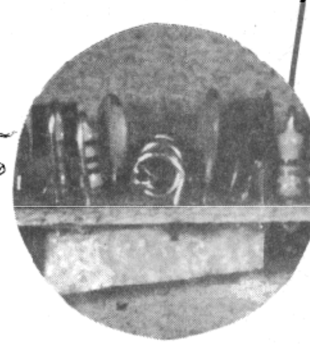
The negative lead is the lead that goes to the case of the microphone.



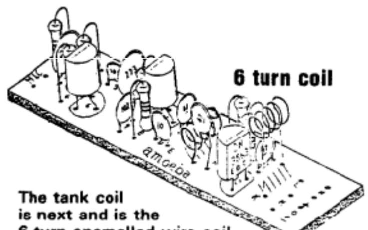
The final transistor is a 2N 3563. It fits down holes marked 'J' and pushes neatly up to the board and soldered quickly to prevent over-heating.

Fit the electret mic as shown with the earth tag near the edge of the board. If the mic has a fat earth tag, solder this tag and the next together and fit them both down the negative hole. The other lead goes to the load resistor and capacitor.



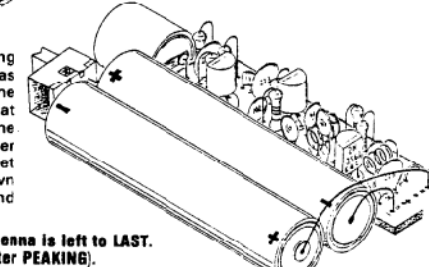


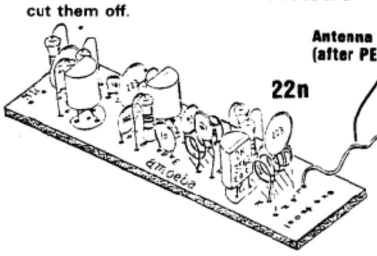
A close-up of the 47p soldered to the 3/4 turn position on the oscillator coil.



Solder the switch to the batteries. The positive end of one battery goes to the positive on the board via a length of hook-up wire and the negative lead goes to the negative on the board via tinned copper wire.

The tank coil is next and is the 6 turn enamelled wire coil. Firstly remove the insulation from about 1/2cm from each end by heating the wire with a soldering iron that has been tinned with solder. Refer to the diagram for the lead length to see what we mean. After a few seconds the insulation will burn away and the solder will 'take.' Don't breathe the fumes or let them get in your eyes. Fit the coil down the holes marked 'K.' Solder the leads and cut them off.





Antenna is left to LAST. (after PEAKING).

The antenna can be left to last and is fitted down hole marked 'L.' The next component to add is the 22n ceramic (marked 223) and fits down holes marked 'M.' Solder in place and trim the leads.

You should now refer to the photos and note the position of the 8 turn RFC at the end of the board. Scrape the enamel off the leads and tin them before soldering the coil to the board.

This completes construction and you are now ready for the tuning operation and peaking. This involves selecting a frequency on which you will transmit that is away from any radio stations and peaking the circuit to get the maximum output.

TESTING AND PEAKING

You may think our method of testing a transmitter is back-to-front because we start at the output and work towards the front end. But when you look at it more closely, you will see why.

Once you have the output stage working, you have a starting point and from there the procedure is fairly straight-forward.

The output of the transmitter consists of two parts. The base part is called the 'carrier' and this is a constant frequency. If we are transmitting at 100MHz, it is a 100MHz frequency. Added to this is the audio component and this causes the base frequency to increase and decrease by an amount equal to the audio frequency being picked up by the microphone.

This audio tone FREQUENCY MODULATES the carrier and this gives the term FM transmission.

We use this knowledge to fault-find the project. Our first concern is to be able to detect the carrier. This is picked up on an FM radio as a 'dead spot' or 'clear spot' on the dial when the transmitter is on. When the transmitter is turned off, the background noise appears.

The carrier is produced by the oscillator

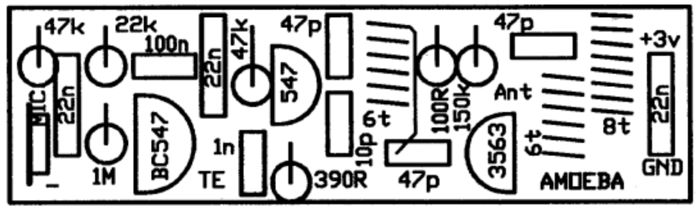
Trackwork for the Amoeba

stage (the BC 547) and the linear amplifier (the 2N 3563) will transfer this frequency to the antenna with increased driving power. When we detect a carrier, we prove that both stages are working. If a dead spot is not heard, you should firstly assume the frequency of transmission is off the FM band.

To adjust the transmitter, all you need do is stretch the turns of the oscillator coil (making sure they do not touch each other if bare tinned copper wire is used). Tune across the entire band on the FM radio, looking for a silent spot.

The bandwidth of the transmitter will be quite narrow and it will be necessary to sweep the band fairly slowly. If nothing is heard, go over some of the simple faults such as making sure the project is ON, the radio is on the correct band (88MHz to 108MHz), the radio has an antenna connected and no metal objects are near the transmitter.

You must detect a carrier before progressing any further. This is the starting point and no other sections can be tested until this is successful. Unless you have a 100MHz CRO, there is no other way to see if the project is transmitting.



Amoeba overlay showing the position for all the components.

This is not exactly true as another solution is to make a second model. If the second model works successfully, (and I see no reason why it shouldn't), you can use it to physically check the spacing of the coil, placement of the parts and the position on the FM band, to see why things are not coming through on the first model. When a dip is heard, you are half-way home.

In fact you are 90% home. The rest is down-hill. The next step is the testing of the audio stage or stages. Although the project contains one audio stage, we can consider the microphone to be a stage since it is an active device containing a FET transistor.

If either the microphone or pre-amplifier stage does not work, you will only get a carrier output. Make sure the voltage on the microphone is at least 50mV and the collector of the pre-amplifier is at least .8v.

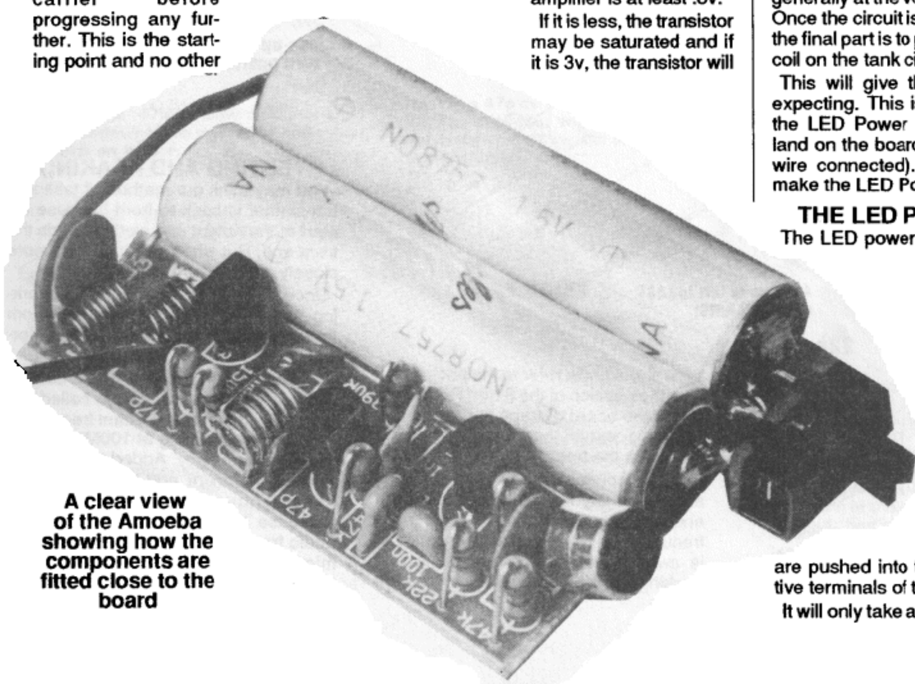
If it is less, the transistor may be saturated and if it is 3v, the transistor will not be conducting. Check the base voltage also. It should be .65v. If this fails to locate the fault, you can use almost any CRO to pick up the waveform at a number of locations on the board, around the audio section.

By whistling into the microphone and picking up the waveform at the output of the mic (at the point where the load resistor connects to the mic), you will be able to see the output of the microphone.

Next, pick up the waveform at the other end of the coupling capacitor and note that some of the amplitude has been lost. This point is also the base of the audio transistor and you can determine the gain of the transistor by comparing the output with the input. The gain should be between 50 and 100.

The output is injected into the base of the oscillator stage via a DC blocking capacitor and this is where the CRO capability finishes. You will need a 100MHz CRO from now on. You should adjust the oscillator coil to a frequency away from a radio station and this is generally at the very bottom of the band. Once the circuit is working successfully, the final part is to peak it by adjusting the coil on the tank circuit.

This will give the range you will be expecting. This is done by connecting the LED Power Meter to the antenna land on the board (without the antenna wire connected). But first we have to make the LED Power Meter.

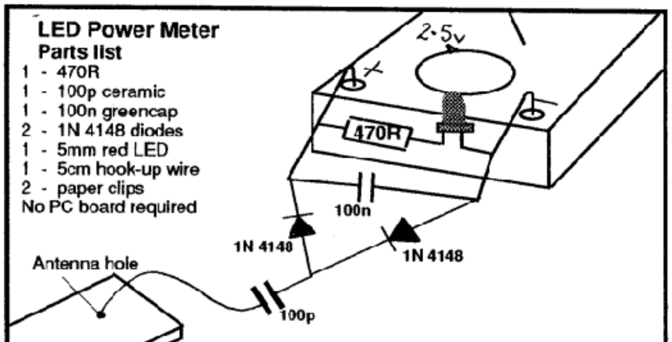


A clear view of the Amoeba showing how the components are fitted close to the board

THE LED POWER METER

The LED power Meter is a simple RF detector using diodes to charge a capacitor. The voltage developed across the capacitor is shown on a multimeter set to a low voltage range. The circuit is soldered together without the need for a PC board, as can be seen in the diagram above and the two paper clips are pushed into the positive and negative terminals of the multimeter.

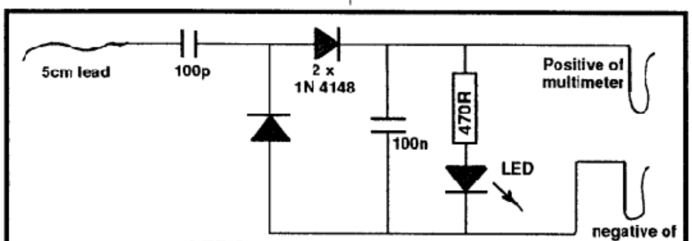
It will only take a few minutes to put this



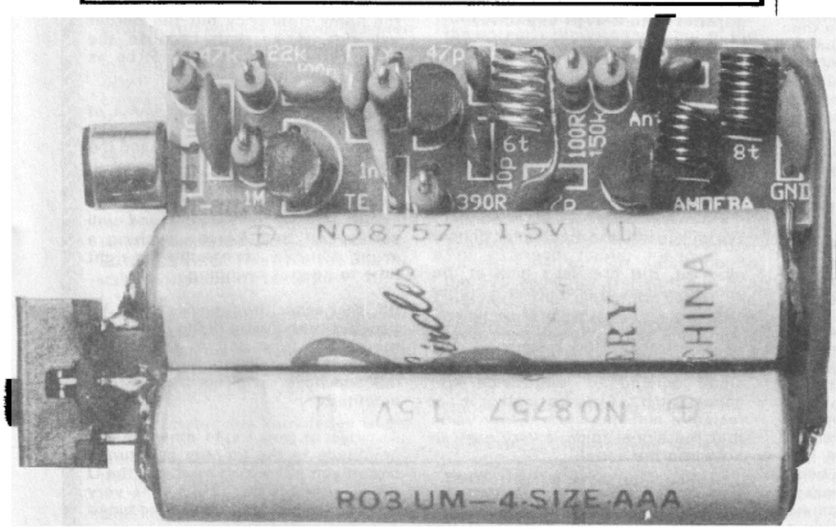
Using the LED Power Meter to peak the output.

circuit together and you are ready for the Peaking operation. The LED Power Meter has two ranges. The low range measures output voltage up to about 1.5v and at this level the LED does not come on as it requires at least 1.7v for it to turn on. Thus the LED does not put any load on the circuit so you can measure very low outputs such as the oscillator stage.

As the voltage rises over 1.7v, the LED starts to turn on and thus the circuit turns onto a POWER METER to measure milliwatts of output power. This power is indicated by the illumination of the LED and since a LED can't lie, you can compare the output of one transmitter with another.



LED Power Meter circuit


Completed Amoeba project with batteries and switch attached

USING THE LED POWER METER

Connect the 5cm wander lead to the collector of the oscillator transistor on the Amoeba board and turn the project on.

The lead of the LED Power Meter will act as an antenna, so place a radio nearby and tune it to about 88.5MHz or somewhere at the low end of the band. Move the turns of the 6 turn oscillator coil either together of stretch them apart until a feedback whistle is picked up by the radio. This is the frequency of transmission.

When the turns are pushed together the frequency decreases and when moved apart, the frequency increases.

Now place the wander lead from the LED Power Meter onto the antenna point on the board and move the turns of the 6 turn tank coil either together or apart until the reading on the Power Meter is a maximum.

You must not use any metal objects near the coil as you do this as this will upset the reading.

The best item to use is a match or plastic knitting needle as you should keep your fingers and hands away from the coil while adjusting it.

The circuit will peak to about 1.25v to 1.65v (the voltage will depend on the quality of the transistors). Once you are satisfied the output is a maximum, remove the LED Power Meter and solder the antenna lead to the board.

Move the radio a short distance away and tune across the band to make sure the output is only coming through at one spot on the dial.

If you get two spots, the frequency of the oscillator and tank circuit do not coincide. Go back and adjust the tank coil until the two frequencies are the same.

When this is done, the project will be "peaked" and will deliver the maximum output.

The project is now ready to fit into a Tic Tac box. The ON/OFF switch can be operated by opening the lid and switching the bug on. It does not matter if the lid is open or closed, the microphone will pick up the faintest sounds in a room and transmit them to an FM radio up to 400 metres away. Of course, this will depend on the positioning of the antenna and the quality of the radio. The antenna should be stretched out and placed over a high shelf etc so that the signal has an opportunity to radiate effectively.

Do a bit of experimenting and you will be very impressed with the performance.

THE TANK CIRCUIT

By now you will be aware that the only major difference between the ANT and the AMOEBA BUG is the TANK CIRCUIT.

This circuit consists of a 6-turn coil in parallel with a 47pf capacitor. It looks to be a minor improvement and you may think it will make little difference to the performance of the circuit. But you will be wrong!

It makes an enormous difference and the way these two components function is very impressive.

In fact the theory behind the way they function is so complex that it could take pages to fully explain. The reason is that they are RESONATING at the same frequency as the oscillator circuit and this means that the voltage and current flowing in and around the tank circuit is completely different to what you may think.

When a coil and capacitor are resonating a number of new terms are encountered and the voltages and currents are considerably higher than the rail voltage and the supply current.

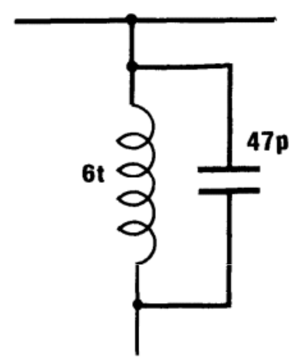
That is why it is so different. In our testing, we found the output was only a few millivolts when the circuit was non-resonant (i.e. with a 330R load resistor) and increased to over 1200 millivolts when it was TUNED.
Tuned means resonating (this term is very similar to the word oscillating) and to get the parallel circuit to resonate the turns of the coil must be compressed or expanded until the output power is a maximum. Our simple power meter is connected to a multimeter and will indicate when the maximum power is being delivered to the antenna. A fairly simple device, but it works.

The phenomenon of resonance makes the output stage considerably more efficient than using a load resistor as the same energy is being taken from the battery but more is being transferred to the antenna. Very little is lost in the tuned circuit.

When we talk about a resonant circuit we mean a circuit that is resonating and more specifically a circuit that is receiving pulses of energy arriving at the precise moment to keep the circuit swinging back and forth exactly like pushing a swing at the correct instant.

If we take the swing example, it can be pushed such that it swings back to a position that is higher or further up the arc than the pusher! You have possibly done this many times.

Exactly the same can happen in a resonant circuit. The voltage developed across it can be as much as 100 or even 300 times greater than the applied voltage. This means that a 12v circuit could see a voltage of 3600v across the capacitor (and coil)!



This is the tank circuit we are talking about - A 6 turn coil in parallel with a 47pf capacitor.

This is theoretical and applies to an unloaded resonant circuit. As soon as you connect it up, and ask it to deliver, the output drops to between 2 and 100. Even so, you can see that a parallel combination is making the output stage two or more times more efficient than a purely resistive load.

We will go into the mechanics of how a resonant circuit operates in a moment. But first let's look at the consequences of producing a higher voltage.

At the transmitted frequency, the aerial is seen as a resistive load plus a small amount of inductance and capacitance. But basically it is resistive and has such a low value that the signal finds it very easy to flow into the aerial.

This means energy is lost from the circuit in the form of electromagnetic radiation. When the voltage at the aerial is increased it will allow a higher current to flow into the antenna and thus the output power will increase.

This means that when a tuned circuit produces a higher voltage, more energy will flow into the aerial and this gives us the improved performance we have called the AMOEBA.

In terms of increased efficiency, our output power detector circuit showed an enormous increase as mentioned previously and when related to range, our field tests showed this to be increased at least double, even under the worst conditions.

THE Q FACTOR

This leads us to another very important term that relates to the efficiency of a tuned circuit. It's called the **Q** factor.

There are a number of ways of defining the Q factor but basically it is the ease with which a resonant circuit oscillates. If we place a coil and capacitor in parallel and put them in the middle of our work bench, nothing will happen. But if we connect a wire to one end, chances are the circuit will resonate.

This is because the wire will pick up radio signals and one of the signals may be the exact frequency of the tuned circuit.

If you decrease the value of the coil (open up the turns or remove a turn) and increase the value of the capacitor, the circuit will resonate at the same frequency but the output will not be as high because the energy from the coil will not be as much as before.

Thus there is an optimum value of inductance/capacitance for any given frequency and this is called the optimum L/C ratio.

The signal picked up by the tuned circuit will be very small and will correspond to a person pushing a swing minutely, at exactly the right time to keep it swinging.

All the other frequencies will be similar to the swing being pushed at the wrong time and in the wrong direction and will cancel each other out and have no effect on the final amplitude.

As soon as you try to measure the amplitude of the voltage in a tuned circuit you put a load on it and the Q drops enormously. Thus it is very difficult to observe an unloaded tuned circuit.

The second amazing fact is a high Q circuit will respond to only 1 frequency and as the Q factor is lowered (through loading or poor selection of coil and capacitor values) the 'frequency-band' increases.

Thus it is important to have a high Q circuit, so that only the required frequency is produced. This is called selectivity and makes the bug transmit all its energy on a very narrow band.

The tank circuit must be fine tuned to match the oscillator frequency and this is done by adjusting the spacing of the turns of the coil.

The exact set-up procedure is covered in the main part of the article and you will need a detector circuit and multimeter to peak the output.

HOW THE TANK CIRCUIT WORKS

We have said the tank circuit produces a voltage greater than the supply voltage. But how does this happen?

To understand this you need to know about collapsing magnetic fields. When an electro magnet is switched off, the collapsing magnetic field produces a voltage in each of the turns that is in the opposite direction to the applied voltage and because the magnetic field collapses very quickly the voltage can be as much as 100 times or even higher than the applied voltage.

Take the example of a buzzer, relay or spark coil in a car.

If you connect a buzzer to a power source, you will see a spark between the points. This is the high voltage jumping the air gap as the points open. The same will happen if you connect a relay to a battery and touch the two ends of the coil with wet fingers. You will feel a tingle as soon as the relay is removed from the battery.

This is due to the collapsing magnetic field producing a voltage in the winding and this can be as much as 80 to 100 volts. This time you feel the voltage instead of seeing it.

The size of the voltage will depend on the number of turns and the amount of magnetic material in the core but it is important to note that the voltage is higher than the supply.

If we transfer this knowledge to the tank circuit, we see how the higher voltage is produced. It comes from the inductor.

But how does the circuit resonate and what does 'resonate' mean?

Resonate means oscillate at a frequency that is natural (characteristic) for a given value of inductor and capacitor.

If we connect a coil and capacitor in parallel and place them across the terminals of a battery, the capacitor will be in an uncharged state and will charge up. The current will also produce a magnetic field in the coil but let's neglect this for the moment.

When the supply is removed, the charge from the capacitor will flow into the coil and produce a magnetic field. After a short period of time the capacitor will become discharged and unable to maintain the field.

At this stage the field collapses and produces a voltage in each turn that is of opposite polarity and higher than before.

The energy in the collapsing magnetic field is converted to electricity and this charges the capacitor.

The energy will be less than before due to losses in the system and the capacitor will receive only a fraction of the original. However some WILL be returned.

If we provide a transistor arrangement that turns on at the precise instant when the capacitor is charging, it will be able to add energy and top-up the capacitor. This will give us the same amount of energy as we had at the start of the cycle.

This is what happens in the tank circuit. The transistor injects energy into the capacitor and turns off. But the antenna draws energy out of the circuit and to see the effect it has we need to go back to the beginning of the cycle.

Let's start at the instant when the transistor turns ON. This action draws one end of the tank circuit low. The antenna sees this low potential and very little energy will be radiated but the 47pf capacitor will charge.

The next thing to happen is the output transistor will turn off. This is due to the 47p capacitor and works in this manner: The waveform from the oscillator circuit is only a maximum for a short period of time and once it starts to fall, it draws the 47p low and charges it for the next cycle. This action robs the base of the output transistor with turn-on voltage.

The result is the transistor turns OFF.

The 47p in the tank circuit delivers its energy to the coil and at the same time a very small amount to the antenna. This discharges the capacitor and when the energy has almost been spent, the magnetic field starts to collapse.

We have seen what happens and now the higher voltage from the coil is sent back to the capacitor and antenna.

This high voltage sees the antenna as a low resistance and readily flows into it. Thus the returning energy is split between the antenna and capacitor.

Ideally most of the energy flows into the antenna and little into the capacitor so that when the transistor turns on, it needs a fair amount of topping-up.

The voltage appearing at the base of the antenna could be twice or three times the supply voltage and this represents the Q of the tank circuit.

The loading effect of the antenna will affect the Q of the circuit and to reduce the loading a small capacitor (10pf to 33pf) can be inserted in the base of the antenna.

As the Q is raised, the bandwidth of transmission is narrowed and the energy becomes concentrated on a narrower and narrower band.

The voltage on the antenna also increases and thus the range is improved.

There are optimum values for all this and it will take experimenting to get the best results.

The main point of the exercise is to see the advantage of the tank circuit and to realise that much less loss is incurred than with a load resistor.

The tank circuit DELIVERS to the antenna by converting the pulses of energy from the output transistor into a smooth waveform that is ideal for producing electromagnetic waves.

The diagrams on the opposite page can also represent the Q of the oscillator circuit or the Q of the tank circuit. They apply whenever energy is picked off a coil/capacitor combination.

As the coupling capacitor is increased (we have used 47p in the Amoeba), or the antenna load is increased, the pick-off will be greater but the Q of the circuit will decrease so you may not get any improvement. You have to experiment to get the best output.

The drastic lowering of Q means you are beginning to transmit on two different frequencies. This is obviously undesirable and the only way to avoid it is to use a radio to detect if one or two peaks are present.

A high Q circuit also introduces two other design factors. These are 1. The ratio of the diameter of the coil to its length and 2. the L/C ratio of the tuned circuit.

It's difficult to know where to start when designing a high Q circuit but if you begin with the coil, everything else will fall into place. This is because the inductance of the coil (or more accurately its efficiency) plays the most important role.

The efficiency is the amount of energy released, compared with the amount of energy inputted and this depends on many factors, one of which is the ratio of the diameter of the coil to its length.

Ideally the length should be between one and two times the diameter and this will allow the collapsing magnetic field to have maximum effect when cutting the adjacent turns.

The other factor **L/C RATIO** means the value of the capacitor must be chosen so that at the resonant frequency, the inductive reactance of the coil (in ohms) is equal to the capacitive reactance of the capacitor (also in ohms). This means the energy contained in the capacitor will be just the right amount that can be handled by the coil.

Wire size for the coil is not important, as such, but a fairly thick gauge will keep the turns in position whenever the project is handled and that's why it has been chosen.

The one thing that is important is the placement and type of capacitor. A ceramic capacitor has been used in the prototype and you should keep to this type as other types (such as mica or styro) have a different reactance value at high frequencies. Also it is important to keep the leads short (as shown in the drawings) as long leads on the capacitor or coil will alter the inductance value considerably.

After all, we are talking about pf (puff) values and microhenry values and a change of only a few per cent will take the operating frequency off the band.

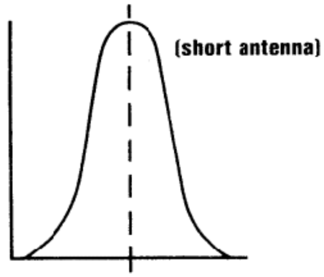


Fig. 1(a): HIGH 'Q.'

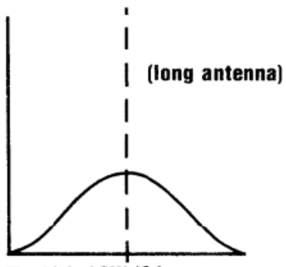


Fig 1(c): LOW 'Q.'

THE EFFECT OF ANTENNA ON Q OF A TANK CIRCUIT:

As the length of the antenna increases, the impedance and effective Q of the tank circuit decreases. Fig 1(a) shows the effective Q of the tank circuit when a short antenna is coupled to the output. This represents an antenna of about 2cm to 10cm long.
Fig 1(b) shows the Q when a medium length antenna is connected, such as 10cm to 30cm.
Fig 1(c). As the antenna is increased in length, the resonance curve becomes broader and the Q value decreases, however this is the optimum condition as the maximum amount of energy is being transferred to the antenna.
Fig 1(d). If the antenna is loaded (such as holding it with your hand), the resonance curve becomes even broader and double resonance humps develop with very poor energy transfer resulting.

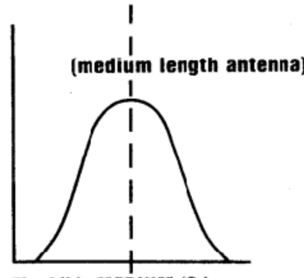


Fig 1(b): MEDIUM 'Q.'

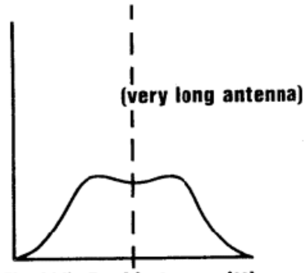


Fig 1(d): Double transmitting humps due to heavy loading effects.

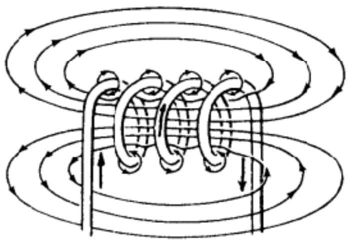


Figure 2 is a simplified diagram of the magnetic lines of force surrounding the oscillator coil when a current is flowing.

Use Flemings Right Hand curled fingers rule to determine the direction of flux (and thus the North Pole) when the direction of current flow is known.

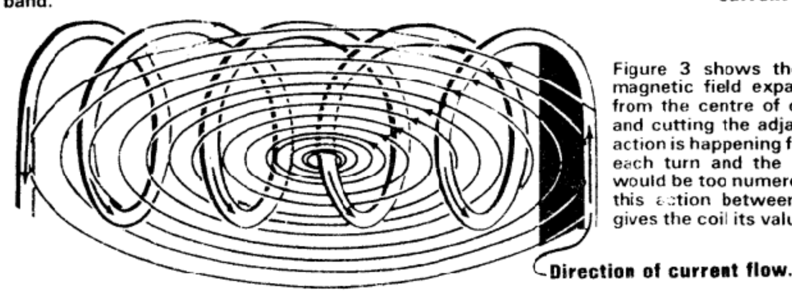


Figure 3 shows the action of the magnetic field expanding outwards from the centre of one of the turns and cutting the adjacent turns. This action is happening from every part of each turn and the number of lines would be too numerous to draw. It is this action between the turns that gives the coil its value of inductance.

JOB INTERVIEW

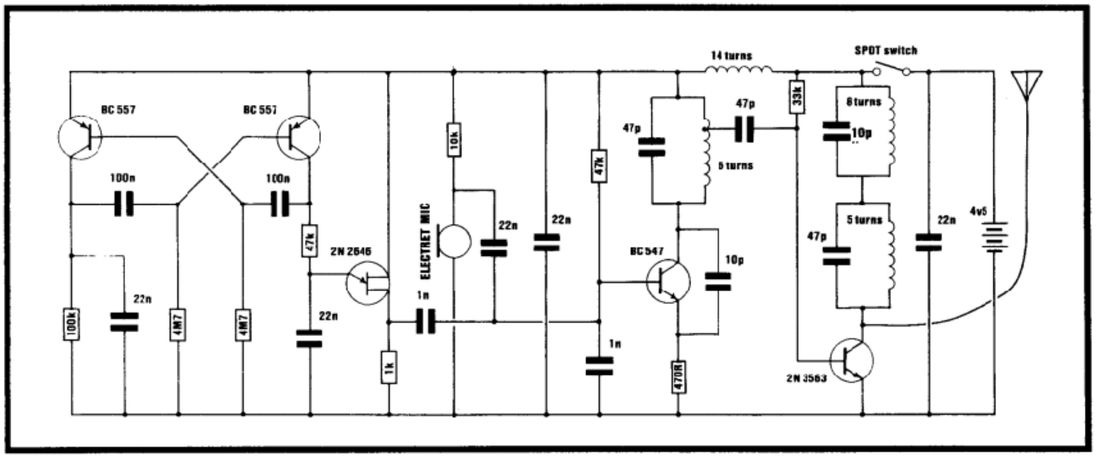
I get asked all the time, what preparation should I do for a job interview?
If you intend entering the electronics field, you can consider taking a number of projects with you.
This will draw the attention of the interviewer and show you have an interest and understanding of electronics. Just about any projects are suitable.
It has worked in the past and I am sure it will work for you.

HIKERS ALARM

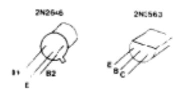
Kit of parts: $20.35 USD
Postage: $4.50 USD
LED Power Meter: $1.25 extra

A handy alarm for bushwalkers

email Colin: talking@tpg.com.au for paypal details



HIKERS ALARM CIRCUIT



Due to lack of space in this issue we have had to reduce the Hikers Alarm article from four pages to two.

We have also changed the PC board to a new CAD (computer drawn graphics) design to make the project easier to put together. All the components are now marked on the board and the 10p ceramic is on top of the board so don't go too much by the old photo we have included. It just gives the approximate position and size of the components but little more.

The idea of the Hikers Alarm is to provide a light-weight, low-cost beacon that can be carried by bushwalkers and anyone going on a venture.

In the event of an accident, the beacon can be set up very quickly by throwing the antenna over a tree and turning the unit on.

Sadly, many adventurers get into trouble, even on week-end walks, and this project could save a life. Sometimes the search party can come within metres of an accident victim and still fail to locate him - he may be unconscious or simply unable to hear them.

Or more often the search party cannot see or hear him due to the foliage or other obstructions.

Our tests showed the range of the Hikers Alarm to be a few kilometres in a built up area and it should be about the same in a wooded or slightly hilly area. To pick up the beacon, a standard FM radio is tuned to the lower part of the band to detect a beep - beep - beep tone.

This project will increase the chances of discovery many-fold and with a battery life of about 48 hours it can be used during daylight hours to get about 5 days of transmission.

The Hikers Alarm has been a reasonably popular kit but when it is responsible for the saving of a life, it will gain a much greater demand.

To track the signal requires RDF equipment. This simply means a Radio Direction Finding receiver and the essential part of a direction finding radio is an antenna that is capable of being rotated.

The simplest antenna is a rectangular or frame antenna and you can construct this on a frame 30cm x 30cm with 25 turns of hook up wire. The radio should also have a signal strength meter so that when the antenna is rotated the meter will deflect to indicate the strength of the signal.

At maximum deflection the signal must be coming from the front or rear of the antenna. You have to choose one of the directions and take a further reading along the track to see if the signal has increased or decreased.

In this way you 'home-in' on the beacon and locate the source.

ASSEMBLY

This isn't a beginners project. The components are fairly compact and you need a fair degree of skill to get everything onto the board and peak

PARTS LIST

1 - 470R
1 - 1k
1 - 10k
1 - 33k
2 - 47k
1 - 100k
2 - 4M7
2 - 10p ceramics
3 - 47p ceramics
2 - 1n ceramics
5 - 22n ceramics
2 - 100n monoblocks

1 - BC 547 RF oscillator transistor
2 - BC 557 multivibrator transistors
1 - 2N 2646 UJT transistor
1 - 2N 3563 RF output transistor

1 - 5 turn .5mm enamelled wire 3mm dia coil
1 - 6 turn .61mm tinned copper wire 3mm coil
1 - 8 turn .5mm enamelled wire 3mm dia coil
1 - 14 turn .5mm enamelled wire 3mm dia coil

1 - electret mic - cut PC board to fit mic.
1 - SPDT mini slide switch
1 - 3 metres antenna wire
3 - 'N' cells.

1 HIKERS ALARM PC board

the output.

The first thing to do is cut the board so that the microphone fits over the edge. Don't fit the microphone until last so that the leads are not fractured by movement.

Use the photos and diagrams on this page to help fit the components. Some parts are very easy to fit and these can positioned first. This will leave vacant holes to help you position the rest of the parts.

The 47p that taps onto the 6 turn oscillator coil is soldered to the first turn (near the positive rail) as shown in the photo.

Keep everything close to the board so that the whole project will fit into a Tic Tac box.

The switch is fitted to the board with 3 short lengths of tinned copper wire and the top of the switch is kept as high as possible so that it can be turned on and off through the door of the Tic Tac box.

The 8 turn and 14 turn coils mount upright on the board and the 5 and 6 turn coils lay flat.

The last component to add is the microphone. The negative lead is the one that goes to the case of the microphone.

Clean the bottom of each 'N' cell with a file or sandpaper before tinning with a hot iron. They are then soldered together with tinned copper wire and soldered to the board.

This completes the assembly and the next step is to adjust the frequency to between 88.3MHz and 90MHz and peak the output. We have picked this band as it is the low end of the FM band and provides the best range. Don't go below 88.3MHz as some drift in the frequency may occur as the batteries get used up and we don't want the frequency to go off the band.

You won't have to worry about a clear spot on the band as there are very few stations in the country areas, where you will be using the alarm.

PEAKING

Fit the peaker or LED Power Meter to the collector of the oscillator transistor and turn the unit on. A reading on the meter will indicate the oscillator is working and

Full-size layout of the PC board showing how small the board really is.

you should tune a radio to about 88.5MHz and put the radio about 3-4 metres from the project.

Squash or separate the turns of the 6 turn coil until you hear a beep in the radio and also a feedback whistle. Moving the turns apart will raise the frequency of transmission and squashing them together will lower it.

The Peaker circuit is simply used as an antenna at the moment and it is now transferred to the collector of the output transistor (2N 3563).

Without touching the tuning of the radio, move the turns of the 5 turn tank coil until the beep and feedback whistle are heard again.

This will make the oscillator and tank stages operate at the same frequency and you will notice the output of the circuit will increase when this occurs.

We now adjust the spacing of the RFC coil by watching the meter and noting when it has a maximum reading.

You may like to fit the antenna and test the circuit for range. The tank coil may need fine adjustment due to the loading effect of the antenna.

The circuit is now peaked and ready for last minute finishing touches.

It's a good idea to mark the "ON" position for the switch with red nail polish so that you can see when the circuit is ON.

IF IT DOESN'T WORK

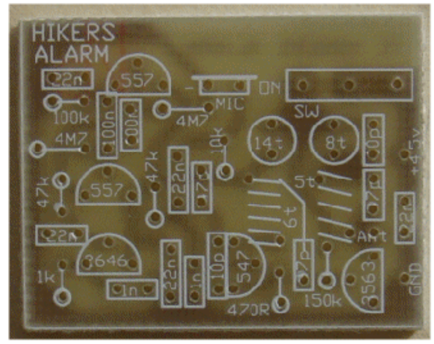
If the project doesn't work, you will have to work out where the fault is coming from by referring to the full article. Photocopies are available for $2.00 as the original book has now fully sold out. There are 5 sections in this project and you must concentrate on one at a time. But before doing anything, read the article so you know how to approach the problem.

THE CASE

The project has been designed to fit into a Tic Tac box and you should be able to fit the works neatly if you have followed our instructions.

The 3m antenna passes through a hole in the bottom of the box and is wound up neatly, ready for use.

Place everything into a zip top bag so that it won't get wet and it's ready for the next time you go for a hike.



ENLARGED VIEW OF THE HIKERS ALARM ARTWORK

Note: This is an old photo. The 10p is now mounted on top of the board and the overlay shows where everything goes.

VOX Mk IV with BEEP

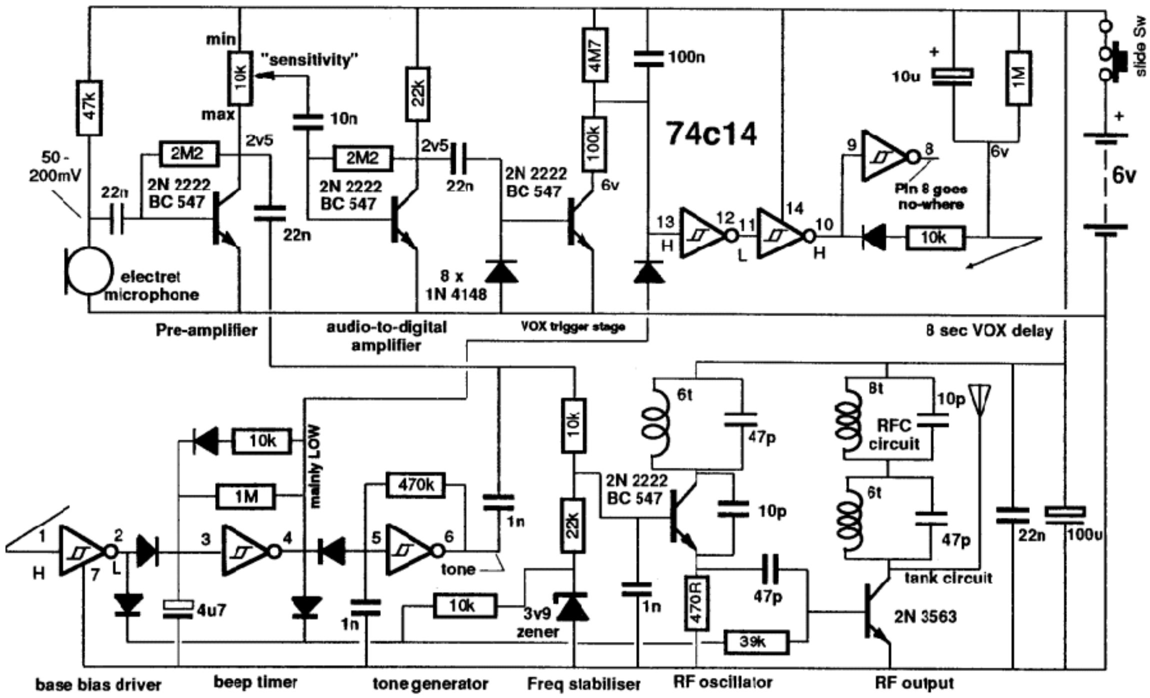
VOX = Voice Operated Switch

OUR LONG-RANGE VOICE-OPERATED FM BUG

Kit of Parts: $25.80 USD
Post: $4.50 USD

LED power meter required to peak the bug: $1.25 USD

email Colin Mitchell to pay by PayPal: talking@tpg.com.au



VOX Mk IV with BEEP

Note: DC voltages during beep mode

This VOX Bug takes over from our MkIII model and overcomes two slight problems that showed up when the MkIII kits went out for construction by our readers. This first improvement makes sure the beep comes through on the same frequency as the audio.

We also re-designed the circuit so that the oscillator was biased by a zener voltage. This provided a degree of stability so that the frequency was kept stable as the supply voltage fell during the life of the batteries.

The second improvement is extra sensitivity in the VOX section. We added a transistor (we called it the VOX trigger stage) after the analogue-to-digital stage to increase the waveform even further so that the bug turns on with a whisper at 3 metres.

If you haven't been following our series on FM transmitters you should read the article on VOX Mk III. It will bring you up to date with the development of these circuits and show you the order in which they were developed and our suggested order for building them.

FEATURES
Range: about 1800ft - 600metres
Current: .8mA on beep
10-12mA on transmit
Supply: 4 x AAA cells
Battery life: 600-800Hrs
Frequency range 88-108MHz
Vox sensitivity: turns on with speech at 15ft (5 metres)

We have already mentioned that FM is by far the most efficient way to transmit as a few milliwatts will produce a signal that will reach up to 1km with clarity as good as any commercial FM station.

Keeping this in mind we consider this circuit to be the most advanced on the kit market.

It offers the advantage of consuming very little current (about .8mA) when in the listening mode and provides a homing beep so you can tune into the frequency at any time and be able to pick it up when the bug turns on.

This means the transmitting current (10 - 12mA) is only drawn when noises or voices are detected and the life of the battery can be increased by some 800% or more.

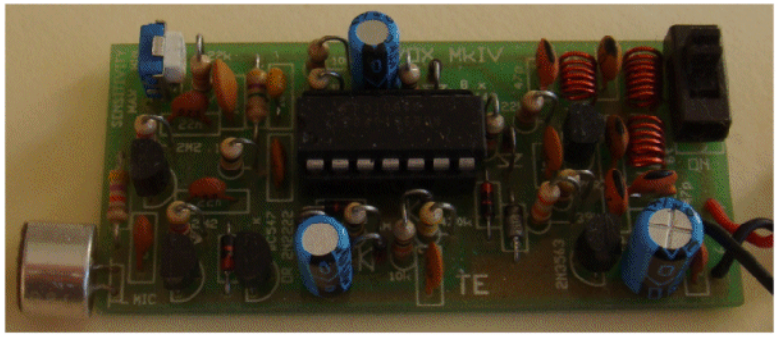
By careful peaking of the circuit and placement of antenna, you will be able to get an output with a coverage of 1km or more.

Its uses can extend to protection of house and property, cars, equipment, factories and almost anything you wish.

We have found that nothing is safe from prying eyes and itchy fingers. We have had thousands of dollars worth of goods stolen and had to increase our security considerably.

The VOX IV is one of the devices we use and have added it to our surveillance range in made-up form, for those who are not able to put things together themselves.

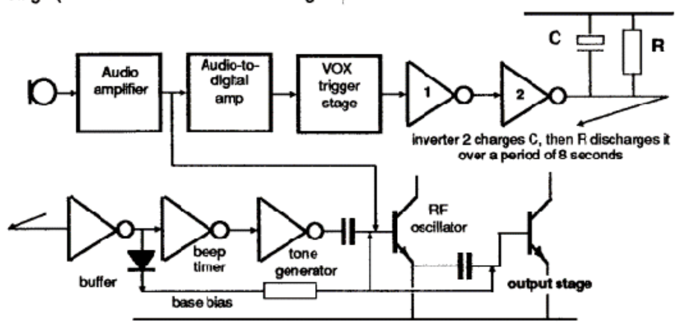
HOW THE CIRCUIT WORKS



A close-up view of the VOX MkIV

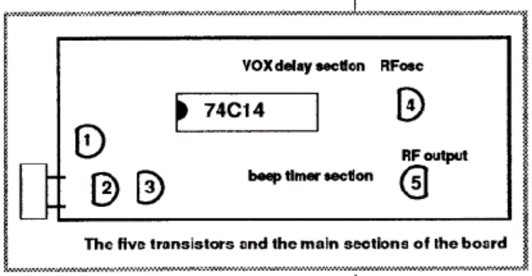
The circuit picks up sounds with a sensitive electret microphone and passes the signal to a common emitter amplifier using a 2N 2222 or BC 547 transistor. We have called this stage the audio amplifier stage. Almost any transistor can be used and we have used the most common type to indicate that it is not special. This stage is common to both the audio and VOX signals and amplifies them about 70 times before sending them in two directions, one through the mini trim pot to the VOX section and the other through a 22n-22k to the transmitter.

The load for the amplifier is a 10k mini trim pot and when the wiper is near the positive rail, the output is zero. As the wiper is brought towards the collector, more of the VOX signal is picked off and passed to another common emitter stage (we have called the audio-to-digi-



BLOCK DIAGRAM OF VOX MkIV

tal stage) that amplifies it further. The next stage we have called a VOX trigger stage and is designed to convert the audio signal to a digital signal to operate a Schmitt trigger inverter. A Schmitt trigger inverter requires a fairly large signal for it to change from one state to the other and the VOX stage does this by being biased OFF and only turning ON when the input signal is above .6v. This



The five transistors and the main sections of the board

nakes the stage noise-free and produces almost full-rail swing when audio is detected. The diode on the base sends the negative parts of the signal to ground (the negative rail) and leaves only the positive portions to turn on the transistor.

Since this stage is off when not required, it draws no current when the bug is in the beep mode. This makes the input of the Schmitt inverter HIGH via the 4M7 resistor and when audio is detected, the 100n capacitor is charged via the 100k resistor. The object of the 100n is to stretch the pulses so that the 10uF electrolytic at the output of the two inverters is charged by a wider stream of pulses.

Now for a little background on the Schmitt trigger.

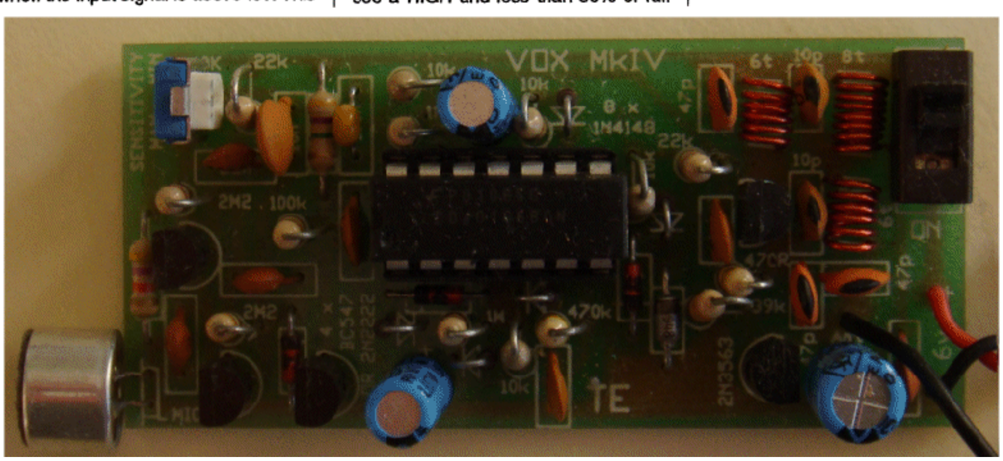
A Schmitt trigger requires a level greater than 70% of rail voltage for it to see a HIGH and less than 30% of rail voltage for it to see a LOW. If the supply is 6v, the difference between a HIGH and a LOW is about 40% of rail voltage or a swing of 2.4v (2,400mV).

This is a fairly large waveform and to make sure this amplitude is available when we speak softly at about 3 metres from the microphone, we need plenty of gain. That's why we need three stages. The first two raise the signal to quite a few hundred millivolts and the third gives us a guaranteed 2,400mV or greater signal to operate the digital gate. The analogue-to-digital stage converts the audio signal (analogue signal) into a large signal and the "VOX trigger stage" triggers the inverter.

With three stages of amplification, even the slightest whisper at 3 metres will trigger the inverter. If you were to listen

PARTS LIST

1 - 470R
4 - 10k
2 - 22k
1 - 39k
1 - 47k
1 - 100k
1 - 470k
2 - 1M
2 - 2M2
1 - 4M7
1 - 10k mini trim pot
2 - 10p ceramics
3 - 47p ceramics
3 - 1n ceramics
1 - 10n ceramic
4 - 22n ceramics
1 - 100n monoblock
1 - 4u7 16v electrolytic
1 - 10u 16v electrolytic
1 - 100u 16v electrolytic
4 - 2N 2222A or BC 547 transistors
1 - 2N 3563 transistor
8 - 1N 4148 diodes
1 - 3v9 zener diode 400mW
1 - 74c14 hex Schmitt trigger IC
1 - 14 pin IC socket
1 - electret microphone insert
1 - 6turn .5mm wire 3mm dia coil
1 - 6turn .5mm wire 3mm dia coil
1 - 8turn .5mm wire 3mm dia coil
1 - spdt mini slide switch
1 - 15cm tinned copper wire
4 - AA or AAA cells (comes with AAA)
1 - 4-cell battery holder (extra cost)
1 - 175cm antenna wire
1 - **VOX MkIV PC board**
1 - LED Power meter kit (for peaking) available for $1.25 extra.



to the signal at or around the third stage, it would seem distorted. But this is not important as we are injecting it into a digital stage and the inverter only responds to amplitudes.

We have used two inverters so that the output is HIGH during rest periods and this means the 10uF is uncharged. When audio is detected the input of the first inverter goes low and so does the output of the second inverter. This causes the electrolytic to charge via the diode and 10k resistor.

When the pulses of audio charge the 10uF electrolytic, pin 1 goes LOW and pin 2 goes HIGH. This freezes the beep oscillator by jamming pin 3 HIGH and at the same time supplying voltage to the base of the oscillator and output stages. This turns on the bug for transmitting audio. The frequency of the RF oscillator has been kept stable by zener reference diode on the base so that the voltage will remain constant, even though the supply voltage will drop as the batteries age.

For as long as audio is detected by the microphone, the delay circuit (10uF and 1M) will remain charged and the transmitter will stay active. As soon as the audio ceases, the 10u is discharged by the 1M resistor and after about 8 seconds the transmitter will turn off.

To prevent the tone from the beep circuit triggering the bug into transmission, we have added a diode from the output of the beep to pin 13 of the VOX trigger stage to keep the 100n charged.

Also, to assist in understanding how the inverters sit when in the beep mode we have added letters L=LOW and H=HIGH to the input and output of the gates.

CONSTRUCTION

The overlay on the board shows where all the parts are placed.

We do not expect beginners to tackle this project as it is one of the more advance in the series - try some of the simpler circuits first.

The most important factor in construction is to keep all the components close to the board. Make sure you buy a kit so that all the parts are the correct size and value. Junk parts and old-style components will be too big and you will not be able to keep everything neat.

The coils in the kit are pre-wound and any change from those supplied will alter the frequency at which the VOX transmits. The wire diameter is not extremely critical nor is the fact that the wire is tinned copper or enamelled, but the diameter of the coil is very important as is the spacing of the turns.

After you get the circuit working you can experiment with different sizes and values to see if you can improve the performance. But don't start to experiment until you know what you are doing.

You will notice the layout of the board closely follows the circuit diagram and this is important when fault-finding, as you need to be able to quickly locate each part when trouble-shooting.

The pin-out of the IC dictates where the parts must be placed on the board and this helps when trouble-shooting.

When constructing the project, you can start at one end of the board and work your way across, fitting each part as you come to it. Some parts stand up while others lie down and it is important to fit the IC socket before any other components as some of the parts are very close to it.

You should be aware of the need to fit the diodes, transistors, microphone and electrolytics around the correct way as they will not work in reverse and some of them may be damaged if the power is applied when they are incorrectly fitted. Read our previous articles, such as Ant, Amoeba, Ultima and VOX Mk I, for guidance in determining the polarity of the voltage sensitive components.

TESTING THE BUG

There are quite a number of features in this design and each can be tested separately.

Firstly we will assume the project works when first turned on. If you have followed our instructions and assembled a kit, this will be the case as ALL our designs work first go if you follow the instructions. We test everything thoroughly before presenting it in the magazine.

The only cause for failure will be something minor such as a faulty switch, battery connection, damaged component or solder bridge etc.

The design itself is guaranteed to work as we construct numerous prototypes to make sure everything works perfectly.

However, if yours doesn't work, you can consider yourself lucky as the only way to learn electronics is by trouble-shooting.

It's very important to go through the circuit systematically with non-damaging tests so that each stage is tested individually. Sometimes a test can overload an output of a gate or short-circuit a transistor and these types of tests should be avoided — you only create more problems than you solve.

You must also make sure that every possible test is carried out otherwise you may miss a test and never find the fault!

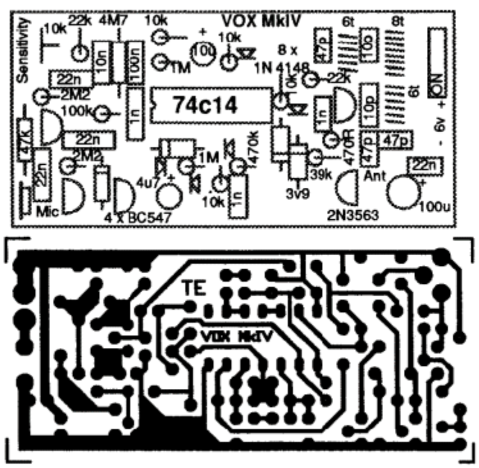
It is very important to carry out the tests in the correct sequence and this is what we have been explaining in the "If It Doesn't Work" sections of each project. The same applies with this project. You must go through the tests in a logical manner and once you master the sequence you can apply it to all types of circuits.

With this project, the first thing to do is to get power to the transmitter and this is done by removing the IC and taking pin 2 or 4 HIGH. This will turn ON both the oscillator and output stages and allow the bug to work in a similar manner to the Amoeba or Ultima.

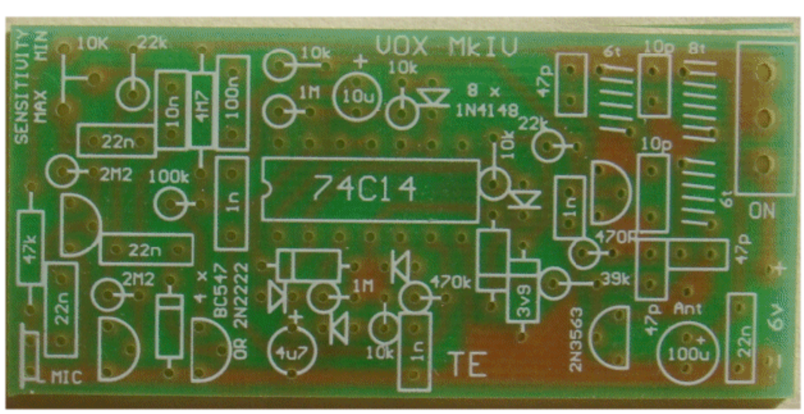
Use the Field Strength Meter (see Security Devices) to detect RF and if no carrier is present, the fault will lie in the oscillator section. Make sure 6v is present on the collector of the oscillator transistor and about 2v on the emitter, (you cannot measure the base). You cannot probe around the oscillator stage and expect it to keep oscillating at its correct frequency as no matter where you place the probe it will act as an antenna and draw off most of the signal. It is virtually impossible to test the oscillator stage under operating conditions unless you pick off only a very small amount of energy. The peaking circuit does this and you can use it to check the output at the collector. If no output is detected, remove the 47p coupling capacitor on the emitter and test again.

The reading on a multimeter should be about .8V and this is only a guide as the length of the lead on the peaker and type of multimeter you use will have an effect on the reading.

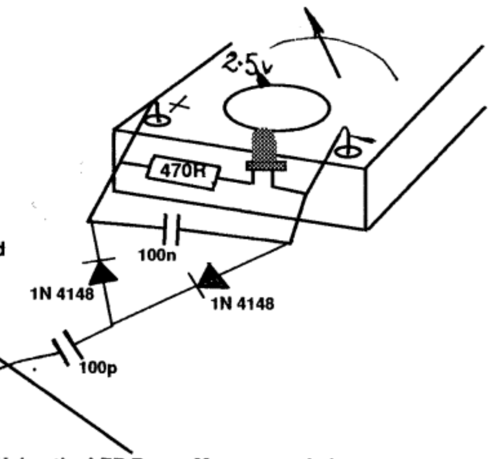
The main cause for a low output will be a faulty transistor, incorrect bias resistors or capacitors. Make sure the 22n capacitor across the power rails is present as this will have an enormous effect on the output of the stage; as will



Vox MkIV artwork. Everything is identified on the overlay, so you shouldn't have any problems fitting the components.



LED Power Meter
Parts list
1 - 470R
1 - 100p ceramic
1 - 100n greencap
2 - 1N 4148 diodes
1 - 5mm red LED
1 - 5cm hook-up wire
2 - paper clips
NO PC board required



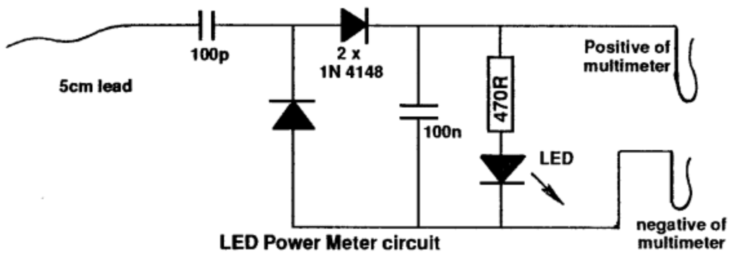
Using the LED Power Meter to peak the output.

a loose and/or sloppy circuit such as one with long leads on the transistors or any of the other components. Keep everything close to the board and the whole circuit as "tight" as possible. The batteries should also be on very short leads and only use 4 AA or AAA cells. Don't use watch cells or a power supply from a transformer as the impedance of anything other than four cells will change the characteristics of the oscillator.

USING THE LED POWER METER
With the oscillator working, you should tune your radio to about 88.5MHz or somewhere at the low end of the band where it is free of any radio stations and is only coming through at one spot on the dial. If you get two or more squeals, the oscillator circuit is not tight enough and you should shorten the length of the leads of the components and close things up.

Reconnect the 47p coupling capacitor and check that the output of the oscillator does not fall appreciably. If it does, the oscillator transistor may be weak, the 47p capacitor may be the wrong value or the base of the output transistor (2N 3563) may be shorted to the emitter.

With the output stage operating you can change the peaker to the collector of the 2N 3563 and move the turns of the tank coil together or apart until the output reaches a maximum. In our case we got a reading of about 9v on the multimeter and when the frequency of the tank circuit is exactly the same as the oscillator, all the energy is being transmitted on one frequency and the radio will give a feedback whistle at only one spot.



LED Power Meter circuit

connect the LED Power Meter to the collector of the oscillator to act as an antenna.

A full description of this simple piece of test equipment has been given in the Ultima article (Security Devices P. 21) and the circuit has been reproduced here to assist those who have not seen this article.

Carefully push the turns of the 6 turn coil together or move them apart until a feedback whistle is heard in the radio. When the turns are pushed together the frequency decreases and when moved apart, the frequency increases. Move the radio a short distance away and tune across the band to make sure the output

If you get two peaks, the frequency of the oscillator and output do not coincide. Keep adjusting the tank coil until the two frequencies are the same.

When this is done, the project will be "peaked" and will deliver the maximum output.

When the antenna is fitted, it will load the output slightly and change the frequency a small amount. If you want to be exact, you can re-adjust the frequency of the tank circuit by using the Field Strength Meter.

We still have two further sections to cover and if you are having trouble with the output stage or tank circuit, you should refer to the Amoeba or Ultima articles for more assistance.

THE VOX SECTION
Next we will look at the VOX section and see how the circuit detects sounds and turns on.

Remove the shorting link on pin 2 or 4 and fit the IC into the socket. Turn the "sensitivity" pot to mid position and switch the bug ON.

Keep the radio away from the microphone to prevent feedback and you should be able to hear all the sounds in the room. If you keep very quiet the bug will turn off after about 8 seconds. If it doesn't, the 10u electrolytic is not being discharged by the 1M resistor and the fault could be a leakage path at the negative end of the electro keeping it charged. Or it could be the 10u and 1M not making contact with the positive rail. You will have to look around the negative lead of the electro with a high impedance multimeter to see why it is not going HIGH. Unfortunately you cannot put a low impedance probe (less than 10M) here as it will prevent the electrolytic discharging sufficiently for the gate to change state.

The only way to see the capacitor discharge is place the positive probe of a high impedance multimeter on the positive rail and monitor the negative of the electro. It will discharge in less than 8 seconds due to the added load you have placed on it (the meter) and if it remains charged, you have leakage coming through from the 10k, or the diode from the beep circuit.

Remove each part in turn until the leakage is located.

When the delay "times-out," the bug shuts down to its listening mode in which the oscillator and output are turned off and the only stages that are operating are the microphone, first audio stage, analogue-to-digital stage and the timer for the beeper. The current consumption falls from about 12mA to .8mA and this extends the life of the battery considerably.

The next section is the beeper stage.

BEEPER STAGE
As soon as the bug is in the listening mode, the timer between pins 3 and 4 comes into operation and rapidly charges the 4u7 via the diode and 10k resistor. During this time the tone oscillator (between pin 5 and 6) comes into operation and produces a square wave of about 300Hz. This tone is fed into the base of the oscillator stage via a 1n capacitor and 10k resistor.

At the same time the oscillator and output stages are turned on via the diode on pin 4.

After a short period of time pin 3 sees a HIGH via the 4u7 electrolytic and the inverter changes state. This shuts off the tone and the bug reverts to the "listening" mode.

When the tone is being produced, the VOX section is prevented from triggering by the diode connected between pins 4 and 13. A few milli-seconds after the tone has ended, the bug will be ready to trigger if it detects audio.

RF OSCILLATOR AND OUTPUT STAGES

The RF oscillator stage is the same as our original **FM BUG** as it has proven to be very reliable.

The only changes have been to tap off a small amount of RF from the emitter with a 47p capacitor (this has been done with hardly any effect on reducing the amplitude of the oscillator) and the zener reference.

We have found that we can draw off more energy at the emitter than at the collector and this means we can deliver more energy to the output stage. This is one of the reasons for the increased output of this design.

The operation of the oscillator has already been covered in our previous articles and the same theory applies.

The output stage has also been covered in our previous articles, including the operation of the RFC (Radio Frequency Choke) between the power rail and the tank circuit. This improves the output considerably by allowing the tank circuit to produce a larger waveform.

All these improvements add up to a very efficient design and we can boast that ours is at least 3 times more efficient than anything else on the market. Other designs require 25-35mA or more to achieve the same range.

IF IT DOESN'T WORK

Most of the hints and guidance to testing this project have already been covered in this and previous articles.

I am surprised that so many readers ring up and ask how to solve a particular fault when we have spent so much time detailing the art of servicing.

I keep repeating myself but the fact is an electronics hobbyist is not someone who can only build a kit but someone who can also repair it!

Anyone can build a piece of equipment. After all, most of our electronic products are put together overseas by people who have never seen a circuit diagram in their life.

Even simple repairs can be attempted without a circuit but when a major fault occurs it is necessary to approach the job in a professional way.

The first thing you need is a circuit diagram and if the project has been working, you can assume the component values are correct and the fault is a failure in one or more of the parts.

But when something doesn't work from the start, you don't know if it is faulty workmanship, faulty components or faulty design!

That's why you have to approach the repair logically as you cannot assume anything. All component values have to be checked, all voltages have to be measured and all soldering has to be inspected.

It's almost impossible to inspect your own work and the best idea is to ask someone else to check it for you.

When projects are sent in to us for servicing, we find the fault relatively quickly as we know what to look for and where to look. Bridges and shorts that appear to be ok are tested for continuity and parts that appear to be soldered are resoldered to make sure the joint is perfect.

This solves most of the troubles as many of the constructors don't realize the importance of perfect soldering and just panic when the project doesn't work first go.

For most of the troubleshooting, refer to the section on "Testing the VOX bug" as it describes how to test the bug as well as find most of the faults.

You must start at the output and work your way towards the microphone. This allows you to use a radio as a piece of test equipment to determine the frequency of the oscillator, the signal strength, as well as the quality of the audio and the sensitivity of the microphone.

By using the LED power meter, Field Strength Meter, a standard Multimeter and a normal FM radio, you will be able to find and fix almost any fault in the bug.

The only thing you will not be able to do is increase the output as this will cause "splash-over" and the output will appear all over the band and create major interference. So don't increase the supply voltage or change the bias on the output transistor.

SUMMARY

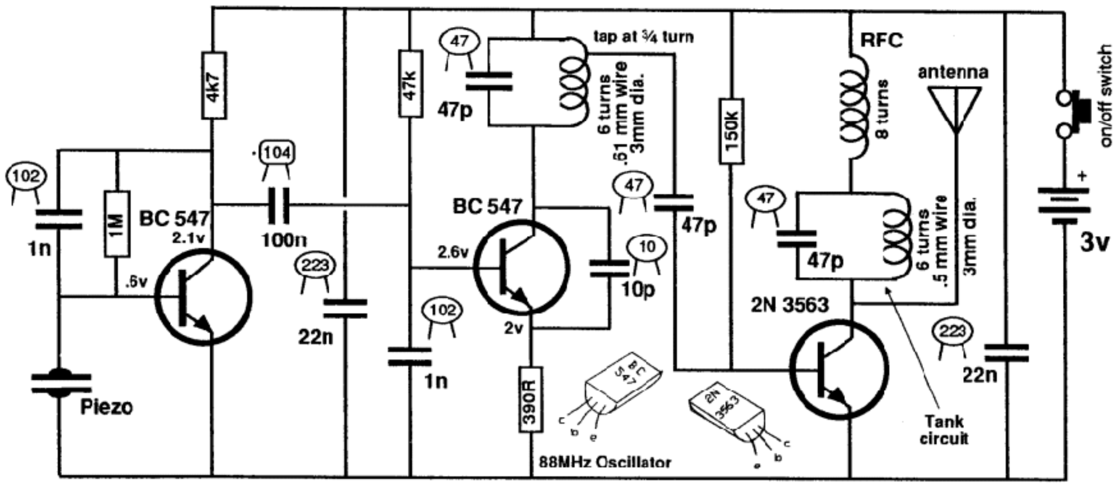
This bug is the top of the range at the moment, both in performance and efficiency.

It is the forerunner to a range of surveillance devices that will enable you to keep an eye on your property and possessions. You will be able to monitor your car, boat, tools and equipment from a distance.

As you can expect, our next design will have more features and as soon as we have time to complete it and give it a field test, it will be in our next security book, so watch out for it.

THE WALL BUG

Our 400 metre WALL BUG



WALL BUG CIRCUIT

One day, many many months ago, an investigator rang to say he had a bug that would 'hear' through 10cm of concrete, and wanted another one. He asked if we could design something similar.

We suggested he bring it around so we could see what we were up against. It seemed amazing that you could hear through solid material and we wanted to see how it worked.

With a price tag of over $250, it must be pretty good! But when it arrived, it was a disappointment. It was simply a 5-transistor Amplifier driving an earphone. The input was a piezo diaphragm with a probe that touched the wall and when we tried it, the amplification was quite good, but at $250, it was grossly overpriced.

The headphone was the limitation. You had to stand at the wall, keeping the unit attached and straining your hearing at the same time.

For the price, you would expect something more for your money. The concept was fairly primitive and we decided to design something considerably better. We started with the Amoeba circuit and after a lot of experimenting we came up with a transmitting wall bug that was more sensitive than the sample we were given.

Being a transmitter, it gave you the freedom of being able to listen in comfort from a distance and you didn't have to stand around with your ear glued to a wall! The secret of the design is the use of a piezo diaphragm. The same type as found in piezo alarms. But we use it in reverse. Instead of emitting a sound, these diaphragms are also capable of picking up a sound and converting the vibrations into electrical impulses.

But these electrical signals are very small and you need a a powerful amplifier to bring them up to the level for injecting into a transmitter stage. We found the sensitivity of these units varies enormously from one type to another and the size of the diaphragm also determines the output.

To get a good result you have to use a sensitive unit. Let me point out the kits use a fairly sensitive item but the made-up versions use a device that is about 4 times more sensitive, so don't expect the kit to come up the quality of the built-up versions. Two "cats whiskers" are soldered to the centre of the diaphragm in the built-up version whereas the one supplied in the kit is a metal cased version that needs to be pushed onto the glass or other solid medium so that the vibrations will pass to the diaphragm.

The diaphragm is attached with Blu Tack and the whole window becomes a microphone. You can pick up sounds nearly as good as an electret microphone and the only trouble is you can hear sounds on the outside of the building at the same level as those on the inside. This means the sounds of birds, cars and even wind comes through quite clearly.

It makes the old adage "Speak softly, the walls may be listening." a reality. In fact everything in the room is vibrating and it makes you wonder how safe it is

PARTS LIST

1 - 390R (orange-white-brown)
1 - 4k7 (yellow-purple-red)
1 - 47k (yellow-purple-orange)
1 - 150k (brown-green-yellow)
1 - 1M (brown-black-green)

1 - 10p ceramic
3 - 47p ceramic
2 - 1n ceramics (102)
2 - 22n ceramics (223)
1 - 100n monoblock (monolithic)(104)

2 - BC 547 transistors
1 - 2N 3563 transistor
1 - 6 turn .61mm tinned copper wire 3mm dia coil
1 - 6 turn .5mm enamelled wire 3mm dia coil
1 - 8 turn .5mm enamelled wire 3mm dia coil
1 - piezo diaphragm
1 - mini slide switch
2 - 30cm hook-up wire - if needed for piezo
2 - AAA cells
1 - 170cm antenna wire

1 - WALL BUG PC BOARD

to hold any form of discussion in an enclosed area.

As with all our devices, they are to be used solely for your own entertainment and to learn the principles of sound detection through homogeneous mediums. You can experiment with our design and try to improve its performance by modifying the pickup and altering the circuit. Let us know how you go.

The most common name for this type of bug is 'Concrete Bug' however it is most often used on a window. In fact we should call it a 'Glass Bug' but somehow it came to be named 'Wall Bug.' But glass is not the only medium. It can be attached to the topside of a ceiling, providing a good 'sounding board' is created.

This can be done by mounting the pick-up on a piece of glass or tile and laying it on top of the ceiling. It is important to make good contact between the surfaces so that vibrations will pass from one medium to the other. As far as wall bugs go, this is one of the best and will transmit about 200 metres.

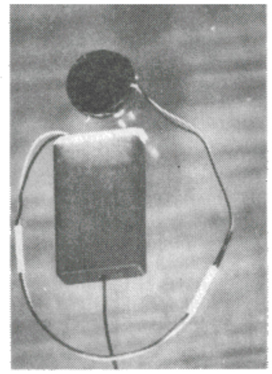
It is interesting to listen to room sounds via a solid medium as you can detect the frequency limitations of various substances such as plaster, glass, tile, wood as well as the distinctly metal sound of the piezo. Also, the reverse use of the piezo element will be new to many readers. If you have a CRO, you can connect the element to the input leads and place it on the workbench. Keep it away from the mains so that it doesn't pick up the 50Hz hum.

With the CRO set to low mV, you can whistle at a fixed distance from the unit and compare the amplitude of different types.

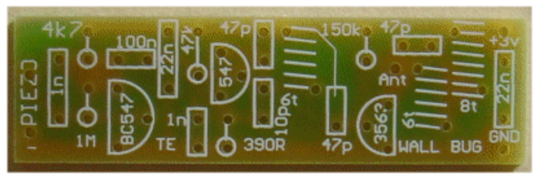
When the piezo is connected to the project, the voltage generated by the diaphragm is amplified by the pre-amp and passed to the RF oscillator to be converted to an FM signal for picking up by an FM radio. Further discussion on the circuit can be found in the Amoeba article.

CONSTRUCTION

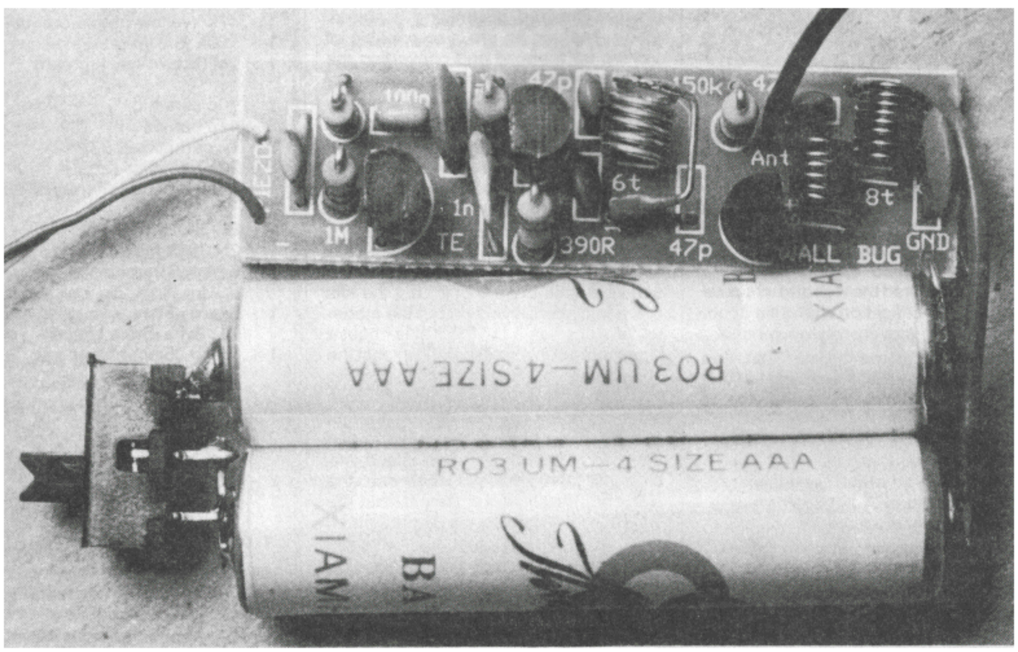
The circuit is very similar to the Amoeba and the only difference is the omission of the 100R, the electret mic, the mic load resistor and 22n coupling capacitor. The load resistor for the pre-amp has been reduced to 4k7 in the wall



Completed wall bug mounted on glass with Blu Tac



Enlarged view of overlay showing detail of component layout.



bug to give the first stage a higher gain and a 1n capacitor has been placed across the piezo to prevent instability.

If you have already made the Amoeba, you will have no trouble with this project.. Fit all the components to the board including the leads to the piezo. It does not matter which way around the leads from the piezo are connected to the board as the signal is what we call "AC" and it doesn't have a polarity.

Solder the batteries as shown in the photo with the slide switch connected to the opposite end of the cells and the project is ready for adjusting and peaking to a frequency away from any other radio stations.

Carry out the necessary adjustments on the oscillator and tank coil as per the Amoeba notes and fit the antenna.

Slide the circuit into a Tic Tac box and switch the unit on. You should be able to get feedback from 3 metres or more and be able to hear sounds in the room, even when the diaphragm is not touching anything.

The output from the piezo will be much better when the case is touching a solid sounding board such as glass or tile and you can do this by attaching two pieces of Blu Tac to the piezo case and pressing it firmly against a window etc.

FAULT FINDING

If the circuit does not produce a whistle, something in the front end will be faulty. It could be the piezo, or the pre-amplifier stage. The best way to locate the fault is with a CRO. You should get a 10mV waveform across the leads of the piezo when whistling at 30cm. The transistor in the pre-amp section will have a gain of about 70 so the output should be about 2100mV into the oscillator stage.

If you don't have a CRO, the only other way to check the front end is with a small audio amplifier. This can be built up from a circuit similar to the dish bug and taken to a set of headphones.

Check the voltage on the collector of the first transistor. It should be higher than 0.9v, otherwise the stage will be saturated.

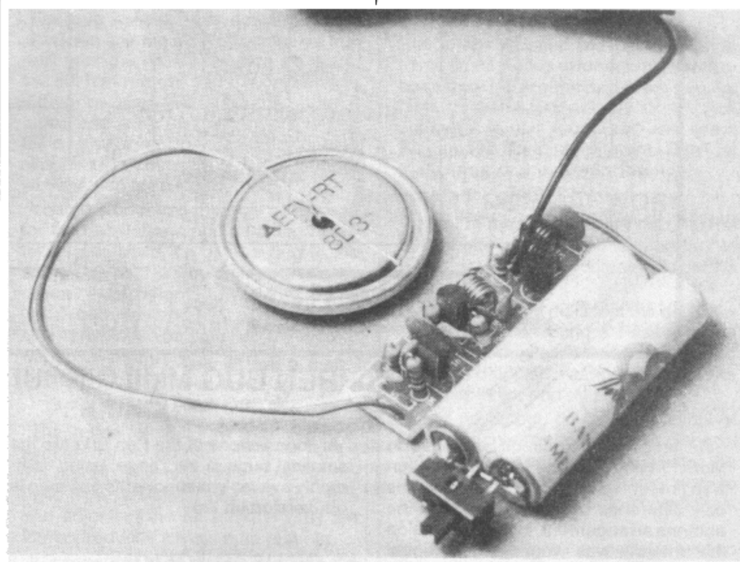
The three faults we found with models coming in for repair were shorts between base and emitter, piezo connected to the wrong points on the board and wrong

The track-work for the WALL BUG

value of load resistor for the first stage.

The only other problem we had with the front end is instability due to the 1n not being connected.

The rest of the circuit is covered in the Amoeba article and the Wall Bug should be ready for many hours of impressive listening.



DETUNING A RADIO

In some areas, especially capital cities, the FM band is filling up very fast end it's hard to get a clear channel near the low frequency end.

One solution is to move the frequency of the bug to below 88MHz. This is called DETUNING the bug and has the advantage of providing a link that will not interfere with anyone else. It gives you a private link and you can be sure you will not be picked up by the next door neighbour.

Sometimes the 84-88MHz band has been given to couriers and other two-way radio operators and it is necessary to check before-hand by detuning a radio and listening for any sounds of life.

The detuning of an FM radio is a relatively simple job. Either the tuning gang can have an additional 1p - 3p3 fitted across it or the turns of the oscillator coil can be moved together very slightly. On some radios you can move the trimmers on the back of the tuning gang and the stations will shift along the dial.

Any of these procedures will cause the FM stations to move up the band slightly so that a vacant space will be generated at the low end of the dial.

By adjusting the bug so that it transmits on this part of the band, you can create your own private link. Check to see that it is off the normal band, and it's done.

The coil we mentioned earlier is easy to find. It's generally an air cored coil and when you go near it with a screwdriver, the stations move along the dial. This coil is very sensitive and only has to be adjusted a very small amount to create the shift. When adjusting the bug, you may have to add one or more turns to the oscillator coil and/or the tank circuit. This will depend on the tolerance of the components and the closeness of the turns of the coil before starting the job.

When going from 88MHz to 84MHz, the turns must be moved together (without touching, if they are tinned copper wire) and it may be necessary to add an extra turn.

For those who want to go to the other end of the band, there's one word of warning. As you go higher in frequency, the gain of the transistor reduces and this means the range will be reduced. At present we are working at the extreme limit of the capability of a BC 547 and if you want to go to 107 - 110 MHz, I suggest you use a better transistor, both for the oscillator and output. Something like a 2N 3563.

The coils in the transmitter may have to be changed and possibly the best idea is to change the 47p for 39p or 33p, while you are at it.

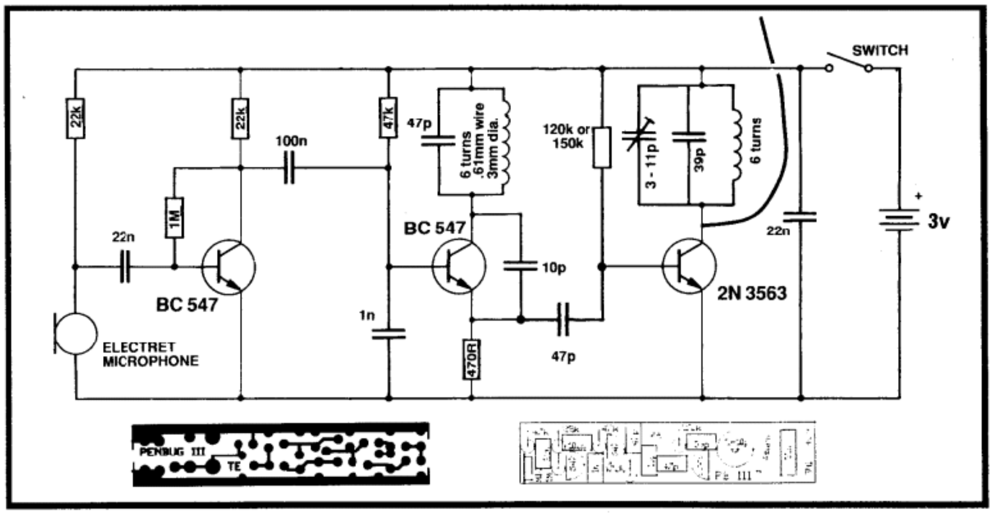
I have not tried the bugs at this frequency but I see no reason why they would not work. If you tune a radio so that it will go up to 120MHz, you will be able to pick up professional bugs as many crystal locked bugs operate at this frequency. Instead of detuning a radio, you can retune it by opening up the turns of the oscillator coil and this will bring the stations down the dial so that the 120MHz region will be receivable.

Kit of Parts $14.60 USD
Postage: $4.50 USD
email Colin for payment:
talking@tpg.com.au
to pay by PayPal

PEN BUG MkIII

A bug that fits inside a marker pen.

The Field Strength Meter
$1.25 extra is required to peak this project.



PEN BUG MkIII CIRCUIT

Our first Pen Bug circuit appeared in More FM Bugs and the MkII modification was presented in Security Devices. The only difference between these was the antenna arrangement. In the MkI version the antenna was wound onto a spiral and fitted into the barrel of the pen. In the Mk II version a tank circuit was added and the coil of the tank circuit used as an active antenna.

It out-performed the earlier model and now we have a further improvement of a longitudinally wound antenna and coupling between the two stages via the emitter of the oscillator.

From the outset let me say that it is very difficult to get a good range from a bug fitted inside a pen.

As you can imagine, it is practically impossible to produce an antenna with any effectiveness from inside a pen barrel and this limits the range of the bug. We got about 10 - 15 metres under good conditions and we think this is a fair achievement.

To get the greatest range it is important to peak the tank circuit very carefully so that it delivers the greatest signal into the antenna. To do this you will need the Field Strength Meter as described on P13 of Security Devices. You simply adjust the air trimmer to get the maximum output - it's a very simple procedure.

All the versions of the Pen Bug are the smallest bugs in our range, using commonly available components and here is our version III.

CONSTRUCTION

Before starting assembly, it is important to have everything ready with the parts laid out on your workbench for easy identification.

Start at one end of the board, the microphone end, but leave the microphone to last.

Each part is fitted as you come to it and everything is easy until you come to the oscillator coil. This is mounted upright on the board and you must bend the ends of the coil so that they fit down the holes in the board. Don't squash the turns together as they may have to be stretched apart during setting of the frequency. Make sure the enamel is scraped off the leads before fitting by using a sharp blade or file or sandpaper. Continue with the rest of the parts including the 3-11p air trimmer and tank coil.

The board is now ready for the microphone, switch and batteries.

You can solder directly to the button cells if you firstly scrape the top and bottom with a blade or file. Make sure the soldering is carried out very quickly otherwise the seals on the cells will be damaged and the contents will ooze out. These chemicals are very corrosive, so be careful.

The microphone is connected to the board with the two short wires supplied on it, so that the lead going to the case goes to the negative rail. The negative rail is the copper strip that runs the length of the bottom of the board. The microphone must be soldered very quickly otherwise the FET inside the case will be damaged and it will lose

PARTS LIST

1 - 470R 1/4watt
2 - 22k
1 - 47k
1 - 150k
1 - 1M
1 - 10p ceramic
1 - 39p " "
2 - 47p " "
1 - 1n " "
2 - 22n " "
1 - 100n monoblock
1 - 3-11p air trimmer
2 - BC 547 transistors
1 - 2N 3563 RF transistor
1 - electret mic insert
2 - 6 turn enamel wire coil 3mm dia
2 - button cells
1 - mini slide switch SPDT
1 - 1.5m enamel wire for antenna
1 - PEN III PC BOARD

sensitivity and produce a lot of background noise.

WINDING THE ANTENNA

The antenna is wound longitudinally on a paper former. To determine the size of this former, take a sheet of stiff paper and cut it to about 7cm wide and wind it loosely 3 times around the project. Open it up slightly larger so that when the wire is added, the antenna will fit over the works.

Wind the wire through the middle and around the outside until the 1.5m is used up. Solder one end to the antenna point on the board.

It's best to have the antenna as far away from the circuit as possible, but if space is limited, it can be slipped over the board.

THE CASE

The only thing we haven't provided in the kit is the case.

This has been left up to you as there are so many different types of pens and markers that will hold the project. It is preferable to use an old, dried out marker as this will save you a couple of dollars and you don't have to handle any messy ink.

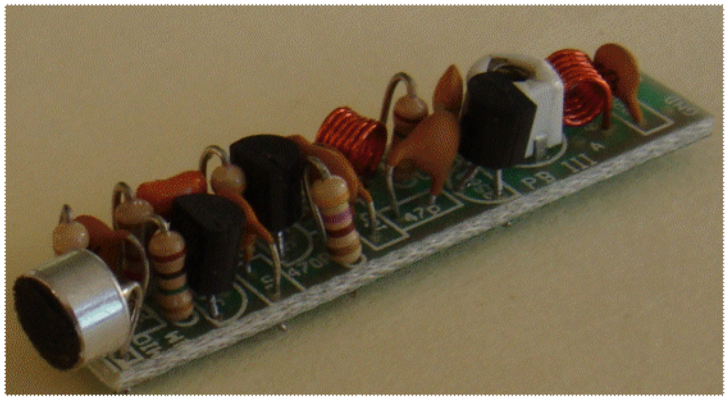
If you want the pen or marker to write normally so that no-one will suspect the contents, you will have to provide a section up the front to hold the pad of ink and this will have to be sectioned off from the rest of the barrel to prevent the ink drying out.

The main aim is to get a case that will fit the board, batteries and switch. After this you can see how much room you have for the ink.

Next you will have to work out the switch arrangement and it can be either a slide switch mounted inside, a pressure switch kept apart with a pin or a reed switch kept open with a magnet on the outside of the case.

When the pin is pulled out or the magnet removed, the switch closes and the bug is activated.

The Commercial bug (as explained the MkII article) did not have a switch. Two button cells were fitted into the barrel and the cap screwed on. The bug was then active and would operate for about 8 hours. The idea is to arm the bug beforehand and leave it at a meeting etc. Later you can go back and pick it up.



The bug we saw was actually a ballpoint pen and the ink was contained in a refill near the tip. By the time we got it, the ink had run out and the only telltale difference was the larger-than-normal barrel and extra weight. Anyone with a fair degree of intelligence would become suspicious at the extra size and wonder why the pen is so cumbersome.

You could not see the hole at the end for the microphone and no external antenna was used. To get our bug to the same size as this would require surface mount components, two very small watch batteries and a lot of extra skill in construction, so be satisfied with something just slightly larger, but much cheaper.

PEAKING

The range of the Pen bug depends almost entirely on peaking or TUNING the output. This is done by placing the Field Strength Meter near the antenna and adjusting the air trimmer until the Meter produces a maximum reading.

It is essential to be able to measure the output without physically touching any part of the circuit and this is why we use the Field Strength Meter.

You must turn the trimmer with a plastic screwdriver as any type of metal implement will change the characteristics of the circuit and give a false reading. When you see the needle fall or "dip" you have peaked the output to a maximum.

The tank circuit is now drawing the maximum energy from the battery and converting it to electro-magnetic radiation.

Place the board inside a marker pen and test the bug for both range and clarity.

If you are satisfied with the results, fit some small pieces of foam to prevent the board moving around and fit the pen tip. Now you are ready to try it out. Ask someone to use your "Pen" and see if they notice anything different. Don't let them know or they'll want one too!

IF IT DOESN'T WORK

Most of the problems will occur in the tank circuit section as it is important to peak this stage very accurately to get the maximum output.

The first thing to do is test the oscillator section by connecting a Peaker to the collector of the oscillator transistor. If no output is detected, remove the 47p coupling capacitor and try again.

If still no output, go over the layout of the components, making sure none of the tracks short together. Since the board is very compact it is very easy to create a solder bridge or fit a component into the wrong holes.

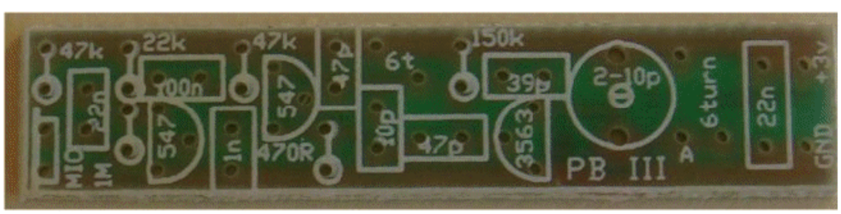
Once you are sure the oscillator section is working, connect the 47p coupling capacitor and place your Field Meter near the antenna.

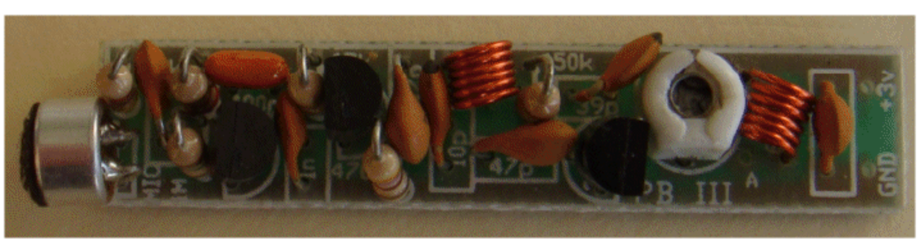
If no reading is detected, the output stage is faulty. Try replacing the RF transistor and check the layout.

Once you can detect a small output from the antenna, adjust the trimmer until the output is a maximum.

Don't forget the plastic screwdriver (such as a knitting needle). Once it's a maximum, don't touch anything as you fit it into a case or you will upset the output.

It's now ready. Have lot's of fun.





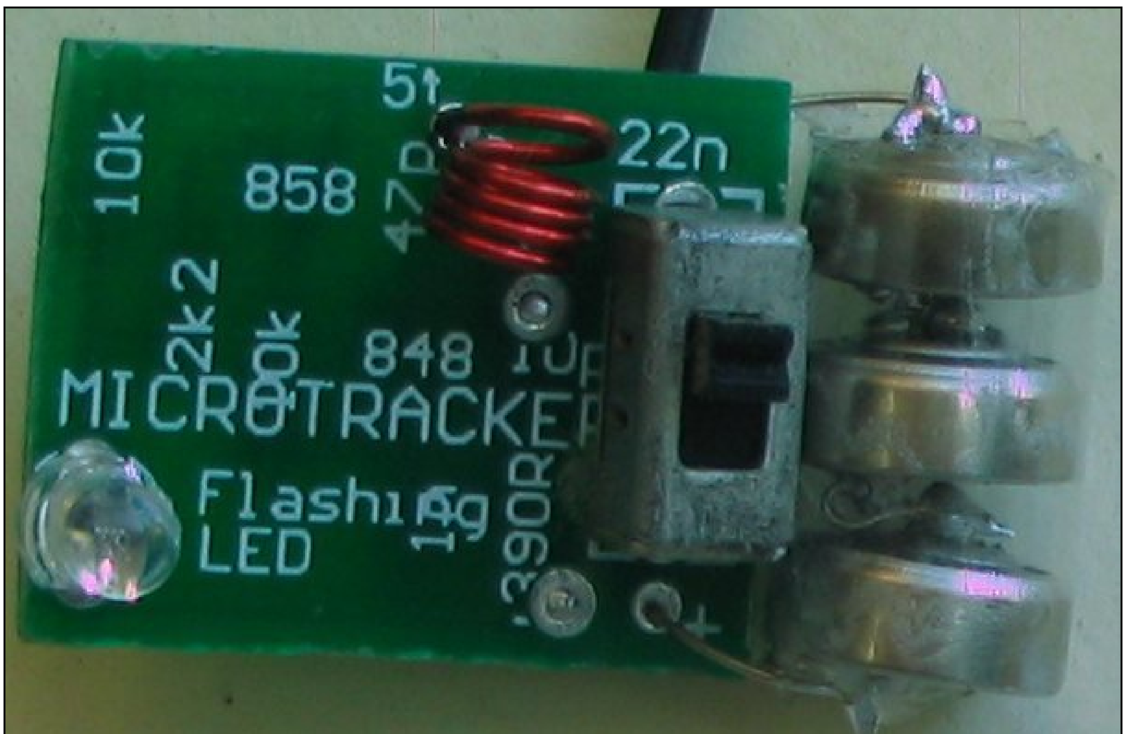
MICRO TRACKER

Our smallest FM Beeper Bug
Size: 0.8in x 0.6in
Fully surface mount
Range: 100m

$9.50 USD incl all parts and PCB
plus $4.50 USD postage to anywhere in the world

pay by PayPal
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit

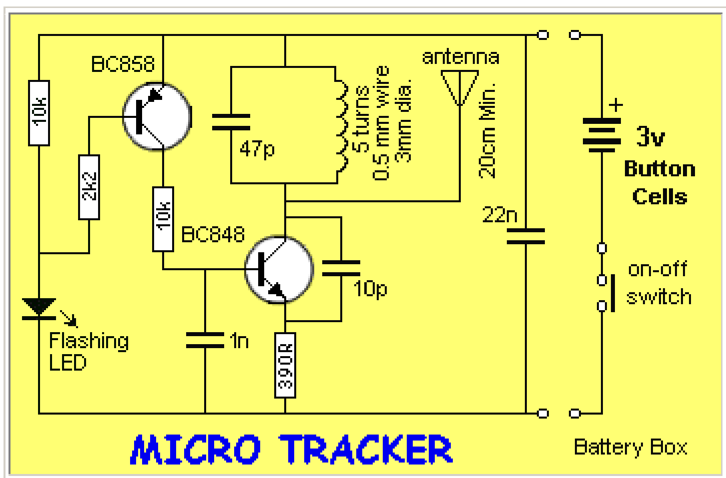
This project uses the Micro Tracker PC board.
The component values are marked on the board.
The output produces a thump-thump-thump- squeal-squeal-thump-thump-thump . . . . . at approx 90MHz but the turns of the coil can be expanded to raise the frequency.



Micro Bug Tracker Circuit

HOW THE CIRCUIT WORKS

The circuit consists of two stages, a digital stage consisting of an ON-OFF waveform and an RF oscillator. The digital stage is a flashing LED and it has an in-built oscillator to turn red-blue and green LEDs on and off.
This action takes current from the supply when the LED is illuminated and almost no current when the LED is not illuminated.
The flashing LED is supplied via a 10k resistor and the flashing still occurs but the LEDs are much duller.
The flashing LED is no different to a transistor turning ON and OFF. The voltage across the LOAD resistor (10k) is detected by a buffer transistor and this transistor turns on and off.
The transistor supplies base current to the RF oscillator and when the oscillator turns ON it produces a carrier that removes the background noise in the receiving radio.
This is how you get the thump-thump-thump in the audio. It is just the difference between the silence and background noise.
The LED also produces a tone during part of the cycle when the LEDs are increasing or decreasing in brightness. This is heard as a squeal on the radio.
The Flashing LED cannot be put in the base of the oscillator stage as this a common-base design as the base voltage rises to nearly the supply voltage and the LED drops at least 1.7v when active and the oscillator stage would not work.



The RF oscillator is designed to operate at about 88MHz and the frequency is set by the inductance of the 5 turn coil together with the 47p capacitor. These two components make up a circuit called a parallel resonant circuit (tank circuit).
The frequency is also determined by the transistor, the 10p feedback capacitor and also to a lesser extent by the biasing components (47k, 100k and 390R resistors).
When the buffer transistor is tuned ON, the 1n base capacitor will charge via the 10k resistor and turn the oscillator transistor ON.
The base voltage will continue to rise and the 10p will have the effect of trying to prevent the emitter from moving. A point in time is reached when the energy from the capacitor is exhausted and it can no longer resist the movement of the emitter. The base-emitter voltage decreases and turns the transistor off. The current flow in the coil then ceases and the magnetic flux collapses. This collapsing magnetic field produces a voltage in the opposite direction and whereas the collector voltage may have been 2.9v, it will now rise to over 3v and charge the 47p in the opposite direction. This voltage will have the effect of charging the 10p and the voltage drop across the 390R emitter resistor will be such that the transistor will be turned more firmly OFF.
As the 10p charges, the emitter voltage will drop to a point where the transistor will begin to turn ON and the current flow through the coil will oppose the collapsing magnetic field.
The voltage across the coil will reverse and the collector voltage will drop. This change will be passed to the emitter via the 10p and the result will be that the transistor will turn ON very hard and short out the 10p. After this the cycle begins again.
What we have is an oscillator that produces AC energy at 88MHz with the amplified audio signal fed into this stage via the 100n, varying the frequency of oscillation to produce the FM signals.

PARTS LIST
1 - 390R (marked 391) 1 - 2k2 marked 222) 2 - 10k (marked 103) 2 - 4p7 surface mount 1 - 47p surface mount 1 - 1n surface mount 1 - 22n surface mount 1 - BC 848 transistor marked ‘1k’ 1 - BC 858 transistor 1 - 3mm flashing LED 1 - 5 turn 3mm dia enamelled coil 3 - 1.5v button cells 1 - battery box 15cm very fine solder 1 - 80cm hook-up wire for antenna **1 - MICRO TRACKER PC board**

Micro Tracker components

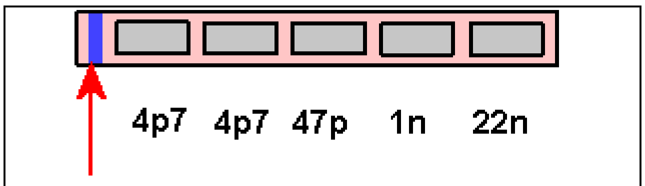
Before starting, place a tiny piece of blu-tack on the top-side of the Micro-Bug Tracker PC board and push it onto your work-bench so it does not move - all the components are mounted on the "underside" of the board.

CONSTRUCTION

All the components for this project are surface-mount.
This includes the two transistors,
Let me warn you once again, the components are very tiny.
Before opening the kit of parts you must prepare a clean space on your workbench so the components can be taken out of the holding cells without being lost.
You will also need a soldering iron with a fine tip.

We use a soldering iron that is commonly called a SOLDERING PENCIL. It is a very small iron with a tip that is sharp enough to prick you!
If you do not have this type of soldering equipment, assembly will be much more difficult and the neatness will not be as good as our photos.
You will be amazed at the improvement you get by simply using the correct equipment and FINE SOLDER.

Now we can get down to assembly:
Use the photo above to identify the placement of the parts aas the board is designed to take two different circuits and the overlay is for the voice transmitter.
The oscillator section is the same for both projects but the LED and transistor are in different places for this project, plus 3 resistors.
Lay out a clean sheet of paper and place the strip of components so the black band is to the left.
The first components to fit onto the board are the resistors and these are in the strip in ascending order. This means the values are: 390R, 2k2, 10k, 10k and are clearly marked with a 3-digit or 4-digit code.
The next components to fit to the board are the 5 capacitors. Unfortunately they are not marked and so you will have to be very careful when removing them so that they are not mixed up.
The size of a capacitor chip is no indication of its value and so you have to take our word that we have placed them in ascending order.
Even the colour of the substrate is no indication of a value so please don't ring us up and say “I have a tiny pink capacitor and a tiny mauve capacitor and a tiny purple capacitor, which is the 1n!”



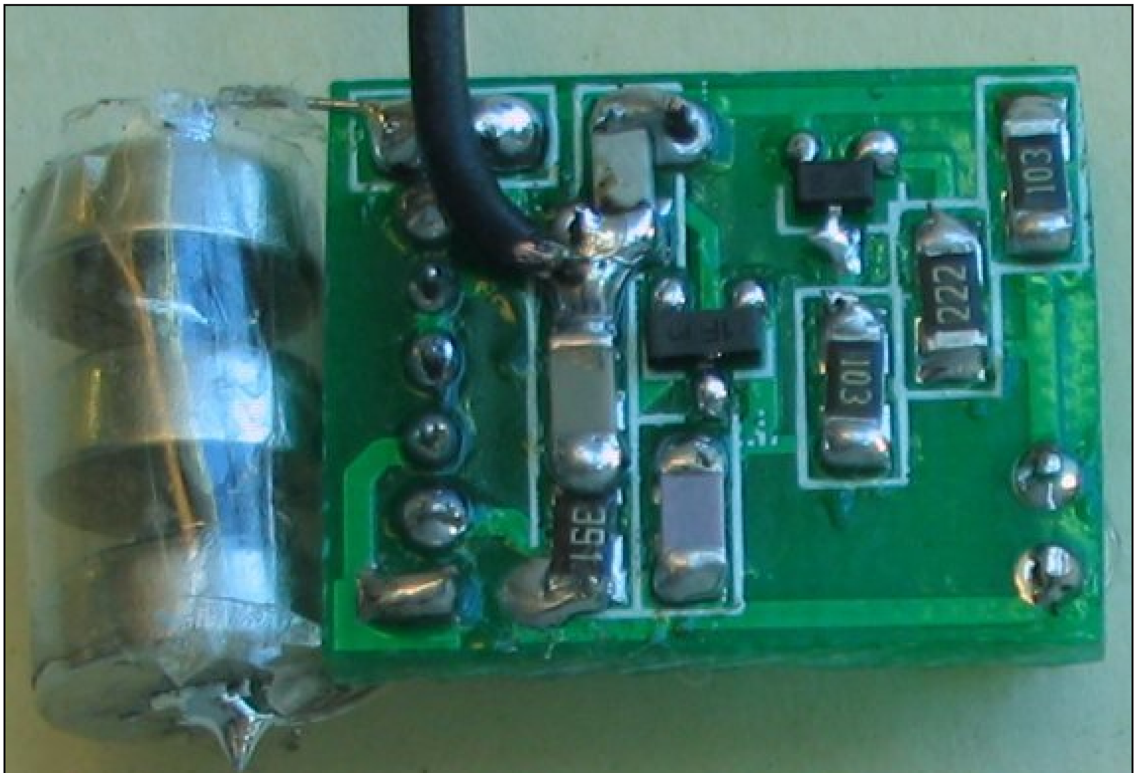
Blue/Black line
The surface-mount capacitors are housed in a carrier strip, with a black line at one end. The black line corresponds to the lowest value of capacitance.

The colours and size will change from one batch to another and from one manufacturer to another.
I know some people are going to plough into construction and lose a component or two so the replacement strips will be available for $2.00 for the set of capacitors $2.00 for the resistors and $2.00 for the transistors plus $3.00 for postage.
This is the best we can do so don't ask for individual components - you're lucky we have a service for replacement parts.
When fitting the components to the board, open up the strip from the black-band end and allow one chip at a time to fall out of its cell to a clean sheet of paper on the bench.
If the component is a resistor, it will have markings on it. Turn it over to reveal the numbers.
This is a three number or four number code to indicate the value in ohms. Make sure it is turned around so the numbers make sense. Sometimes you can hold a resistor around the wrong way and it will appear to be a different value!
The markings for each resistor have been supplied in the parts list so double-check the value before fitting it.
Pick up the resistor with a pair of tweezers or a paper clip that has a tiny piece of Blu-Tack placed on the end and carry the chip to the board.
Hold the chip in place with the paper clip but take the Blu-tack away so that it does not melt and contaminate the joint.
Bring up the soldering iron to one end of the chip and with your third hand, add a small amount of fine solder and make a connection.
The art of soldering surface-mount components will take a little time to master, but you will find they are easier and quicker to fit than conventional components.
We build hundreds of items for customers and the assembly workers have said surface-mount devices are easier and quicker to fit.
If you are using tweezers, you can add a small amount of solder to one end of the chip and when you place it on the board, it will be very quick to solder. Push on the tweezers to make sure the

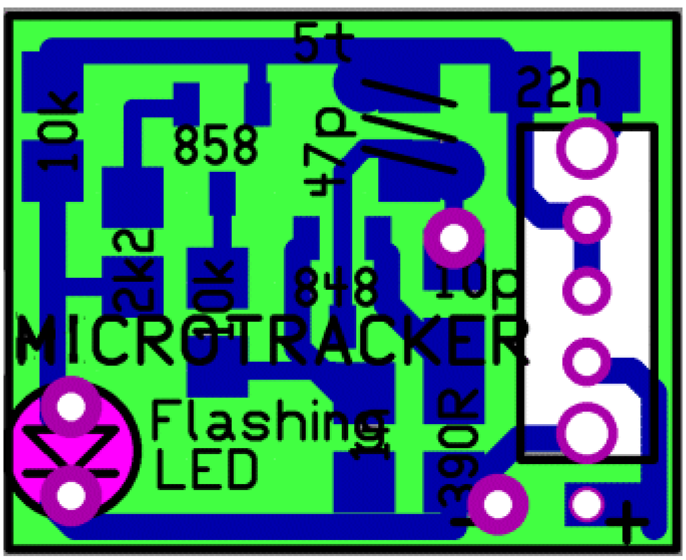
chip sits firmly on the board. Then solder the other end.

Everything takes time to get perfect and since electronics is going in the direction of surface-mount, now is a good time to get your hand in.
Every year, more and more of our consumer electronics are being converted to surface-mount technology.
Already more than 40% mount is surface-mount and the percentage is increasing all the time.
The driving force is economics.
Even though surface mount components are slightly more expensive, the cost of insertion is much lower as they are placed on the board with a pick-and-place machine. These can fit components five-times faster than conventional components.
But the real saving is in the size of the board. This can be reduced by as much as 50% with components on one side or as much as 70% with components on both sides.
The board can be made of much thinner material or even flexible, so the scope for new produces is enormous.
Board for cameras, for instance, are made of paper-thin flexible material so it can fit around the body of the camera with flexible wiring to connect to the button, motor, battery and flash.
But the greatest advantage of surface-mount is the aesthetics. Surface-mount looks professional and makes your product stand out from the rest.

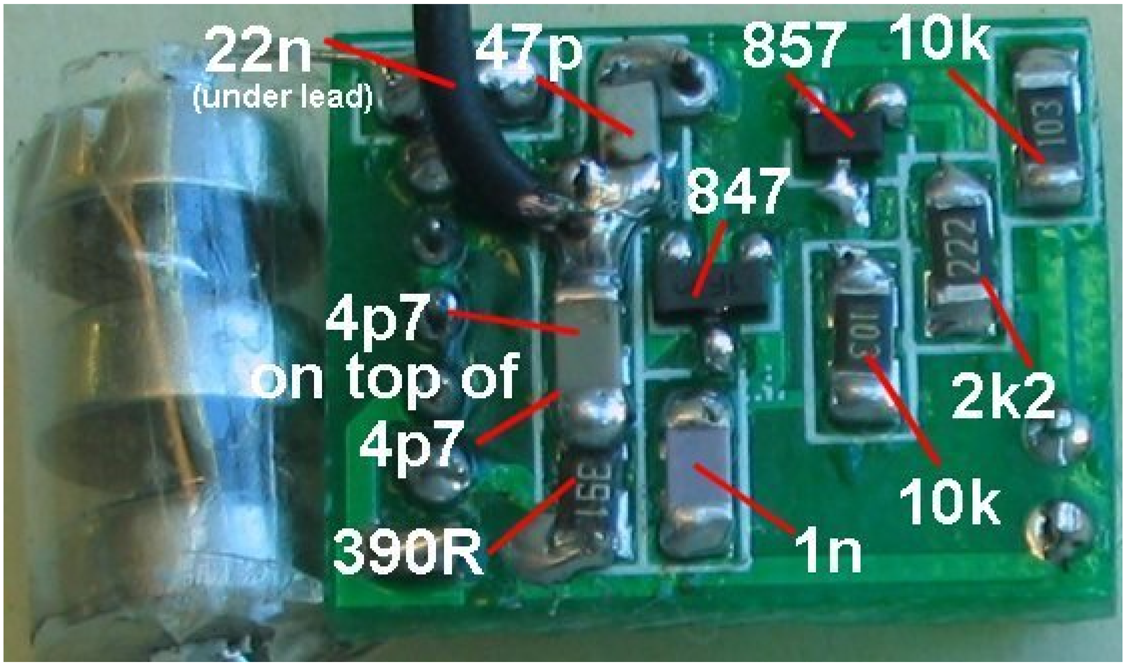
Now back to the topic.
When you get to the capacitors, you must look into the cell before letting it fall out so you can recognise it once it hits the paper.
Refer to the diagram of the strip for the value and then the enlarged diagram of the board for the position of the component.
It doesn't matter which way around the resistors or capacitors are placed and they can even be turned over but there is one thing you must not do.
When you have soldered one end of a component you must not try to straighten it up. This also applies to a component that is standing up slightly.
Any amount of force will fracture the substrate. Even slight pressure can separate the metallised end caps from their substrate and cause the component to go open circuit.
That's why it is important to hold the component in place with the tip of a paper clip while soldering the first end.
If the component shifts, you are in big trouble.
This is because YOU are going to take much longer to re-heat the end and realign it.
If this happens with a transistor, forget it. The transistor will be damaged.
It a component moves, leave it misaligned and try to solder the other end as best as possible.
The damage you will cause in trying to straighten it will be a nightmare to fault-find.
Another problem you will find is some soldering irons are magnetic and the resistor will stick to the tip of the iron if you don't hold them down with something such as a pair of tweezers or paper clip.
Just before we go to the transistors, let me give one final hint.
To reduce the heat build-up in a component, it is best to solder one end then wait a few seconds for the component to cool down before soldering the other end.
This is very important when soldering the transistors.



The Micro Bug Tracker from the bottom. Notice how the parts are positioned and soldered



Micro Tracker PC Board

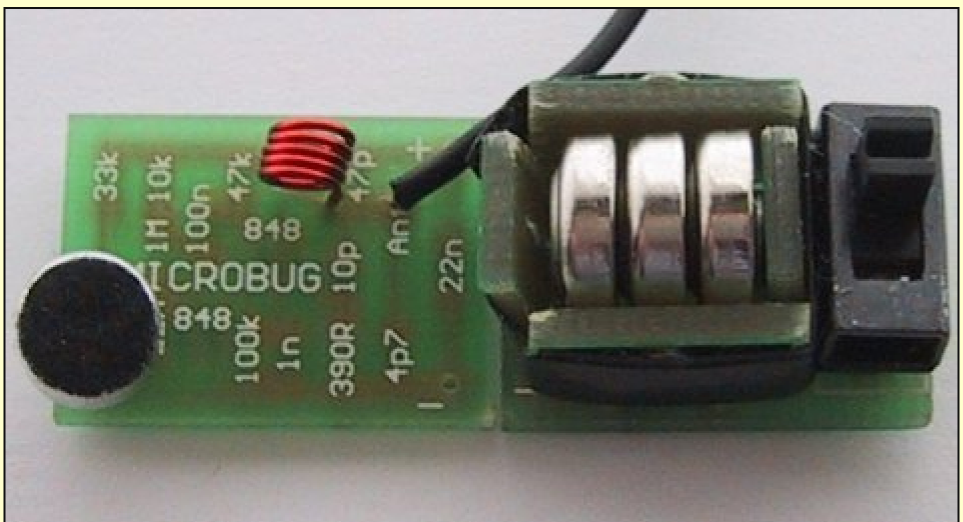


An enlarged view of the underside of the Micro Tracker PCB.
It shows the placement of the surface-mount components.
A 4p7 is placed on top of a 4p7 to make 10p capacitor.

THE MICRO BUG

Our smallest FM transmitter
Size: 0.8in x 0.6in
Fully surface mount
Range: 100m

$14.50 USD incl all parts and PCB
plus $4.50 USD postage to anywhere in the world
Contact Colin Mitchell:
talking@tpg.com.au
for Paypal details



Micro Bug and Battery Box

Before I tell you about this amazing little project, let me say one thing. You have to be an expert at soldering to put it together.
The main difficulty is the surface-mount transistors. All the rest of the components are easy to fit, once you get over the shock of their size, but the transistors are not only microscopic, they are temperature sensitive. They must be soldered quickly with a DELICATE IRON at the RIGHT TEMPERATURE.
We will discuss this more in a moment. I want to get in first so that anyone who has not built at least four of our previous projects, including at least one of our surface-mount kits, do not get the idea that this bug is going to be easy to put together.

Something we have been asked on a number of occasions is: “Why do we keep producing so many FM transmitters projects?

Apart from the fact that they are always extremely popular, each of the designs either incorporates an improvement over a previous design or a new feature.
A reader wrote to us suggesting we design one enormous project incorporating the features of our VOX bugs, our Wall Bug and our long range bugs, with a switch to select a particular feature.
This would be wonderful idea if it were practical, but it would defeat the purpose of the designs as each demonstrates a different feature.
There is no circuit simpler than an FM transmitter. Nothing produces crystal clear audio from two or three stages and transmits to a tuner to give the equivalent of a high wattage amplifier. To make the circuit more complex by adding extra features would defeat the purpose of starting with something simple.
Each of the transmitter circuits we have designed incorporates a number of BUILDING BLOCKS and studying these will help you; not only to understand how the circuit works, but also with designing your own circuits.
Building FM transmitters is definitely a great place to start, as the cost is low and the experience you get is invaluable.

DESIGN IMPROVEMENTS

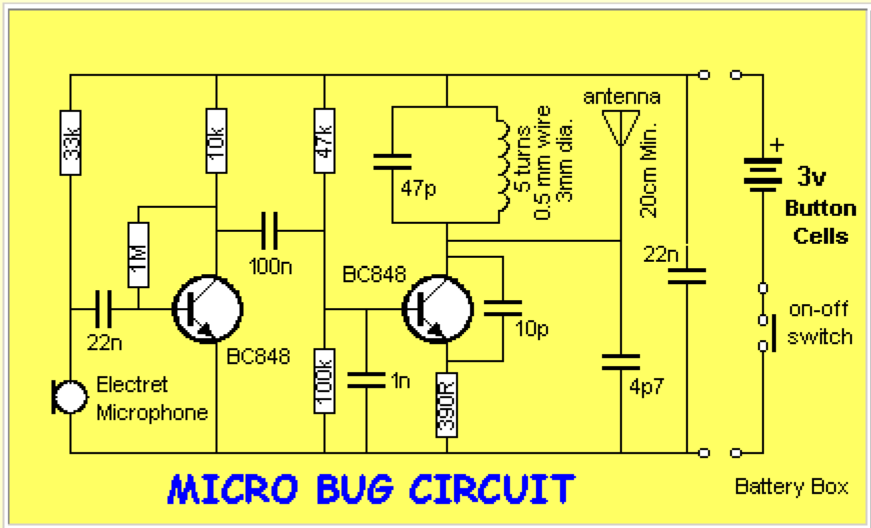
Many of the designs in our transmitter series are on their second or third improvement.
It would be wonderful to design a project that is perfect from the start, but unfortunately this is not reality. There are always improvements and additions that come along after we produce a project. Sometimes the improvements are only small and sometimes they are considerable.
No-one is perfect and we would be the last to admit we are perfect. However we can state our designs are by far the best we have seen, simply due to the fact that we update and improve them to get them to the stage of near perfection.
It's the “I help you, you help me” principle. I sell you something cheap and you buy it in enormous quantity. That's how we work. Everyone can afford our low-cost kits and that's how we stay in business. We help you with designs and you give us feedback and improvements.
This has been the case with all of our projects. When they go into the field we get feedback from constructors. We also have the advantage over other designers in that we sell made-up devices as well as kits and we get first-hand ideas on improvements. That's how we have got to the stage we are at.
And now for a really challenging project.

SMALLER AND SMALLER DEVICES

We are constantly asked for smaller and smaller bugs. Some constructors think it is easier to hide a smaller device.
But the problem with size is the antenna and the batteries.
It's no good having a micro-miniature bug if the antenna has to be 50-100cm long!
The other problem is the size of the battery. As the battery gets smaller and smaller, not only does the life of the bug reduce but the earth plane produced by the mass of the battery is also reduced and the output of the transmitter is reduced.
That's why really small bugs are placed in a metal case. It acts as a ground-plane.
It all boils down to the optimum size for a transmitter and this seems to be about the size of a matchbox.
This size gives us adequate room to fit two AAA cells, a switch and electret microphone as well as a board containing conventional components. But sometimes we have to pander to demand.
At the present, the demand is for a miniature bug.
That's why we have designed the **MICROBUG**. It is the smallest we can go using readily available surface-mount componentry - even then the components are not readily available, although some suppliers are listing packs of 10 of each component. We had to import the very tiny slide switch and microphone.
The circuit is our tried and proven two transistor design and has already been presented as the **Earwig** project.
Even though the circuit is very simple, no-one has been able to improve its performance and all we have done is use surface-mount components to reduce the size.
I am going over the operation of the circuit once again because every time I describe it, I include a few more details of how each component works.

HOW THE CIRCUIT WORKS

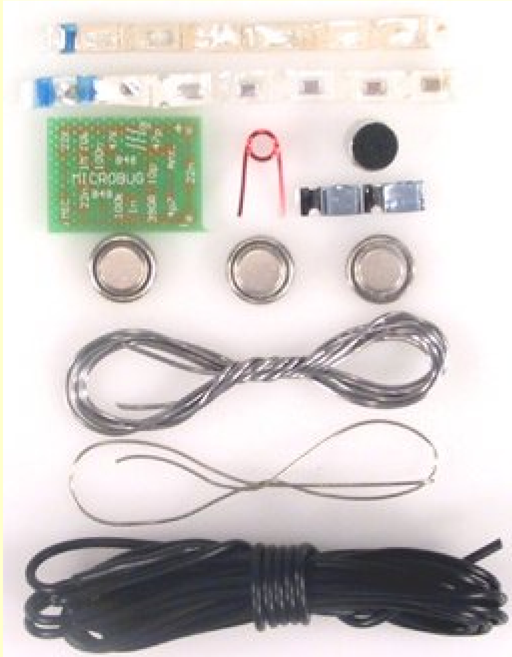
The circuit consists of three stages, an electret microphone, an audio amplifier and an RF oscillator.
The electret microphone consists of only two parts - a FET transistor and a plastic diaphragm. There is nothing else inside the case. The 3-leaded FET has an input, output and earth lead. The mylar diaphragm has been permanently charged with a static charge and this is one of the secrets of the operation of the microphone.



The FET transistor has a very high input impedance and because it is an active device, we call it a stage.
The gain of this device is extremely high because it is able to amplify the charges from a charged surface to produce an output in the millivolt range. When voice (or any sounds) are delivered to the microphone, the air vibrations are passed to the microphone through a tiny hole in the front of the case.
This causes the plastic diaphragm to move back and forth. It is situated very close to an earthed plate and if you have studied static electricity, you will know that charges on a charged surface redistribute when part of the surface is moved towards or away from an earthed surface.
This re-distribution causes charges to move in and out of a lead touching the centre of the diaphragm.
There are two factors that govern the sensitivity of the microphone. One is the manufacturing process and the quality of the charged mylar diaphragm. The other is the current flowing into the microphone via the load resistor. We cannot alter the charge on the diaphragm but the gain of the microphone can be increased or decreased by adjusting the current through the load resistor.
Further qualities such as the clarity of the pick-up is determined by the thickness (thinness) of the diaphragm and the electrostatic charge placed on it during manufacture. These factors cannot be changed by the user.
Creating a plastic that permanently holds an electrostatic charge has been a very difficult thing to do and that's why electret microphones are only a recent invention. Because we are down at the level of detecting individual charges, enormous amplification factors are required and unfortunately there is a wide variation in quality from one unit to another. For this reason they need to be tested and grouped according to sensitivity and for our project, we need the most sensitive type.
Poor quality units cannot be increased in sensitivity by reducing the load resistor as this will produce a lot of back-ground noise like bacon and eggs frying. One you have a good quality microphone, the output is passed to the first audio amplifier via a 22n capacitor.
This value can vary from 10n to 100n without any appreciable change in quality however it is always advisable to use the highest value capacitor to allow the low frequencies to pass through.
The audio amplifier has a gain of about 50 to 70 and passes the signal to the base of the RF oscillator stage.
The RF oscillator is designed to operate at about 88MHz and the frequency is set by the inductance of the 5 turn coil together with the 47p capacitor. These two components make

up a circuit called a parallel resonant circuit (tank circuit).
The frequency is also determined by the transistor, the 10p feedback capacitor and also to a lesser extent by the biasing components (47k, 100k and 390R resistors).
When power is applied, the 1n base capacitor will gradually charge via the 47k resistor and turn the transistor on.
The base voltage will continue to rise and the 10p will have the effect of trying to prevent the emitter from moving. A point in time is reached when the energy from the capacitor is exhausted and it can no longer resist the movement of the emitter. The base-emitter voltage decreases and turns the transistor off. The current flow in the coil then ceases and the magnetic flux collapses.
This collapsing magnetic field produces a voltage in the opposite direction and whereas the collector voltage may have been 2.9v, it will now rise to over 3v and charge the 47p in the opposite direction. This voltage will have the effect of charging the 10p and the voltage drop across the 390R emitter resistor will be such that the transistor will be turned more firmly OFF.
As the 10p charges, the emitter voltage will drop to a point where the transistor will begin to turn ON and the current flow through the coil will oppose the collapsing magnetic field.
The voltage across the coil will reverse and the collector voltage will drop. This change will be passed to the emitter via the 10p and the result will be that the transistor will turn ON very hard and short out the 10p. After this the cycle begins again.
What we have is an oscillator that produces AC energy at 88MHz with the amplified audio signal fed into this stage via the 100n, varying the frequency of oscillation to produce the FM signals.

PARTS LIST
1 - 390R (marked 392) 1 - 10k (marked 103) 1 - 33k (marked 333) 1 - 47k (marked 473) 1 - 100k (marked 104) 1 - 1M (marked 105) 1 - 4p7 surface mount 1 - 10p surface mount 1 - 47p surface mount 1 - 1n surface mount 2 - 22n surface mount 1 - 100n surface mount 2 - BC 848 transistors marked ‘1k’ 1 - 5 turn 3mm dia enamelled coil 1 - mini electret microphone 3 - 1.5v button cells 60cm very fine solder 1 - 80cm hook-up wire for antenna **1 - MICRO BUG PC board**
See Battery Box $2.00 extra



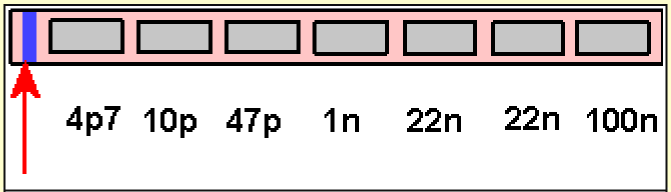
Micro Bug components

Before starting, place a tiny piece of blu-tack on the top-side of the Micro-Bug PC board and push it onto your work-bench so it does not move - all the components are mounted on the "underside" of the board.

CONSTRUCTION

All the components for this project are surface-mount.
This includes the two transistors,
Let me warn you once again, the components are very tiny.
Before opening the kit of parts you must prepare a clean space on your workbench so the components can be taken out of the holding cells without being lost.
You will also need a soldering iron with a fine tip.
We use a soldering iron that is commonly called a SOLDERING PENCIL. It is a very small iron with a tip that is sharp enough to prick you!
If you do not have this type of soldering equipment, assembly will be much more difficult and the neatness will not be as good as our photos.
You will be amazed at the improvement you get by simply using the correct equipment and FINE SOLDER.

Now we can get down to assembly:
Lay out a clean sheet of paper and place the strip of components so the black band is to the left.
The first components to fit onto the board are the resistors and these are in the strip in ascending order. This means the values are: 390R, 10k, 33k, 47k, 100k and 1M.
The next components to fit to the board are the capacitors. Unfortunately they are not marked and so you will have to be very careful when removing them so that they are not mixed up.
The size of a capacitor chip is no indication of its value and so you have to take our word that we have placed them in ascending order.
Even the colour of the substrate is no indication of a value so please don't ring us up and say “I have a tiny pink capacitor and a tiny mauve capacitor and a tiny purple capacitor, which is the 10p!”



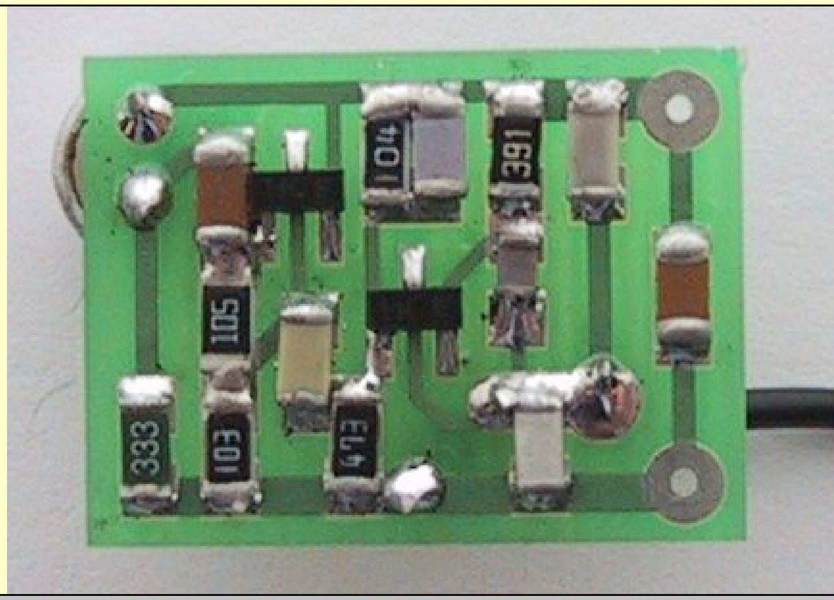
Blue/Black line
The surface-mount capacitors are housed in a carrier strip, with a black line at one end. The black line corresponds to the lowest value of capacitance.

The colors and size will change from one batch to another and from one manufacturer to another.
I know some people are going to plough into construction and lose a component or two so the replacement strips will be available for $8.00 for the set of capacitors $6.00 for the resistors and $4.00 for the transistors plus $2.00 for postage.
This is the best we can do so don't ask for individual components - you're lucky we have a service for replacement parts.
When fitting the components to the board, open up the strip from the black-band end and allow one chip at a time to fall out of its cell to a clean sheet of paper on the bench.
If the component is a resistor, it will have markings on it. Turn it over to reveal the numbers. This is a three number code to indicate the value in ohms. Make sure it is turned around so the numbers make sense. Sometimes you can hold a resistor around the wrong way and it will appear to be a different value!
The markings for each resistor have been supplied in the parts list so double-check the value before fitting it.
Pick up the resistor with a pair of tweezers or a paper clip that has a tiny piece of Blu-Tack placed on the end and carry the chip to the board.
Hold the chip in place with the paper clip but take the Blu-tack away so that it does not melt and contaminate the joint.
Bring up the soldering iron to one end of the chip and with your third hand, add a small amount of fine solder and make a connection.
The art of soldering surface-mount components will take a little time to master, but you will find they are easier and quicker to fit than conventional components.
We build hundreds of items for customers and the assembly workers have said surface-mount devices are easier and quicker to fit.

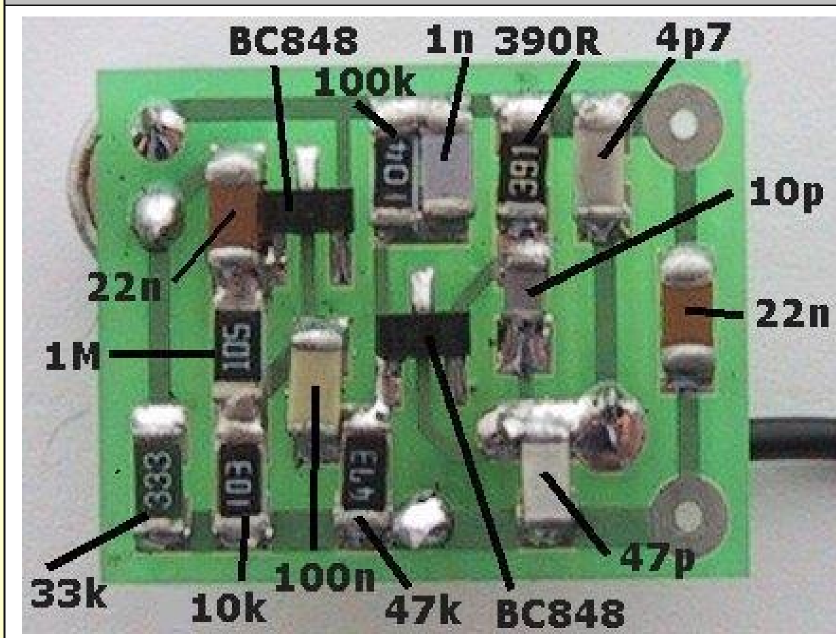
Everything takes time to get perfect and since electronics is going in the direction of surface-mount, now is a good time to get your hand in.
Every year, more and more of our consumer electronics are being converted to surface-mount technology.
Already more than 40% mount is surface-mount and the percentage is increasing all the time. The driving force is economics.
Even though surface mount components are slightly more expensive, the cost of insertion is much lower as they are placed on the board with a pick-and-place machine. These can fit components five-times faster than conventional components.
But the real saving is in the size of the board. This can be reduced by as much as 50% with components on one side or as much as 70% with components on both sides.
The board can be made of much thinner material or even flexible, so the scope for new produces is enormous.
Board for cameras, for instance, are made of paper-thin flexible material so it can fit around the body of the camera with flexible wiring to connect to the button, motor, battery and flash.
But the greatest advantage of surface-mount is the aesthetics. Surface-mount looks professional and makes your product stand out from the rest.

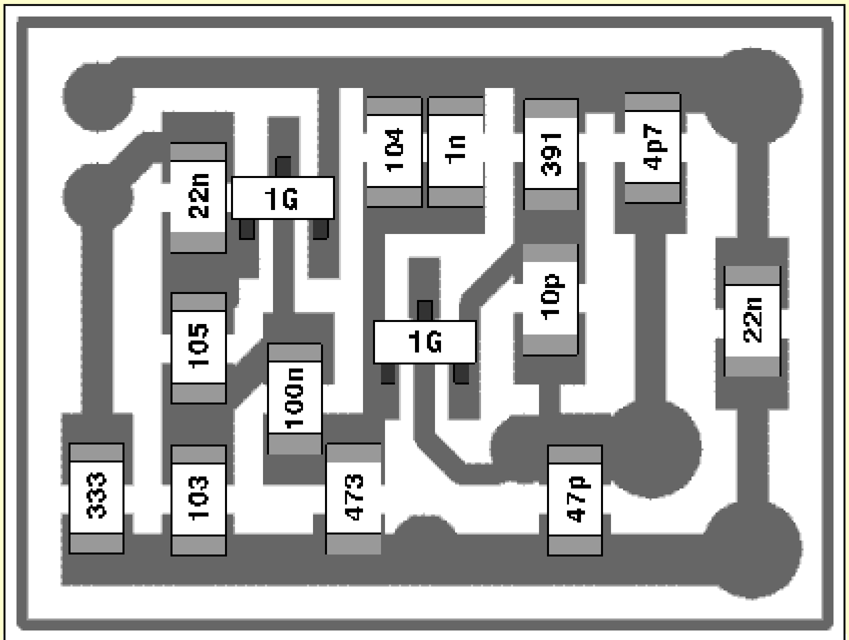
Now back to the topic.
When you get to the capacitors, you must look into the cell before letting it fall out so you can recognise it once it hits the paper.
Refer to the diagram of the strip for the value and then the enlarged diagram of the board for the position of the component.
It doesn't matter which way around the resistors or capacitors are placed and they can even

When you have soldered one end of a component you must not try to straighten it up. This also applies to a component that is standing up slightly.
Any amount of force will fracture the substrate. Even slight pressure can separate the metallised end caps from their substrate and cause the component to go open circuit.
That's why it is important to hold the component in place with the tip of a paper clip while soldering the first end.
If the component shifts, you are in big trouble.
This is because YOU are going to take much longer to re-heat the end and realign it.
If this happens with a transistor, forget it. The transistor will be damaged.
It a component moves, leave it misaligned and try to solder the other end as best as possible. The damage you will cause in trying to straighten it will be a nightmare to fault-find.
Another problem you will find is some soldering irons are magnetic and the resistor will stick to the tip of the iron if you don't hold them down with something such as a pair of tweezers or paper clip.
Just before we go to the transistors, let me give one final hint.
To reduce the heat build-up in a component, it is best to solder one end then wait a few seconds for the component to cool down before soldering the other end.
This is very important when soldering the transistors.



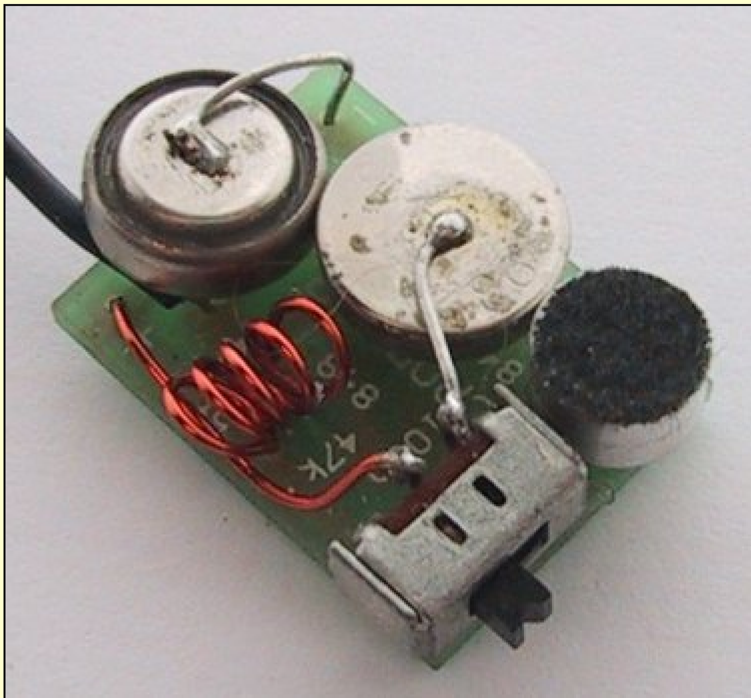
The Micro Bug from the bottom. Notice how neatly the parts are positioned and soldered



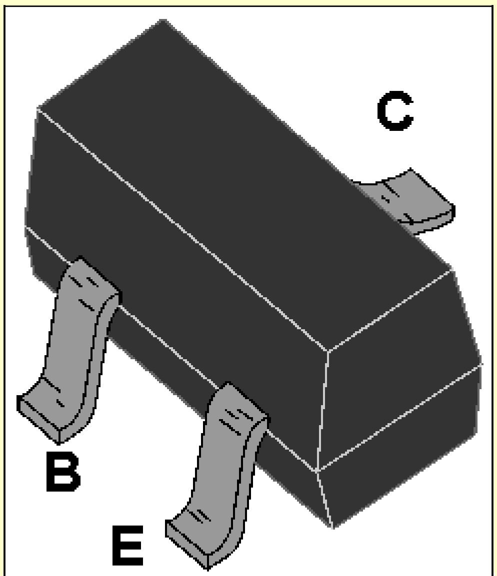


Another view of the underside of the Micro Bug showing the placement of the surface-mount components

Even though the transistors are designed to withstand 10 seconds of soldering in a wave-soldering machine, this does not mean you can take 10 seconds to solder with a soldering iron.
The reason is the wave-solder bath is maintained at a precise temperature and this is the exact temperature to complete the soldering process without overheating the components.
Most soldering irons are above this temperature and this means the soldering time must be reduced. For an iron 30°C above this temperature, the time must be reduced to 3 seconds and for 50°C above, the time must be less than 1/2 second.
Most hobbyist irons come into the 1/2 second category and on top of this, only one lead at a time must be soldered.
Once you know your soldering techniques are acceptable for surface-mount components, and none are being damaged, you can you can work as fast as our assembly section and fit the components about twice as fast as the through-hole types.



The Micro Bug with two button cells soldered to the top of the board with a miniature slide switch.
This is how the project will look with the components supplied in the kit



The pinout of the SM transistor we supply in the kit

THE SURFACE MOUNT TRANSISTOR

Now let's talk about the surface mount transistor.
When you open up your kit of parts you will get quite a shock.

resistor!
But any industrial prototypes have to be assembled by hand and this project will be a good experience for later.
Above you see the outline of the surface mount transistor. The top of the device is too small to fit the full type number and a silly code number has been allocated as follows: BC 847, BC848 (NPN) is marked 1k, but most importantly it is a three leaded package.
This is the same as BC 547. The tiny leads are so short that they just emerge from the case and this means any heat from the soldering iron will travel to the junction very quickly. You have only half a second to complete each solder joint. Any delay will damage the transistor totally and it will fail to amplify.

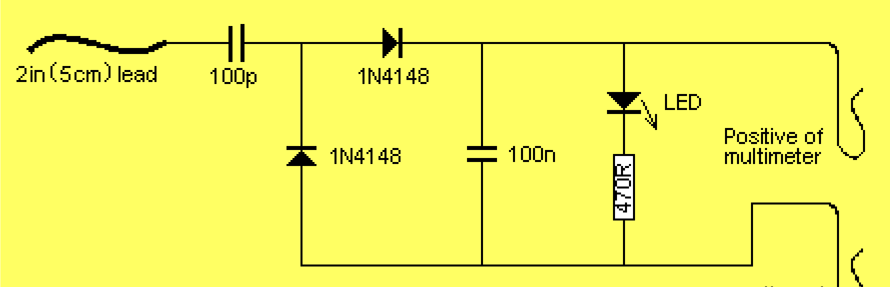
TESTING and GETTING THE CIRCUIT TO WORK

We are going to cover these two at the same time.
Testing the circuit and getting it to transmit on a particular frequency is a learning experience. If the circuit does not work, this is when you will start to learn REAL electronics.
I hope the circuit does not work and you have to fix it, but since our projects have been tried and tested thousands of times, the chances of it not working are very slim. The main fault will be overheating the components and damaging them by trying to move them while soldering.
As I have said, this transmitter is an advancement on a number of projects we have already presented and it has been suggested that you build some of the others to get you accustomed to the performance.

The first thing to do is see if the transmitter works (transmits).
Place it near an FM radio turned to medium volume and tune across the dial, listening for a feedback squeal.
If a squeal is heard, the transmitter is operating on the FM band. If you don't hear a squeal, don't worry as the circuit may be operating just below the band and in this case you will not be able to pick it up.
To find out, remove the antenna lead and fit the **LED Power Meter**.
It will only take 10 minutes or so to build this circuit and connect it to an ordinary multimeter set to low volts range.
Once you have built it, you can go on to the next stage:

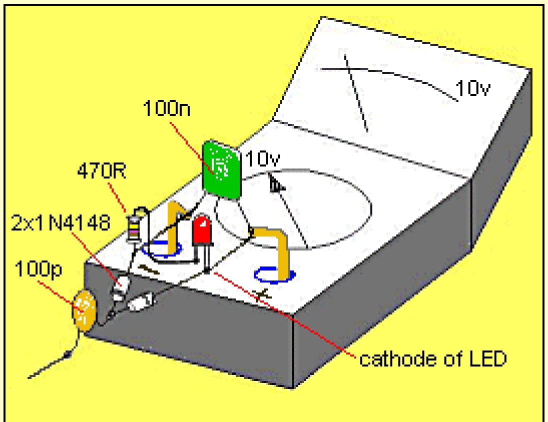
THE LED POWER METER

The LED power Meter is a simple RF detector using diodes to charge a capacitor. The voltage developed across the capacitor is shown on a multimeter set to a low voltage range.



THE LED POWER METER CIRCUIT

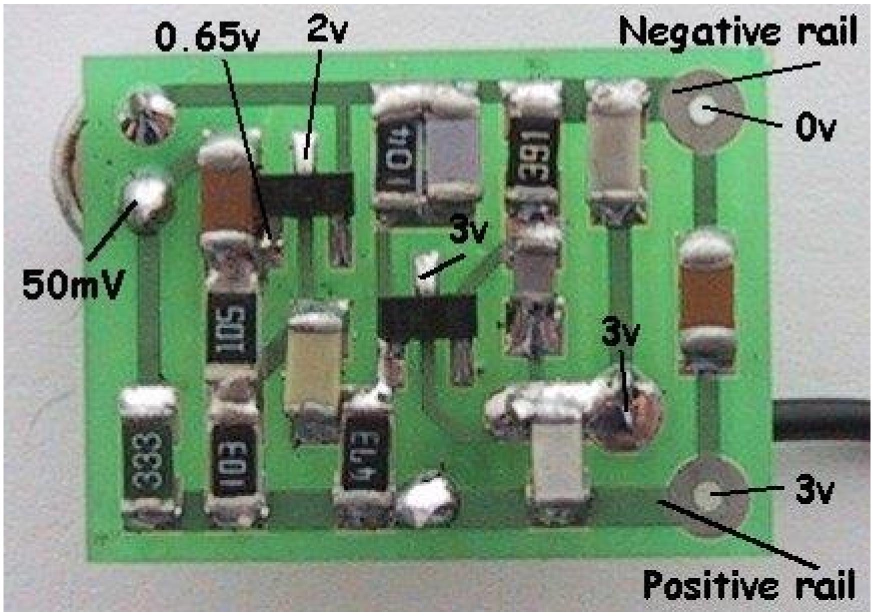
The circuit is soldered together without the need for a PC board, as can be seen in diagram below and paper clips are used for the positive and negative terminals of the multimeter.



The output of the **Micro Bug** is **very low** and you will only get a very small indication on the meter and a very small glow from the LED.
The reading is not calibrated and does not represent milliwatts output. It is only a visual indication.

LED Power Meter Parts List
1 - 470R (yellow-purple-brown) 1 - 100p ceramic (marked 101) 1 - 0.1u (100n) ceramic (called monoblock) (104) 2 - 1N 4148 diodes 1 - 2in (5cm) hook-up wire 2 - paper clips No PC board required

If the multimeter does not show a reading, the output stage is not working.
The two stages in this project are AC coupled (a capacitor separates them) and they can be tested separately.
The first place to go to is the oscillator section. This is called and RF oscillator as it is operating at approx 88MHz.
This is a difficult stage to test as it is operating at a very high frequency.
It is not possible to view the waveform on an ordinary 30MHz CR0 as the circuit is operating at 88MHz and the CR0 will not display the waveform on the screen. All it will show is a mass of lines
- if you are lucky. A 30MHz CR0 will also put such a load on the circuit that it will cease to oscillate.
This means all you can do is take a few voltage measurements and check the continuity of the trackwork.
Firstly check the voltage on the collector of the oscillator transistor. It should be 3v, indicating the coil is making contact through the board. Next measure the voltage on the emitter. It should be about 2v. If it is 0v, the transistor is not being turned on or the 390R is not making contact with the board (the voltage will be about 2.5v to 3v, in this case). The base voltage should be about 2.6v, and if it is much lower than this, the 47k resistor may be the wrong value or the transistor is pulling the voltage down (due to the emitter resistor being the wrong value and/or the base-emitter junction being a short circuit).



A guide to the voltages on the Micro Bug

When you are probing around this stage, the load produced by the leads of the multimeter will often prevent the circuit from operating, so don't expect to get an output on the LED Power Meter when probing the board.
The main reason for this is the leads become an antenna and they absorb the signal.
The LED Power Meter can be connected all the time. It puts a very small load on the circuit and will not affect the performance.

Two problems remain. You cannot test the 47p unless you remove it and test it on a Capacitance Meter. The same applies to the 10p. The cheapest and quickest thing to do is replace the two components (the surface mount components are available as spare parts).
The 1n is also very important and if it has been damaged during assembly (open circuit), the oscillator will not function. This should also be replaced.
Lastly the 22n across the power rails must be in place to get a good output from the oscillator. Try another 22n across it to see if the performance alters. The only other things I can suggest are a shorted or damaged 100n input capacitor and/or a damaged transistor.
Removing the transistor and testing it will be almost impossible as the heat required to desolder the leads will destroy the component.
The only real choice is to replace the transistor and make sure you solder it quickly.
Obviously you will have checked the freshness of the button cells, to make sure the voltage is not too low, and the operation of the switch.
Just in case you are not aware, you cannot connect this project to a power supply or to cells via long leads. The length of the leads will reduce the "tightness of the circuit" and prevent the oscillator from functioning properly.
This should get the oscillator functioning and you can now go to the antenna point and measure the RF via the LED Power Meter.
You must get a reading (a slight reading) on the antenna-point before continuing.

SETTING THE FREQUENCY

The next step is to set the frequency of operation.
This could be below the FM band or above it as the commercial section between 88 and 108MHz is rapidly filling up.
When we first started producing transmitters the band was almost totally

empty, but as minority groups have begun to realize the power of voicing their view on the airwaves, every local community group has its own radio station.
The separation between radio stations is now less than 100kHz and you cannot get another transmission in between.
Just above or below the dial is sometimes the best solution and we have opted for **below the band** when we sell made-up devices, as the range is better.
Simply by adding one more turn to the oscillator coil we can tune below the band and adjust the turns to sit between courier companies and other users.
When thinking of transmitting above the band, you cannot operate between 120MHz and 130MHz as this has been allocated to the emergency band and aircraft traffic control.

With a reading on the **LED power Meter** you know the Micro Bug is transmitting but you don't know the frequency of transmission.
If you want to operate on the 88 -108MHz band, turn on an FM radio and tune across the band. When the radio is at the same frequency as the Micro Bug, it will produce a loud squeal.
If you want to operate below the band you will have to detune the radio so that it will go down to approx 86MHz.
This is done by moving the turns of the air-cored coil near the tuning gang so that the stations move up the scale. This will create an empty spot at the lower end of the band. You can also adjust the trimmers on the back of the tuning capacitor to shift the stations up or down the dial.
In most cases you cannot shift the band very much as the stations begin to "wrap around" the dial and the high stations appear at the lower end. Be satisfied with a small shift. You should now tune the radio to the bottom of the band if you have detuned the radio, or to the top of the band if you have moved the stations down.
For a detuned Micro Bug, you should have 7 turns in the oscillator coil. Move the turns of the coil so that you get a feedback whistle.
If you want to transmit above the commercial band, make sure you have 5 turns on the coil.
One of the main problems with this part of the operation is finding the frequency of transmission. The LED Power Meter will not give you this; it will only let you know when the oscillator is operating.
You need a frequency meter or our FIELD STRENGTH METER MkII (to be described in a future issue). It has a scale marked on the PC board, from 75MHz to 140MHz to let you know the frequency of the signal you are picking up and a set of 3 LEDs to indicate the relative strength of the signal.
If you get a reading on the **LED Power Meter** and an indication on the Field Strength Meter MkII to indicate the frequency is say 90MHz, but the radio only produces a dead spot or quiet spot on the dial, it will indicate the audio from the first stage is not coming through.
This means the fault will lie in the audio amplifier stage and/or electret microphone. The first thing to do is take voltage tests and confirm your readings against those given on the circuit diagram. The collector of the audio transistor should be about half rail voltage (and the voltage on the microphone can be as low as 50 millivolts) and the microphone will still be working perfectly.
To test these stages more fully you need an audio oscillator or audio probe and we have provided an audio injector probe on the **Combo-2** project.
Connect the earth clip of the Combo-2 project to the negative rail of the Micro Bug and inject a signal at the collector of the audio stage.
This will send a tone through the 100n coupling capacitor and produce a buzz from the radio.
If this does not happen, the fault will lie in the 100n monoblock or maybe the end of the capacitor that goes to the collector of the audio stage has a short under the board, taking it to one of the rails and thus shorting out the

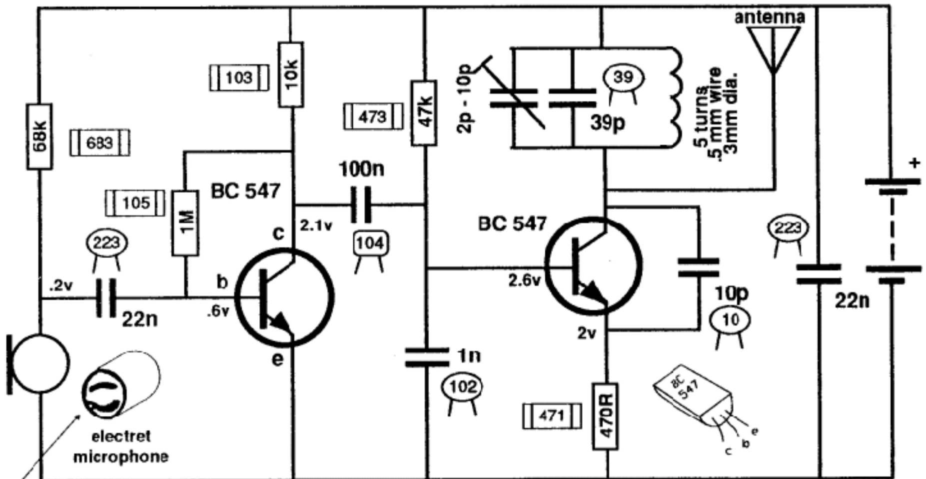
signal.
Once you get a signal at this point, move the probe to the base of the audio transistor. The buzz from the radio should be louder.
If it is weaker, the audio transistor may not be amplifying correctly. It may be damaged or open circuit.
Next, take the audio probe to the output of the microphone. If the output from the radio is reduced, the 22n coupling capacitor may be open circuit or one of the ends may be shorted to the negative rail.
If the output point of the electret microphone produces a loud buzz from the radio, but the microphone does not produce any audio, the most likely cause is a faulty microphone. Check around the microphone for shorts and solder bridges. As a last resort, replace the microphone.

CONCLUSION
This completes the project. It is about as small as you can get and if you have a fine-tipped soldering iron, it should be possible to get it working, provided you follow our instructions carefully.
You will be very pleased when you turn it on as it will pick up the ticking of a clock and anyone whispering nearby.
Surface-mount components are excellent for this type of project.
High-frequency projects like to be very compact as it improves the "Q-factor" (the overall output of the oscillator stage) and surface-mount components make the circuit very "tight."
Once you start working with surface-mount, you will realize it is the only way to go.
We will be presenting more surface-mount projects in the future, keep looking out for them.

VOYAGER MkII

Kit of parts: $12.90 USD
Post: $4.50 USD
email: talking@tpg.com.au
to pay by PayPal

Our 800metre Voyager MkII has a number of improvements



Case of electret mic goes to negative rail

VOYAGER - MkII CIRCUIT

This is the improved version of our popular VOYAGER FM transmitter. The circuit has been improved, the layout has been changed and the board has been produced on CAD.

This has given it a better layout than the old taped artwork board and everything is marked on the topside to help you with assembly.

The other difference is the board sits upright on the top of a 9v battery with the battery snap fitted to the side of the board via short lengths of tinned copper wire as shown in the photos, whereas it laid flat on the battery in the earlier model.

Standing the board upright makes the battery snap very strong and it is easier to connect and remove the board from the battery without damaging the tracks.

The other major difference is the addition of an air trimmer so that you can adjust the frequency slightly after the project has been heatshrunk. This will allow you to move it away from any other radio stations.

When we first started to produce these transmitters the FM band had only a few radio stations and it was easy to get a free spot on the dial.

But in the past few years the band has filled up considerably and it is now almost impossible to get an empty spot where you can experiment.

That's why we have had to include the air trimmer. After the project is complete and heatshrunk, (you need to supply your own length of heatshrink tubing) final tuning can be carried out by cutting an opening in the heatshrink for the top of the trimmer so that it can be adjusted with a small non-metallic screwdriver.

SUMMARY OF SPECIFICATIONS

Range: 800 metres
Supply: 9v
Current consumption: 7mA
Battery life: 50 hours for ZnC
100 hours for alkaline
Tuning range: 80 - 110MHz (by stretching or compressing the oscillator coil)
Fine tune by adjusting the air trimmer (2MHz adjustment)
Stability: Bug to be left in situ - not to be moved or handled.
Antenna length - 170cm

I should also mention that two slight modifications have been made to the circuit. One is the change in value of the base bias transistor for the oscillator. It has been changed from 220k to 47k as we found the 220k produced a small amount of distortion or hollowness to the audio, giving the impression that the sound was coming through a pipe.

The other change is the positioning of the microphone. It is now mounted on the side of the board so that the board is easier to heatshrink.

These modifications are a result of us making hundreds of Voyagers for customers and the new layout is really a dream to put together.

If you have not built any of our FM transmitters, this is one you should not miss out on.

Before I start, let me say that these transmitters are called "bugs" so that

PARTS LIST

1 - 470R surface mount (471)
1 - 10k " " (103)
1 - 47k " " (473)
1 - 68k " " (683)
1 - 1M " " (105)

1 - 10p ceramic
1 - 39p ceramic
1 - 1n ceramic
2 - 22n ceramics
1 - 100n monoblock (monolithic)
1 - Air trimmer 2p - 10p

2 - BC 547 transistors
1 - 5 turn coil .5mm enamelled wire
1 - electret mic insert - high sensitivity
1 - 9v battery snap
1 - 9v battery
1 - 15cm tinned copper wire
1 - 30cm fine solder
1 - 170cm antenna wire

1 - VOYAGER - MkII PC BOARD

they can be described quickly and easily in the text.

They have been designed exclusively so that you will learn the techniques of FM transmission and get the greatest range possible with the minimum of power.

Under no circumstance are you to use or try to use any of them for any improper purpose (if this is possible) and you are to follow the laws in your state, governing their use.

There is no law preventing us showing you how FM transmission works and you must respect our efforts by keeping the airwaves free from interference.

I am sure you will be building these transmitters as a learning exercise and suggest you start at the beginning by building some of the other projects first.

We have compiled the best range of FM transmitters you will ever come across in this book. Each project has been designed to add features to the basic ANT design so that you can see how the range can be increased by adding such things as a tuned output, RFC, emitter coupling, and by increasing the supply voltage.

In this project we will show how increasing the supply voltage improves the range and at the same time we introduce miniaturisation in the form of surface-mount components.

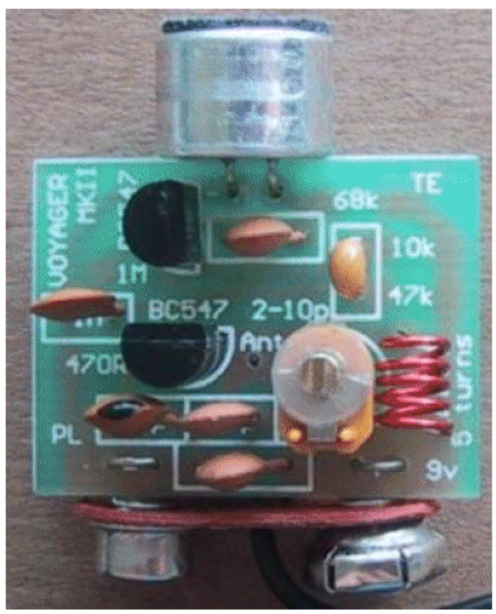
To make construction as simple as possible, we have decided to start with surface mount resistors. Some of the other components such as chip capacitors and transistors are so small that they are almost impossible to solder by hand.

Surface-mount technology is entirely different to normal through-hole placement and some of the differences are explained in this article.

The major difference is size and if you are having trouble picking up and placing 1/4 watt resistors, you will have ten times more difficulty with surface mount. SM items are so small that it takes the keenest eyesight to read the figures on the component and the nimblest of fingers to pick and place them.

But until you buy a kit and see what the parts look like, you will have no idea if you will be able to cope.

Nevertheless surface mount has arrived and is here to stay. Within a few years most manufacturing will include surface mount components and already many designs are entirely surface mount.



Since this will possibly be your first introduction to surface mount, we have decided to introduce it slowly and use normal components for the majority of the circuit and chip resistors for the surface mount section.

Although this may not take up less space, and is sure to work out more expensive, it is the only practical way to start.

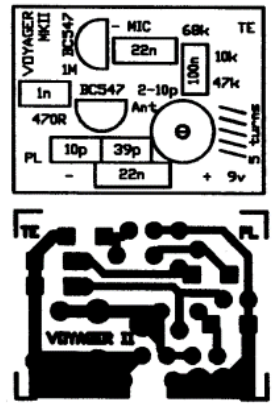
Most SMC's are extremely difficult to buy and very expensive. I don't know of any outlets that sell individual items and only a handful that sell them in lots of 10 or 100. We have to buy them on a reel of 1,000 to 5,000 pieces and this is way beyond the needs of an average hobbyist.

Some of the components for the Voyager are not available in surface-mount form (such as the coil and air trimmer) and anyway the battery is the largest component so there's little point going to extreme lengths in miniaturisation.

The electret microphone is also difficult to get in miniature form and when we tried to get one about a quarter the size of our present unit, about 4 years ago, from a hearing aid manufacturer, we were quoted an astounding $32 each!

We subsequently imported our own and sell them for about $3.00 each. Who do you think bought 100 of our mic's! Yes, the hearing aid manufacturer!

The main reason why we started with chip resistors is their relative ease of handling. Chip capacitors are half the size and have no identification. The



Actual size artwork showing the size of the board and the top overlay.

other factor that makes them very frustrating is their size does not correspond to the value. This is due to the way they are manufactured and the thickness of the layers of substrate.

The main difficulty with surface mount is placing them on the board and holding them in place while soldering. There are a number of aids to help you with this, such as solder pastes and solder creams, silicon and infra-red setting glues but most of these come in syringes and cost as much as $20 for a 25gm tube. For a simple project, this additional cost is out of the question.

To keep costs down we are going to hand solder each resistor without the aid of glue and the technique we use is called RE-FLOW SOLDERING.

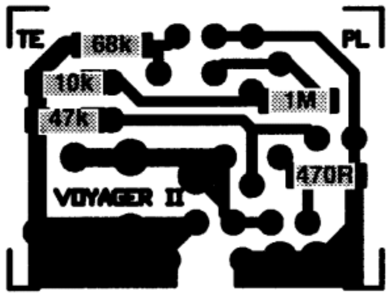
Basically it consists of heating up the solder on the PC board AND THE END OF THE RESISTOR AT THE SAME TIME so that the resistor makes a perfect connection to the board. More is mentioned about this in the assembly section.

For now, all you have to do is read through the article and make sure you know how the project is going to go together, before starting.

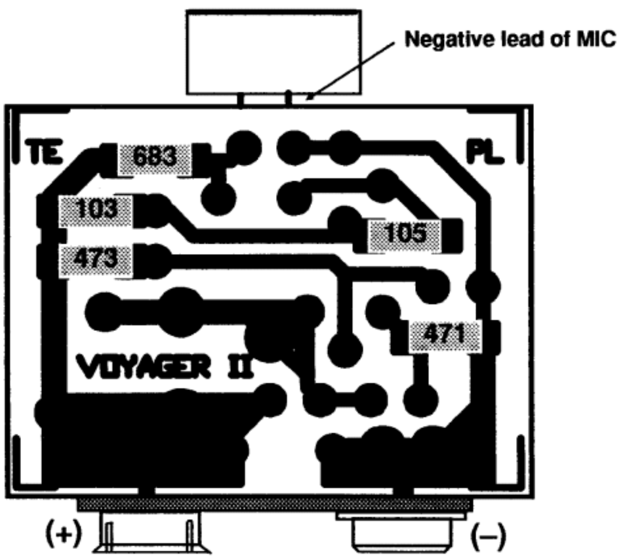
HOW THE CIRCUIT WORKS

The circuit consists of two stages - an audio amplifier and an RF oscillator.

The electret microphone contains a FET transistor and can be counted as a stage, if you wish. The microphone detects audio in the form of air vibrations that enter the hole at the end of the mic and move the diaphragm. This diaphragm is a thin piece of metallised plastic such as mylar and is charged during manufacture. The relative distance of the mylar film to the outer case makes the charges move on the diaphragm (as like charges repel etc). Some of them pass down a lead that touches it and into a FET transistor. The FET amplifies the charges and gives a reading at the output lead. The reason why a FET has been used is due to the fact that it has a very high input impedance and does not have any loading effect on the charges. The audio amplifier (BC547) has a gain of about 70 and amplifies the signal and passes it to the base of the oscillator stage.



The resistor values as compared to the circuit diagram.



Twist two pieces of tinned copper wire together and use it to solder the positive and negative terminals of the 9v battery snap to the PC board.

The oscillator is designed to operate at about 100MHz and this frequency is set by the value of inductance of the 6 turn coil and the capacitor across it. The frequency is also determined to a lesser extent by the transistor, the 10p feedback capacitor and also the biasing components such as the 470R emitter resistor and 47k base bias resistor. The supply voltage also has an effect as the oscillator can be classified as a voltage controlled oscillator.

So, there are a lot of things that set the frequency and even though the parts have a 5%, 10% or 20% tolerance, the frequency can be set very accurately by moving the turns of the coil closer or stretching them apart and then adjusting the air trimmer to the precise frequency you require. The circuit will stay at the desired frequency providing the supply voltage remains constant and the temperature of the parts do not rise appreciably such as it being left in the sun etc.

The voyager is not designed to be handled and is not suitable to be worn on the body - we have other circuits for this type of application.

The operation of the oscillator section is quite complex, so to keep things simple we will commence the discussion when the transistor gets turned on via a pulse from the 10p feedback capacitor. At the end of the discussion you will see how this pulse is generated.

First let me explain how the voltages are set on the oscillator transistor.

The 47k base resistor turns the transistor ON and its value is such that it does not turn it on fully. The feedback pulse from the 10p turns it ON fully by lowering the emitter voltage and OFF fully when it is in the opposite direction.

We normally turn a transistor on and off via the base but the same can be done by holding the base firm and changing the voltage on the emitter. In the Voyager, this is what happens. The base is held firm by the 1n capacitor and the emitter voltage is increased and decreased by the action of the 10p feedback capacitor.

For the capacitor to be able to do this, the emitter must have a DC voltage that can be increased and decreased. This DC voltage is determined by a number of factors that are quite complex and we measured our prototype and found it to be 2v. The base will be .6v higher at 2.6v. To measure the base voltage you need a very high impedance multimeter so that you don't load the circuit and get a false reading.

The base voltage is fixed at 2.6v by the 1n capacitor and does not rise or fall when the oscillator is operating. (It only rises and falls when the audio is injected into the base from the 100n capacitor from the audio stage.)

So, where do we start?

The best place to start is the tuned circuit. The capacitor and inductor are in parallel and form a tuned circuit. They find it very easy to pass energy back and forth and when a small amount of energy is delivered to them via the transistor, the waveform generated by them is sinusoidal and if we imagine the transistor is removed for a moment, we can see that the 10p capacitor detects this waveform and passes it to the emitter resistor..

If we put the transistor back we can see that a pulse that reduces the voltage on the emitter will make the voltage between the base and emitter larger. This action turns the transistor ON and delivers a burst of energy to the tuned circuit. As the waveform continues through its cycle, a point will be reached where the pulse through the feedback capacitor will be in the opposite direction and this time it will turn the transistor off.

This is how the circuit works and continues at the incredible rate of 100 million times per second.

RESISTOR AND CAPACITOR VALUES

With the size of resistors and capacitors getting smaller and smaller, the space for identifying the value is getting less and less.

To make things simple, a uniform numbering system has been adopted, consisting of three digits. The first two give the value of the capacitor in pF or the value of resistance in ohms and the third digit is the multiplier.

This brings both capacitors and resistors into the same code and once you can read the code, you can identify everything.

As an example, we will take a 47k resistor. See the third chip in the diagram opposite. The digits are 4 - 7 - 3. The digit "3" represents the number of zeros to put after the number "47." Thus we get 47,000 ohms.

A 470 ohm resistor is "47" and one zero, thus we get 471 on a chip. A 10k is "10" and three zeros, thus 103 is written on the chip. A 68k is written "68" and three zeros, thus 683 is written on the chip and 1M is written "10" and five zeros. Thus the chip has 105 on it. These are the five values used in the Voyager.

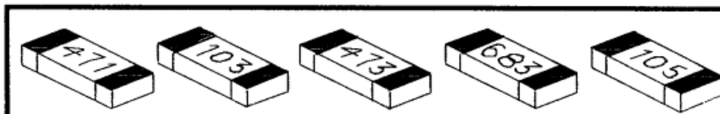
A 10 ohm resistor is "10" and NO ZEROS, so the marking is 100. I know, I don't like it either but 150 on a chip is 15 ohms and not 150 ohms. 150 ohms is "151." Don't ask me what 1 ohm is because surface mount resistors start at 10 ohms and go to about 4M7.

It's only the range from 10 ohms to 100 ohms that will cause problems. When you see markings such as 120, 180, 470 etc it is best to check the resistance with a multimeter, to make sure the resistances are 12 ohms, 18 ohms and 47 ohms.

Keeping this in mind, we go to the markings for capacitors. The basic unit for surface mount capacitors is pF (sounded 'puff') and instead of using the word kilo for thousand (as with resistors) we use nano ('n' for short). Thus 102 is 1n and 103 is 10n. Extending this further we get 104 for 100n and 105 for 1uF.

For those who have to convert from the old system, 10n is equal to .01uF and 100n is .1uF. 223 is 22n or .022uF and 1n is 1,000pF or .001uF. For surface mount capacitors, you must think in pF. This will allow you to build our next surface mount project and any others in the future.

One point to note: With surface mount capacitors, the size of the chip is no indication of capacitance. The structure of the chip can be single layer or multilayer and this affects the size.



The 5 chip resistors used in this project are: 470R, 10k, 47k, 68k and 1M.

WHY?

How many times have you built a project and it doesn't function as described?

Don't blame yourself, it could be due to poor circuit design, in which the values chosen by the designer are not the most suitable. Let's look at how this comes about.

All components have a spread of parameters called TOLERANCE. This includes resistors with a tolerance of 1%, 5% or 10%, capacitors, (with a tolerance of 10%, 20% or even 50%), transistors, electret microphones, coils and even integrated circuits.

Then we have another factor called "limits." Each component in a circuit should be chosen so that its value is the most appropriate to that required. In other words, the circuit should work equally well if we select the next higher value or next lower value. If not, the circuit is very critical or the chosen value is not the most appropriate.

The amount by which a value can be increased or decreased and still allow the circuit to function, is called the LIMIT.

When a project is published in a magazine or book, there is an enormous range of builders with varying skills, drawing their supplies from many different sources.

Sometimes they use the designated values, othertimes they use the next value. Some components have tolerance values of ±5% while others can be as much as 50% higher than the marked value. When these variations are combined, you can quite often come up with a circuit that does not work!

Take an electret microphone for example. On a 3v supply, some microphones are super-sensitive with a 47k load resistor, others may require a 4k7 to get a barely acceptable result.

By looking at the two you could not tell them apart. It's only when you put them in a circuit that the difference is detected. The microphones we buy for the Voyager have a very high sensitivity whereas most microphones that are available from hobby shops are medium sensitivity. Our transmitters are capable of picking up the ticking of a clock from 3 metres or the slightest whisper from 5 metres. There is no way of changing the sensitivity of an electret microphone, it's all in the charging of the mylar film inside the unit, during the time of manufacture.

There is also an enormous variation in the quality of transistors. Some manufacturer's produce very poor quality devices while the same type from other manufacturers may be superb. This is one of the main reasons why it's best to buy a kit. Kit suppliers know which brand is best and only supply the best quality. By buying a kit, the risk of failure is minimized.

ASSEMBLY

Before you do anything, prepare the workbench.

Lay out a couple of sheets of clean white paper and place the kit of parts on one. Don't take the resistors out of the carriers until you are ready - a resistor dropped may be a resistor lost.

Study the board and note that all the components are identified by the printing on the top of the board, called the overlay or legend. You really don't need any instructions at all, but since this may be your first attempt at surface-mount, we will give you some helpful hints.

Note how the board stands on top of a 9v battery, with the battery snap soldered to the edge of the board. The positive and negative lands on the board are large so that the connections to the snap will be strong.

The microphone fits on the top of the board with two short wires and overhangs the board. Some microphones come with wires attached and this makes them easy to fit. Other microphones may need to have wires attached and these can be obtained from the ends of capacitors.

The only 4 components that have to be fitted around the correct way are the two transistors, the microphone and battery snap. All the other parts, including the capacitors, air trimmer, coil and resistors can be soldered around either way.

Once you have studied the photos, the PC board and components, you can start.

Here is the order for assembly:
5 surface mount resistors.
6 capacitors.
2 transistors.
air trimmer
5-turn coil
battery snap
microphone.
antenna lead.

Now for the finer points:

The surface mount resistors required a fair degree of skill and you have to be good at soldering if you want to make the board look neat.

Refer to the two diagrams on the following page and note the top diagram shows where each of the resistors goes according to the values shown on the circuit diagram. The lower diagram shows the values of the resistors according to the 3-digit resistor code.

Place the strip of resistors on the workbench and take one out of the carrier strip, keeping the code numbers on top. Turn the resistor around so that the numbers make sense (make sure you don't read the numbers around the wrong way!) and place it on the board as shown in the photo and diagram, so that it is correctly placed on the solder lands.

There are two ways of soldering the chip. One is to sit it in place and heat one end with a soldering iron while applying solder and then repeat with the other end.

The other is called RE-FLOW.

In this method, you add a little solder to each land and tin each end of the resistor while holding it in your fingers. Yes! You can actually hold the chip while soldering the opposite end. If you can't, you are taking too long.

When both the lands and the ends of the chip are tinned, it is placed in position and held with a piece of wire such as a paper clip while one end is touched with a soldering iron. This is repeated with the other end.

It is important not to put any force on the chip as you are soldering it as the ends can be easily fractured and the resistor will go open circuit. A hairline crack will be produced that you will not be able to see. The only way to check that the resistor has not been damaged is to measure it with a multimeter.

The other 4 chips are placed on the board in exactly the same way, making sure they are covering the lands and sitting flat on the board.

Double check the codes and if everything is correct you have carried out your first surface-mount construction!

The rest of the assembly is a lot easier, it's just a matter of doing things in the correct order.

All the other components are mounted on the top of the board and when two formats are combined like this, the assembly is called HYBRID.

Refer to the layout diagram for the placement of the 6 capacitors. These are soldered in place, one at a time. Some of the leads may have to be bent slightly to allow the component to fit down the holes as it is almost impossible to get all components in either .1" or .2" spacing.

Next, the two transistors are soldered in place. Push them down as far as they will go as we want to keep the profile low. In addition, we have designed the circuit with the transistor leads as short as possible. If you place the transistors high off the board, the performance of the oscillator will be different to our prototype.

Solder the leads quickly so that you don't heat up the transistor too much.

The air trimmer is next. This must be soldered very quickly otherwise the plastic insulation between the plates will melt. Keep a finger on the trimmer to act as a heatsink and everything will be ok.

The coil is made from enamel coated wire and this coating must be scraped off with a knife or burnt off with a hot soldering iron so that the two ends are bright and shiny and TINNED before fitting to the board.

The kit comes with a pre-wound coil but if you are making it yourself, here are the details:

Wind 5 turns of 24B&S (.5mm) or 21B&S (.71mm) on a 3mm diameter shaft such as a medium Philips screw driver and space the turns as shown in the photo.

The coil determines the frequency of the oscillator and the turns will be stretched apart or squashed together after the project is complete. At this stage it does not matter about the spacing of the turns, as long as the ends fit neatly down the holes in the board.

If you have made the coil from enamelled wire, don't forget to tin the ends. This is done while the coil is on the screwdriver so that it acts as a heatsink.

Push the coil up to the board and solder it in place with the turns evenly spaced.

Now the battery snap. If you want this project to get the range we have specified, the circuit must be as tight as possible and this means the battery must be as close to the board as possible. To do this we take a battery snap out of its plastic jacket and solder it directly to the edge of the board. The "crown" terminal is soldered to the positive land on the board. Use plenty of solder at it is necessary to make a good mechanical connection.

The terminals must not be able to be rotated and if they can be turned, they should be soldered at the centre of rotation. Use very little solder inside the crown as the positive terminal of the battery must be able to fit inside it to make contact.

One of the last components to fit is the microphone as its two leads are very fine and any bending will cause them to break.

The microphone in the kit comes with two short wires attached and if you look at the solder-lands on the back you will see one goes to the case. This is the negative terminal and must be soldered down the negative hole on the board. See the Gnat article on pages 26 and 27 for a close-up of the bottom of the microphone, and circuit diagram.

Finally the antenna. This is soldered down the hole market "ant." You have a choice of two antennas, a 15cm tinned copper wire antenna and a 170cm half-wave antenna. This has been done to allow you to experiment as the main purpose of these FM transmitters is to achieve the greatest range with the least power. We want you to try different antenna combinations to see which is the most effective.

If you only want about 30-50metre range, the 15cm antenna will be sufficient but if you want to get the maximum range, you will need the half-wave antenna.

SETTING UP

Once all the components have been soldered in position, the project can be set up and tested for performance. The test procedure is to connect the LED Power Meter to the antenna point on the board.

The construction and use of the LED Power Meter is covered in the Amoeba article on page 28. It is designed to take the RF output and turn it into a DC voltage so that you can read it on a multimeter.

By using this piece of test equipment you can determine if the project is delivering an output, however you do not know if the frequency is on the FM band or outside it - this will be the next test. But firstly you should see if the output is between 6v and 12v, for a 9v supply. The variation in voltage will depend on the quality of the oscillator transistor, the frequency being produced and the "tightness" of the circuit.

The next step is to see if the output is on the FM band and to do this you can leave the LED Power Meter connected to the output as its short lead will act as an antenna.

Bring an FM radio near the project and turn the volume up full so that when you tune across the band, you will hear a squeal when the frequency is detected.

By moving the Voyager away you will be able to pick up the sounds it detects. Make sure the frequency of transmission is well away from any radio stations as the signal from a station will swamp the Voyager when you are testing it for range. You can do this by adjusting the air trimmer. You can see the vanes moving in and out of mesh with the stators and the meshing should be midway at the start so that you can raise or lower the frequency by turning the trimmer.

As the vanes move out of mesh, the capacitance of the trimmer decreases and the frequency of the bug increases. When adjusting the capacitor you must use a non-metallic instrument. The best is a plastic knitting needle filed to make it into a flat screwdriver.

If you do not get a squeal from the radio you can assume the frequency is lower than the band (as we have designed the output to be very close to the bottom of the band) and it may be just a little too low.

In this case you will have to raise the frequency by expanding the turns of the coil. This will bring the output onto the FM band and you can shift it slightly up or down with the air trimmer to get it away from other stations.

You can now solder the short antenna onto the board if you require a range of about 30-50 metres or use the half-wave antenna if you want 800 metres.

To get the maximum range, the antenna should be stretched out straight and placed either horizontally or vertically. The receiving antenna must be in the same plane to get the maximum range and both antennas should be as high as possible.

The signal is generally not affected by brick walls, glass or plaster but it will not pass through metal of any kind such as the foil insulation that is currently required in the walls of new buildings.

The signal will also find it difficult to get out of a car and you must place the antenna near a window but not close to the metal frame-work as this will almost totally absorb the signal. The range from a car will be limited to about 100 metres so don't expect any more.

In the open, you should be able to get a lot further than 800 metres as our test was made from our assembly room and over a slight hill so that we can offer a genuine range as might be expected in a normal situation.

IF IT DOESN'T WORK

If you cannot detect an output on the LED Power Meter, you can safely assume the oscillator stage is not working.

Measure the current for the project. It should be about 7mA. If it is only about 3mA, the oscillator transistor may be damaged or not being turned on. The only voltage you can measure with an ordinary multimeter is the emitter (2v), as the base requires a very high impedance meter to get an accurate reading. If the emitter is zero, the transistor is not being turned on and you should check the 47k base-bias resistor. If it is about 3v, the 10p feedback capacitor may be open. If it is 9v, the transistor may be shorted or the 470R resistor may be open circuit.

But the most likely cause will be a soldering fault, such as a bridge between two tracks, poorly soldered joints, or two components that have been swapped - such as the 47k and 470R.

The best thing to do is give the project to someone else to check as it is very difficult to check your own work.

If you have used your own parts to build the project, the fault could be in the markings on the components (or incorrect reading of the values) or the wrong size coil. The only solution is to buy a kit and put it together - you can then compare one project with the other.

If you are picking up a blank spot on the dial but no audio, the fault will lie in the first stage or the microphone.

Check the voltage on the collector of the audio transistor. It should be about 2v, however if it is above 6v or less than 1v, the transistor will not be biased correctly and the 1M base-bias resistor may be at fault.

The electret microphone needs only about 50mV across it to work correctly and the only real way to check it and the audio stage is to use a CRO or audio amplifier (our prototype had 200mV across the microphone). By whistling into the microphone at a distance of about 30cm you will get an output of about 10mV - 30mV. The audio transistor will provide a gain of about 70 and produce an output of about 700mV - 2,100mV.

If the microphone does not produce at least 10mV, it may be around the wrong way, damaged, or have very low sensitivity. Reducing the 68k load resistor may help if the microphone is a low sensitivity type.

FITTING THE BATTERY

The Voyager is designed to fit on top of a 9v battery and doesn't need any case or potting. The safest thing is not to enclose it at all.

Fully-assembled devices are available from Talking Electronics for those who are not good at soldering or want a built-up unit. They are covered with heat-shrink so they can be safely handled and placed in position to monitor the surroundings. You can heatshrink your model by buying a short length of tubing and placing it over the board and shrinking with a candle or gas torch. Crimp the ends with a pair of pointed-nose pliers so that they stick together and make a good seal. Cut around the two battery terminals and make a smaller hole for the air trimmer so that the frequency can be adjusted, and the project is ready for use.

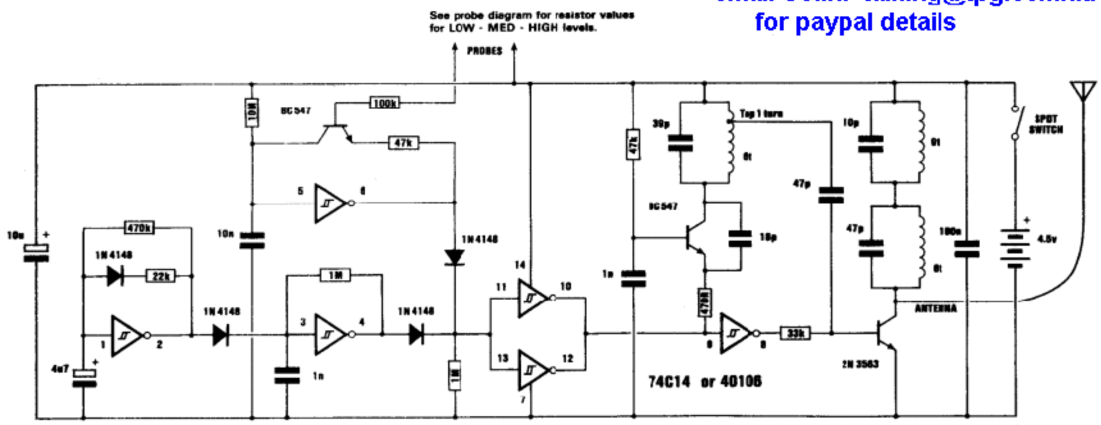
There's nothing much more to talk about except to say that if you liked the challenge of working with surface-mount components, we have produced a more advanced FM transmitter, called the VOX V, also included in this issue. It is available for $32.50 plus post and offers a real challenge in surface-mount construction. Please refer to the price list in the centre pages of this issue as you will need the LED power meter and Field Strength Meter to assist you in getting the best performance out of the bug.

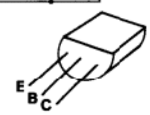
WATER BUG

Detects water and transmits up to 1km

Kit of parts: $20.35 USD
Postage: $4.50 USD
LED Power Meter: $1.25 extra

email Colin: talking@tpg.com.au
for paypal details





2N3563

WATER BUG CIRCUIT

This project first appeared in "Bugging and its Prevention," Page 21. It has been reduced from 5 pages to 2 to fit into this issue.

Very few of "Bugging and Its Prevention" are available and if you are lucky enough to get your hands on a copy, you can read the full article as it covers the construction in more detail.

The WATER BUG can be used to monitor remote situations such as dams, basements, fields etc to determine the presence or absence of water. A set of probes connects to the input of the circuit to enable to you determine the level of water and as it rises, the pitch of the tone increases. In the kit we have provided for three water levels: LOW, MED and HIGH.

The advantage of this circuit is it consumes very little power when sitting around as current is only drawn when the bug is transmitting. This means even small cells such as AA or AAA will last 3 to 6 months or more.

CONSTRUCTION

The project requires a fair degree of skill in construction and you should have built a couple of our simpler bugs beforehand to make sure you are good at recognising the components and can solder neatly.

Use the overlay on the board and also the photos and diagrams in this article to help with assembly.

All the parts fit onto the board. Some resistors stand up while others lie down, depending on the space available. The diodes, transistors and IC must be placed around the correct way, otherwise they may be damaged when the supply is connected.

The 47p between oscillator and output is soldered directly to the first turn of the tinned copper wire coil. We say the first turn but it is really only about 3/4 of a turn from where the wire emerges through the hole in the board. Make sure it is the turn near the edge of the board as tapping the other end of the coil will prevent the circuit from working.

The notch or dimple at the end of the IC indicates pin 1 and this fits over the dot on the PC board. The IC socket has one corner cut off and this identifies pin 1 so place this corner over pin 1.

The overlay on the board shows how the transistors are placed and they are pushed down close to the board so that they are not higher than any of the other components.

The black band (or may be another colour) on the diodes indicates the cathode and this goes down the hole indicated with a line as shown in the diagram on the next page.

PARTS LIST

1 - 470R (yellow-purple-brown-gold)
1 - 22k (red-red-orange-gold)
1 - 33k (orange-orange-orange-gold)
2 - 47k (yellow-purple-orange-gold)
1 - 100k (HIGH tone) brown-black-yel
1 - 470k (MED tone)yell-purple-yellow
1 - 470k (yellow-purple-yellow-gold)
1 - 1M (LOW tone) brown-black-green
2 - 1M (brown-black-green-gold)
1 - 10M (brown-black-blue-gold)
1 - 10p ceramic
1 - 18p ceramic
1 - 39p ceramic
2 - 47p ceramics
2 - 1n ceramics "102"
1 - 10n ceramic "103"
1 - 100n monoblock "104"
1 - 4u7 PC mount electrolytic
1 - 10u PC mount electrolytic
2 - BC 547 transistors
1 - 2N 3563 RF transistor
4 - 1N 4148 diodes
1 - 74c14 (40106) Hex Schmitt IC
1 - 6 turn tinned copper wire coil
1 - 6 turn enamelled wire coil
1 - 9 turn enamelled wire coil
1 - 14 pin IC socket
3 - AAA cells
1 - SPDT slide switch
1 - 175cm twin hook-up wire
1 - 50cm twin hook-up wire
1 - 20cm tinned copper wire

1 - WATER BUG PC BOARD

When all the parts have been fitted and the probes conected, we do three things for the final stage of alignment:

1: Check the current consumption of the circuit. 2: Set the frequency to between 88MHz - 90MHz and 3: Peak the output.

CURRENT CONSUMPTION

Firstly we measure the current consumption. It should be almost zero (about 20 microamps) when the circuit is timing and not more than 20mA when it is producing a tone.

Since the tone burst is very short it will be difficult to get a reading on a multimeter and all you will see is the needle flicking very briefly.

To find out how much current the circuit consumes, you must jam it ON by connecting pins 11 and 13 of the IC to the positive rail.

The tone will not be produced during this operation but the oscillator will produce a constant carrier and the output stage will provide a signal that can be picked up by a radio as a "quiet spot."

If the current is between 10-20mA, everything is working ok. A current higher or less than this indicates a fault and the section on "IF IT DOESN'T WORK," in VOX MkIII (later in this issue), will help locate the fault.

SETTING THE FREQUENCY

The next job is to set the frequency. Most of our bugs are designed to operate at about 88 - 90MHz and you should search for a free spot on the dial where there are no radio stations.

Remove the antenna lead and while pins 11 and 13 are connected to positive, connect the input of the Peaker to the collector of the oscillator transistor and move the turns of the oscillator coil so that the radio picks up the "quiet spot." By pushing the turns of the oscillator coil together, the "spot" will move down the dial and when separated, the spot will move up.

At the moment, the Peaker is acting as a short antenna and we are not concerned with the reading on the meter. As a matter of interest, it should be about .5v to 1v.

Now remove the peaker from the oscillator stage and place it on the collector of the output transistor. Here the reading will be higher and we are still using the Peaker as a short antenna.

Without touching the radio, adjust the turns of the 6 turn tank coil so that the quiet spot is again picked up. This will make the frequency of the tank circuit the same as the oscillator and the two stages will be in harmony.

PEAKING

Finally, the project is peaked by adjusing the turns of the RFC until the reading on the multimeter is a maximum. This improves the output up to 50% by allowing the RFC to do its job as we have described in other articles.

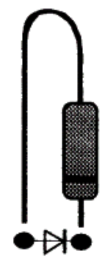
Remove the short on the IC, fit the antenna and the bug will begin to produce a beep, when the probes are touched.

MOUNTING

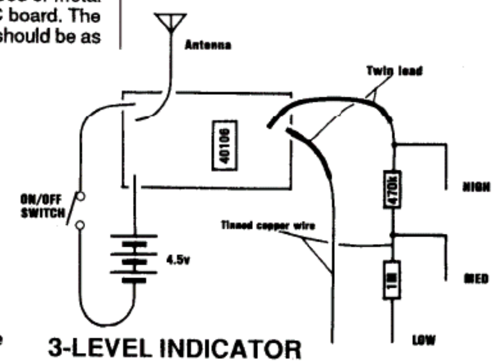
If you are going to use the bug in an open field or remote situation, it should be fitted into a small plastic box to protect it from moisture and dust etc.

Bring the probe leads through a small hole and determine out how many levels of water you wish to detect. The probes can be nails in a piece of wood or metal plates such as pieces of PC board. The surface area of the probes should be as large as possible so that the circuit will detect the first sign of water. Place the probes at the required levels, add the resistors to create the tones and the project is complete.

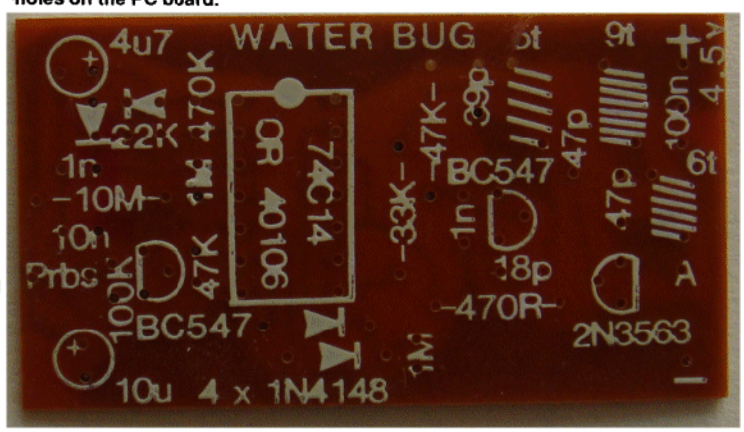
This project has already been used in many areas of protection and monitoring. It has enormous potential for use on farms as it is much cheaper than anything else on the market. All it requires is to be shown around and others will see its benefits. Do us a favour and promote it. In doing so, you will help yourself and us. I want this bug to get the recognition and sales it deserves, so see what you can do.

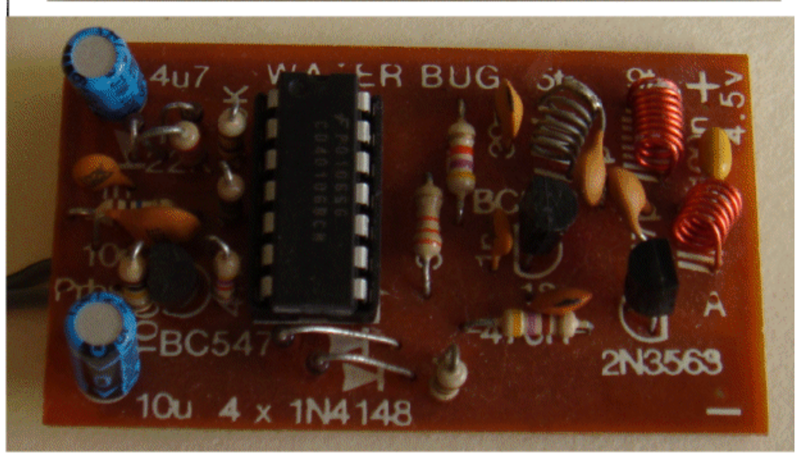


Fitting a diode down the holes on the PC board.



3-LEVEL INDICATOR





ULTIMA MkII FM BUG

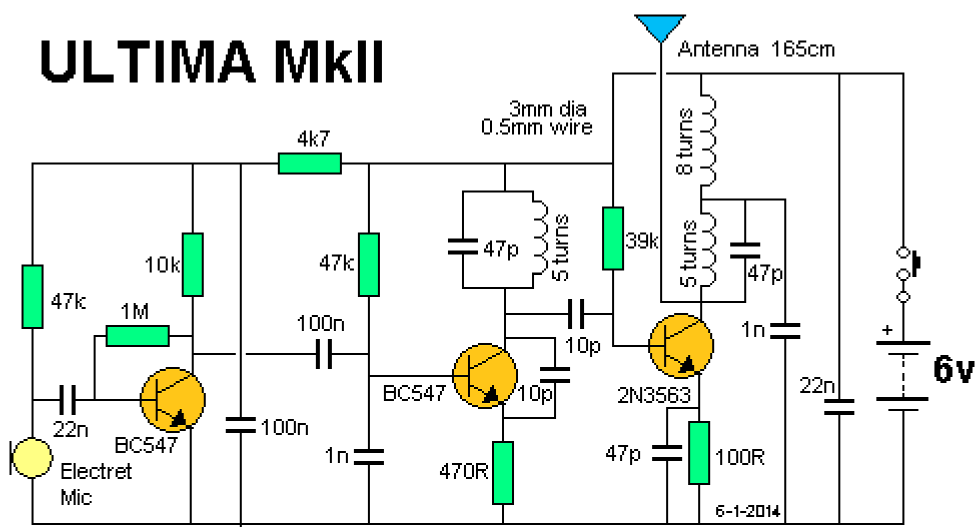
Home

Our 1km FM Transmitter

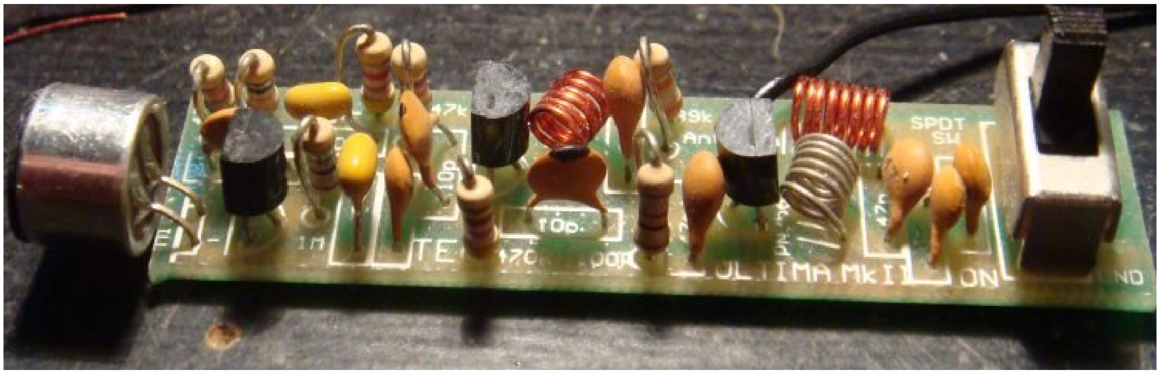
Kit of parts: $15.50 USD
Postage $4.50 USD
pay by PayPal
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit

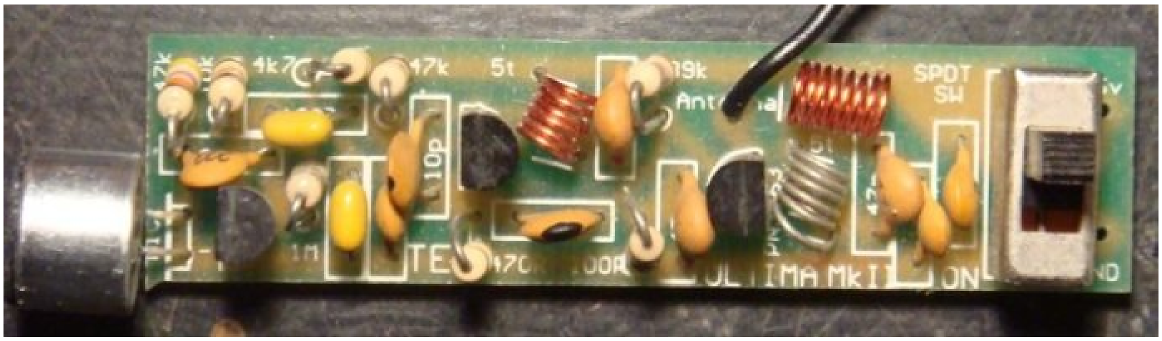
The LED Power Meter can be used to detect the output.
$1.25 extra

Encouraged by the popularity of all our previous bugs, we have designed another FM transmitter, this time with a range of 1km.



ULTIMA MkII circuit





The components fitted to the ULTIMA

The efficiency of this design is slightly higher than our other designs as the power consumption is about double and yet the Effective Radiated Power (ERP) is about 4 times.
This is proved by the fact that the range is about twice, as it requires 4 times the power to double the range.
In this project we will cover some of the design features that make the circuit so efficient. Basically it is the higher voltage but there are also other contributing factors.
The way it works is this:
The minimum operating voltage for most transistor circuits is 1v, so a 1.5v supply will give a circuit about 100 metre range. At 3v it will reach about 400 metres and at 6v it will reach about 1km. You will recall the increased range of the Voyager was purely due to the 9v supply and this time the 6v supply, as well as the tuned output, will assist in providing the output power.
With any transmitting device, the primary requirement is range. To achieve this, an efficient antenna system must be used and although a dipole or loaded antenna provides a slight antenna gain, the usual purpose for which this project is intended, makes a special antenna impractical.
The main use for the Ultima is as an emergency beacon or signaling device and in such a situation, the user may only have the branch of a tree to throw the antenna over.
For this reason, and to keep the transmitter compact, a length of hook-up wire about 1metre long is provided.

The advantage of transmitting on the FM band should be obvious as most cars are now fitted with an FM receiver and they can be used to pick up the transmission without the need for any special receiving equipment.
If a frequency was set aside at the lower end of the FM band for such a purpose a safety channel could be set up at all types of outdoor centres where the transmissions would not interfere with any commercial operations as few if any FM stations are in remote areas.
Maybe something like this will be introduced in the near future. It's a "catch 22" situation where you would have to use it illegally, to get it approved nationally.
The Ultima project is built on a PC board 1.5cm x 7cm and can be fitted into a variety of cases. The most appropriate will depend on the intended use and if you want the project to be as small as possible, it can be heat-shrunk and made virtually watertight.
FM transmission is highly efficient and a few milliwatts can get you a long way. The clarity of FM, its lack of background noise and immunity to electrical interference makes it ideal for faithfully monitoring all types of sounds.
The impressive range of the Ultima makes it ideal as a surveillance device, for monitoring remote sheds and buildings, where the slightest disturbance will be picked up and relayed to the monitoring point.
The Ultima is not intended as a hand-held microphone as frankly the microphone sensitivity is too

high and the circuit is not "tight" enough to prevent the effect of stray capacitance of your body causing the frequency to drift. See our handheld transmitter, the ANT, for this.

HOW THE CIRCUIT WORKS

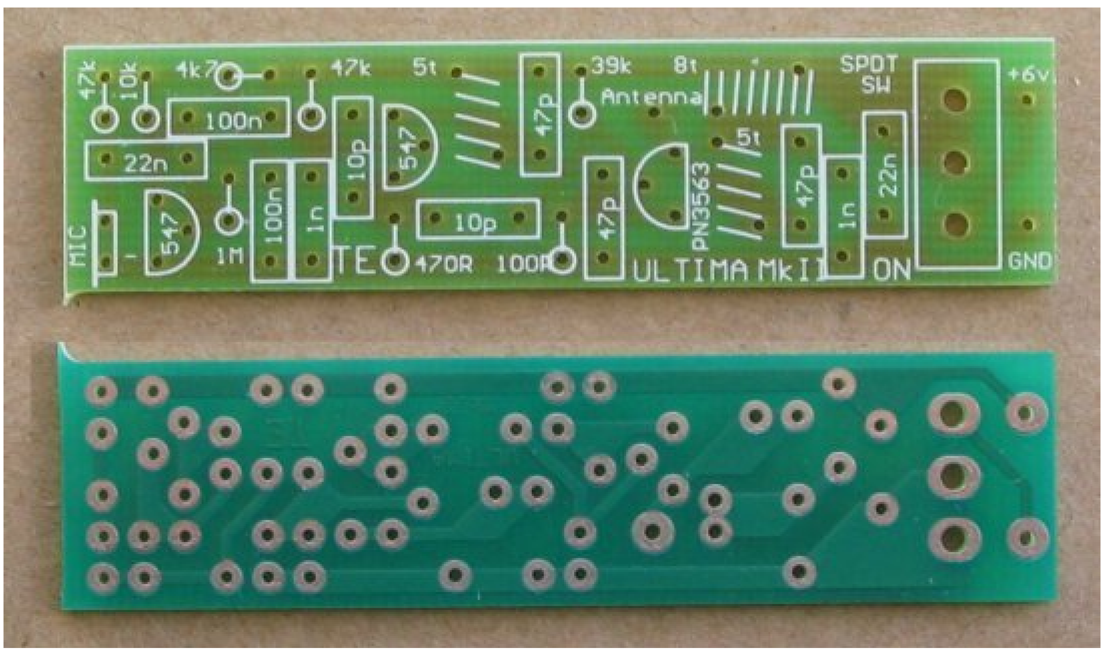
The main purpose of a transmitter is to get the greatest distance with the least current consumption.
To this end, the Ultima is the ultimate in design. It contains 3 novel features that have possibly never before been incorporated in the one design.
The front end is a simple common emitter stage with a gain of about 70-100, and decoupled from the battery via a 4k7 and 100n capacitor. These two components prevent motor-boating (instability) at low frequency.
There's another little known fact to be aware of, when designing the front end of a high gain amplifier such as this.
Since the electret microphone is an active device (it contains a FET), the gain of the FET must not be allowed to be too high, otherwise the front end will break into oscillation (sometimes called front-end squeal).
The gain is kept low by making the load resistor HIGH and that's why we have chosen 47k.
Coupling the audio to the RF oscillator is a 100n capacitor and this value is needed to pass the low audio frequencies.
The first of our "unusual" features is the 47k turn-on resistor on the base of the oscillator transistor.
After a great deal of experimenting we found a high value base resistor was sufficient to turn the transistor ON and produce a high amplitude waveform.
The oscillator circuit has been designed to oscillate at about 88MHz. The tuning capacitor in the oscillator is 47p and when the frequency is set, it remains set.
The Ultima is not a tunable bug and you should select a clear spot on the dial when setting it up, so that you don't interfere with any radio stations.
Apart from being illegal to transmit over a commercial station, you would have almost no chance of achieving any range if you were to do so.
The output of the oscillator is taken from the collector via a 10p.
The aim of the tapping is to pick off as much signal as possible without overloading the oscillator. In technical terms we need a considerable amount of current to drive the output stage as gain is quite low (possibly about 5-20), depending on the quality of the transistor and the frequency of operation.
At 100MHz, the reactance of the 10p will be only about 200 ohms and that's why a small value such as this can be used.
The output stage has a number of features worth mentioning.
Firstly the emitter capacitor and resistor network may appear to be unnecessary as the stage is not a full bridge design. These components reduce the peak current and increase the input impedance of the output stage as seen by the oscillator stage. This improves and guarantees "start-up" of the circuit.
To get the greatest range from the Ultima, the output stage must be peaked and this is an essential part of the tuning and aligning. The tuned circuit in the output stage consists of a 5 turn coil and 47pF capacitor. The 8 turn coil is effectively an RFC (Radio Frequency Choke) to improve the matching of the output circuit to the antenna. The 1n capacitor on the RFC is designed to reduce harmonics and prevent interference on TV sets in the vicinity.

As output power is increased, the effect of harmonics becomes a real problem.
Shielding the project will have little effect as they are already appearing on the antenna and it's too late to suppress them once they get this far.
As we have said, one of the important stages in the construction is to peak the output. To do this, a simple POWER METER is required and its construction is also covered. The circuit attaches to a standard multimeter and uses the meter to give an indication of the signal strength. It also has a Light Emitting Diode that illuminates to give an indication of the relative power being emitted.
The illumination of the LED will give a valuable indication when peaking the circuit and will show how critical the values are at high frequency.
An on/off switch allows the project to be turned off when not required and the current consumption of our prototype was measured at 8mA, allowing a set of AA cells to last for about 150hours.
The 2N 3563 transistor in the output has been chosen as it gives the best performance at the least cost.
Surprisingly, a BC 547 will operate quite satisfactorily as an oscillator at 100MHz but provides very little gain at this frequency.

It only requires a gain greater than unity to function as an oscillator but in the output, a 2N 3563 provides a gain of between 5-20 and delivers the output we need.
No matter what other tricks you add to the output stage, you will not achieve better performance - for the same current.
The suggested maximum current for a 2N 3563 is 10-12-15mA (depending on the specification sheet you use), and only by decreasing the value of the bias resistor, does the output rise by a noticeable amount.
As you experiment with the circuit and peak it, you will see the changes in output power on the meter and/or the LED. But if range is increased at the expense of more current, you haven't improved the efficiency.
Our prototype produced 2v across the LED/resistor combination and the chip inside the LED could be seen to glow quite noticeably.
Not a great deal of weight can be put on this as a lot of RF energy is floating around the meter and will get into the movement to create a false reading.
But if you can see the LED glowing you know that energy MUST be present and that's why we have called it a LED POWER METER.

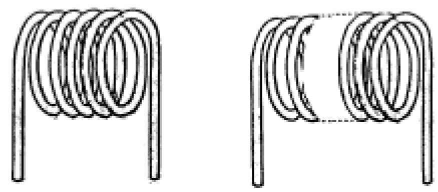
ASSEMBLY

A complete kit of components, including pre-wound coils and roll-tinned PC board is available from us and we hope you will buy more than one kit! Many readers buy two or more for their friends and some keep coming back for more!
The PC board is shown below.



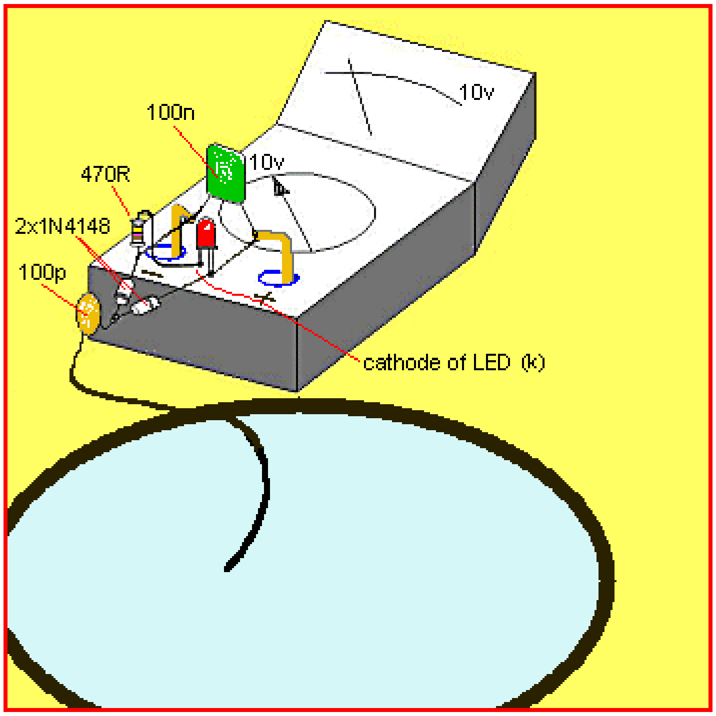
Without exaggeration, it has taken hundreds of hours of experimenting and at least 100 trips "around the block" to see how effective each modification has been.
Sometimes an improvement via the power meter did not co-relate to an improvement in range. You must always make a "field test" - it's the only proof.
Although the circuit is not critical as such, a lot of work has gone into the selection of each component and the layout of the board.
If you want your model to perform as good as ours, it is important to use the exact same components and the same layout. That's why I suggest you buy a kit.
It you are a seasoned hobbyist, and know what you are doing, you will know the type of components to use. But if you are unsure or missing one or two of the critical parts, don't take the chance, buy a kit.
I am not going to go through the finer points of placing the parts on the board as we expect you will have made some of our other designs already.
The coil winding details are below for those who wish to wind their own. You can use slightly different gauge wire but the coil diameter and spacing is critical.
All the parts for the Ultima fit onto the board almost exactly as they appear in the circuit diagram. This makes the circuit very easy to follow and is one of the factors to good layout.

The coils are enamel coated and the enamel must be scraped off or burn off before fitting them to the board. It is not satisfactory to expect the enameling to burn off at the time when the coil is being soldered in place.
All the components should be pressed firmly up to the board before soldering. This also applies to the transistors. They should be pushed down to the same height as the resistors as can be seen in the photograph.
The PC board contains a legend and the accompanying photos will show where everything goes.
The next stage is tuning and peaking but before this can be carried out, you will need to make up the LED POWER METER.

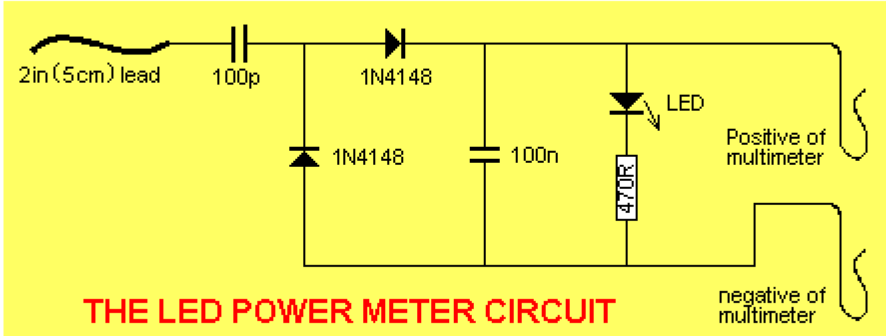


COIL WINDING DETAILS:
1 - 5 turn tinned copper coil (.6mm wire) wound on a 3mm diam screwdriver.
1 - 5 turn enamelled wire coil (.5mm wire) wound on a 3mm
diam screwdriver.
1 - 8 turn enamelled wire coil (.5mm wire) wound on a 3mm
diam screwdriver.
The turns are counted at the top of each loop. Five loops at the top indicates a five turn coil etc.

THE LED POWER METER



The LED Power Meter



The LED power Meter is a simple RF detector using diodes to charge a capacitor. The voltage developed across the capacitor is indicated by a multimeter set to a low voltage range. The circuit is soldered together without the need for a PC board, as can be seen in the diagram above and paper clips are used for the positive and negative terminals of the multimeter.
It will only take a few minutes to put this circuit together. The power from the output of the Ultima is indicated by the illumination of a LED and the voltage reading on the multimeter gives a further indication of the output.
The reading is not calibrated and does not represent milliwatts output. It is only a visual indication.

LED Power Meter Parts
1 - 470R 1 - 100p ceramic 1 - 100n ceramic 2 - 1N 4148 diodes 1 - 5mm Red LED 1 - 2in (5cm) hook-up wire 2 - paper clips No PC board required

USING THE LED POWER METER

To get the best performance out of this transmitter, an RF power meter is used to maximize the output.
Since the output is very low, a conventional RF power meter cannot be used. We need an RF milliwatt meter.
The circuit described in this section is very simple and uses a standard multimeter to show the reading.
Across the input is a LED and resistor and the degree of brightness of the LED, together with the voltage reading on the meter, gives an indication of the energy level.
A digital multimeter may be used but the presence of RF may produce a false reading.
Likewise, the radiated energy may upset some analogue meters and you may get full scale deflection on the 15v range as well as the 250v range. But the LED won't lie. It will accurately indicate the RF and you can see the change in brightness as you adjust the coils in the output stage.
Build the circuit for the LED Power Meter exactly as shown in the photo and make sure the input lead is exactly 5mn long. If you keep to the same layout as shown, your readings will closely coincide with ours.
When dealing with RF, lead length is very important and if the input lead is longer, the meter will produce a lower reading.
The type of multimeter will also affect the reading and this is why we cannot give a quantitative value for the output.
We don't have any means of providing a "standard" as we don't have any bench-mark or reference point.
As soon as you build the power meter you will be able to test the transmitter.
Connect the input lead to the antenna point on the Ultima board (don't fit the antenna lead yet) and switch on. Switch the multimeter to the 2v (or 2.5v or 5v) range.
Keep the transmitter away from the meter to prevent the movement being influenced by the RF

and you should get a reading of about 2v.
The LED will glow quite noticeably and you can see the output on the LED before the circuit is peaked.
Tune the radio across the band and there may be a number of spots where a signal is detected and it is important to pick the fundamental.
The weaker side-tones have no range and this is where a tuning indicator comes in. It will quickly indicate the fundamental frequency.
Move the radio away to confirm that the fundamental is being detected.
Or you cantune it to about 88.5MHz or somewhere at the low end of the band and move the turns of the 5 turn oscillator coil either together or stretch them apart until a feedback whistle is picked up by the radio. This is the frequency of transmission.
When the turns are pushed together the frequency decreases and when moved apart, the frequency increases.
You must not use any metal objects near the coil when moving the turns. If you do, the reading will be upset.
The best item to use is a match or plastic knitting needle as you should keep your fingers and hands away from the coil while adjusting it.
Now stretch or compress the 5 turns of the output TANK CIRCUIT so that the reading on the POWER METER increases.
The multimeter will show a reading of about 2v and this voltage will depend on getting the two sections of the circuit to operate at the same frequency. Once you are satisfied the project is working, remove the LED Power Meter and solder the antenna lead to the board.
Move the radio a short distance away and tune across the band to make sure the output is coming through and to see if you have picked up the main frequency of transmission.
Carry out some experiments yourself and you will be very impressed with the performance.
By moving the Ultima further away you will be able to pick up the sounds it detects. Make sure the frequency of transmission is well away from any radio stations as the signal from a station will swamp the Ultima when you are testing it for range. If you want to change the frequency, you will have to set the frequency of the oscillator section then adjust the output stage again, by using Power Meter
If you do not get a squeal from the radio you can assume the frequency is lower than the band (we have designed the output to be very close to the bottom of the band) and it may be just a little too low.
In this case you will have to raise the frequency by expanding the turns of the coil. This will bring the output onto the FM band.
To get the maximum range the antenna should be stretched out straight and placed either horizontally or vertically. The receiving antenna must be in the same plane to get the maximum range and both antennas should be as high as possible.
The signal is generally not affected by brick walls, glass or plaster but it will not pass through metal of any kind such as aluminium foil or metal cladding. Trees can also have an effect due to the amount of moisture they contain.
The signal will also find it difficult to get out of a car and you must place the antenna near a window but away from the metal frame-work as this will almost totally absorb the signal. The range from a car will be a lot less than the 800m we stated at the beginning.

IF IT DOESN'T WORK

If you cannot detect an output on the LED Power Meter, you can safely assume the oscillator stage is not working.
Measure the current for the project. It should be about 7mA. If it is only about 3mA, the oscillator transistor may be damaged or not being turned on.
You cannot measure any of the voltages around the oscillator transistor and expect to get an accurate reading as the leads of a multimeter will upset the operation of the circuit.
However if you measure the voltage on the emitter of the second transistor and find it is zero, it is not being turned on and you should check the 47k base-bias resistor. If it is 6v, the transistor may be shorted or the 470R resistor may be open circuit.
But the most likely cause of the project not working will be a soldering fault, such as a bridge between two tracks, poorly soldered joints, or two components that have been swapped - such as the 47k and 470R.
The best thing to do is give the project to someone else to check as it is very difficult to check your own work.
If you are picking up a blank spot (called the carrier) on the dial but no audio, the fault will lie in the first stage or the microphone.
Check the voltage on the collector of the audio transistor. It should be about 2.4v, however if it is

above 5v or less than 1v, the transistor will not be biased correctly and the 1M base-bias resistor may be at fault.
The electret microphone needs only about 50mV across it to work and the only real way to check it and the audio stage is to use a CRO or audio amplifier (our prototype had 200mV DC across the microphone). By whistling into the microphone at a distance of about one foot (30cm), you will get an output of about 10 - 30mV. The audio transistor will provide a gain of about 70 and produce an output of about 700mV - 2,100mV, as mentioned previously.
If the microphone does not produce at least 10mV, it may be around the wrong way, damaged, or have very low sensitivity. Reducing the 68k load resistor may help if the microphone is a low sensitivity type.

MODS

If you want to detune the transmitter to below 88MHz or run it at the top end of the band, you will have to change the oscillator section as well as the output section as they both determine the frequency.
To detune the transmitter to say 85-87MHz, you will need to add one turn to both the oscillator coil and the tank coil, making them 6 turns.
To operate at 10BMHz, you will need to change both the 47p's in the oscillator stage and tank circuit to 39p and follow the peaking procedure described above.

IF IT DOESN'T WORK

Before you get involved in any technical problems, have someone check the construction for dry joints, parts placement, shorts, and the like. Nine times out of ten it's something simple.
Next check the current. It should be 8-10mA and any value outside this will indicate a fault is present. Also check the voltage across the power rails and the voltage across the front end (about 5v).
Next you must determine if the fault is in the audio section or the RF section.
If the carrier is being produced you will get a blank spot on the dial and the power LED will light up.
In this case the fault lies in the front end and can be due to the microphone being around the wrong way, the audio transistor being faulty, the 100n capacitor not passing the signal or one of a number of faults.
Firstly check the voltage across the electret microphone. If it is between .0.1v and 1v, the mic is drawing current and if you want to see the output signal, you will need a CRO or mini amplifier.
A voltage of 2-3v on the collector of the audio transistor will indicate it is biased correctly and any value outside this may mean the transistor is faulty or has a gain above or below that expected.
In a self-biasing stage such as this, the gain of the transistor sets the collector voltage and maximum amplification is achieved when the collector is sitting at mid rail.

Two other components affecting the audio are the 22n and 100n capacitors.
They may be damaged due to soldering and the only way to check them is by bridging another capacitor across each or using a mini amplifier to detect the audio.
If you have access to a CRO, you can observe the signal at each point in the circuit and almost no fault will escape you. (Only the audio section).
Replacing all the components is a last resort but may be necessary if simple tests do not reveal the fault.
On the other hand, if no carrier is produced, the oscillator or output stage will be at fault.
Firstly check the oscillator stage by removing the 47p capacitor from the oscillator coil and connecting the input lead of the LED POWER METER to the collector of the BC 547.
The meter should deflect slightly but the LED will not come on as it requires at least 1.7v to be present before the LED will start to illuminate.
The LED and resistor do not have to be removed as they do not impose any load on the circuit until the voltage rises to above 1.7v.
If the meter does not deflect, the fault will lie in the oscillator stage. The first component to change is the transistor, then the 10p feedback capacitor.
Make sure the 39k turn-on resistor is providing a voltage to the base of the oscillator transistor. It will be difficult to measure this voltage accurately as the stage is producing RF and will upset the meter reading.

Make sure the 470R has a voltage across it and this will indicate the transistor is turned-on.
If the 47p capacitor has shorted the circuit will not oscillate. If these tests fail to locate the fault, you should assemble another kit and come back to this one later.

Reconnect the 47p and take the LED Power Meter to the antenna connection.
NO deflection of the LED POWER METER can only mean one thing. The output stage is not operating.

Firstly test the output transistor and make sure the voltages are correct.
The enamel on the coils must be removed before soldering as it does not conduct electricity at all.
Make sure the 39k provides a turn-on voltage and you can try shorting across the 100R if you think this resistor is open.
A low RF output can be due to an open 22n capacitor across the battery, the coils in the collector being spread too far apart or a faulty RF transistor.
The only other possible explanation is damage to some of the components during soldering.
For the cost of another kit, the quickest and easiest way is to start again. You will take more care with the next construction and hopefully things will work out successfully.

MOUNTING

The project can be mounted in a jiffy box that is large enough to take the PC board and a battery holder. This will give it protection from the weather etc if used in an outdoor situation.
If you want the project to be as small as possible, the PC board can be heat-shrunk but you must be careful that the heat-shrinking does not move the coils and change their frequency. Do not use a voltage higher than 6v as the circuit is not designed for it and harmonics will be produced that will interfere with TV reception.
I hope you find this project as interesting as we did. The range is most impressive and it is incredible that such a low output will reach 1km.

ULTIMA MkII
Parts List
Cost: $15.50 USD
plus $4.50 USD postage

1 - 100R (all resistors 1/4 watt)
1 - 470R
1 - 4k7
1 - 10k
1 - 39k
2 - 47k
1 - 1M

2 - 10p
3 - 47p
2 - In
2 - 22n
2 - 100n monoblocks

2 - BC 547 transistors
1 - 2N 3563 RF transistor
1 - 5 turn tinned copper wire coil
1 - 5 turn enamelled wire coil
1 - 8 turn enamelled wire coil
1 - electret microphone insert
4 - AAA or AA cells
1 - mini slide switch SPDT
1 - length hook-up wire for antenna (1.6m long)

1 - "ULTIMA" PC BOARD
(You can specify AA cells or AAA cells)

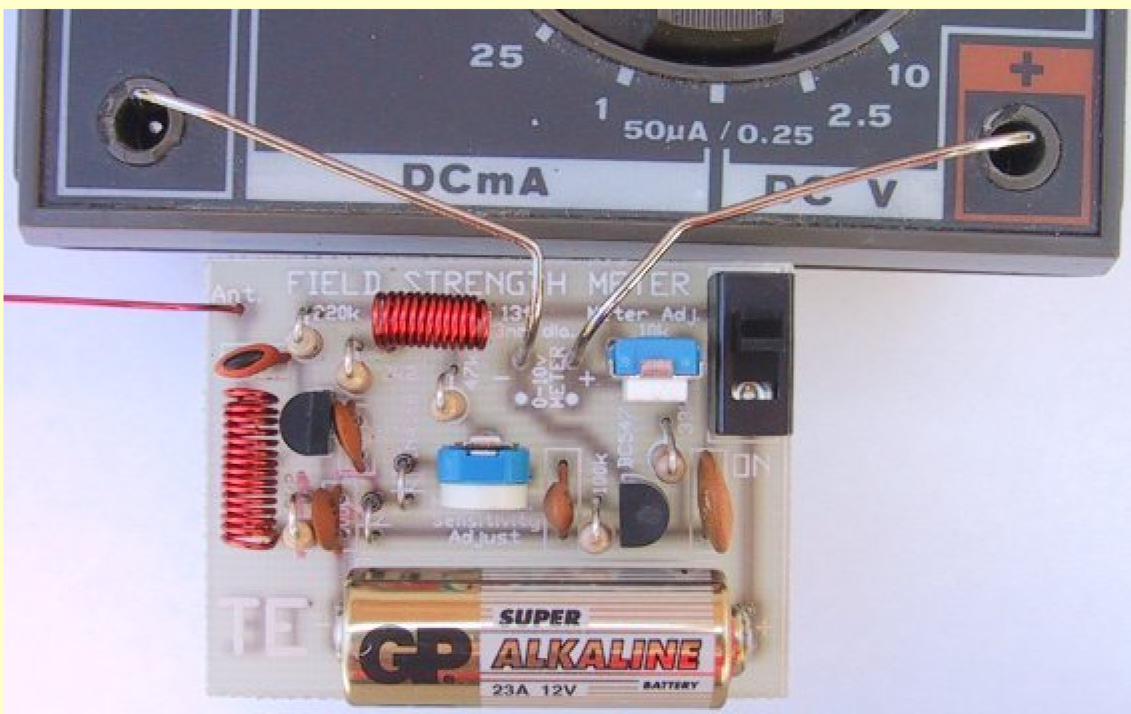
Field Strength Meter MkI

Essential for checking the output of our FM transmitters

Kit of parts: $10.80 USD
Postage $4.50 USD
pay by PayPal

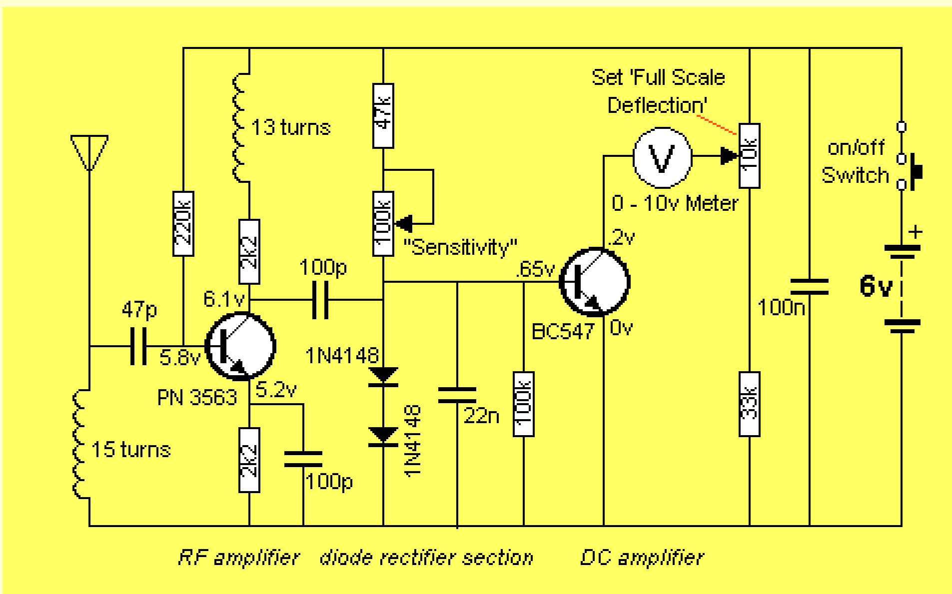
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit

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 many of our FM transmitters that have a coil in the output stage that can be adjusted for optimum output.



A close-up of the Field Strength Meter MkI connected to a multimeter with paper clips fitted to the multimeter terminals

A close-up of the circuit Board showing the the position of the components



Field Strength Meter MkI Circuit. A 2N2222A transistor can be used in either/both locations

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 to find one that 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 millivolts on the receiving antenna and if you need 600 millivolts to turn a diode ON, the field strength meter

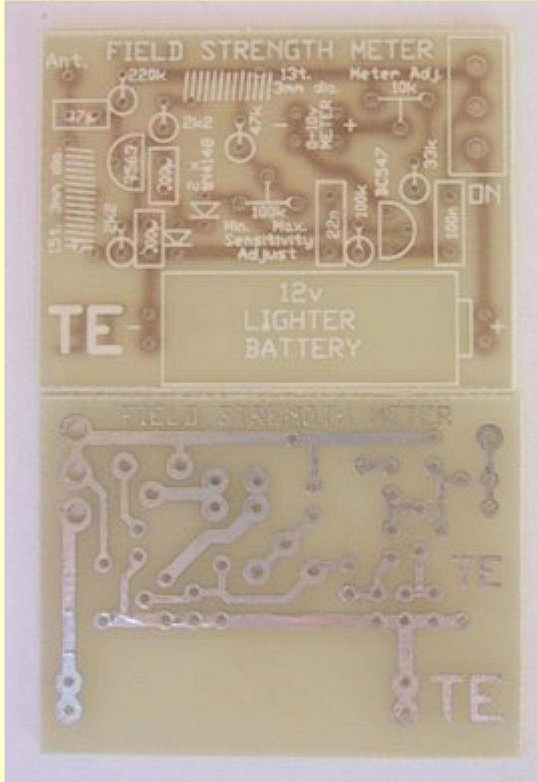
becomes very insensitive.
Our design overcomes this problem and produces a reading up to 10cm from a bug. This means you can adjust and peak a bug with the antenna fitted and get an accurate indication of the power it is producing.
Up to now you have had to rely on the "LED Power Meter" as described in a previous article 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, 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.

HOW THE CIRCUIT WORKS

The circuit consists basically of an RF amplifier, diode rectifier and a DC amplifier. The first feature that may be 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 causing the front end to self-oscillate.
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.
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, 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 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.

Field Strength Meter Mk I Kit

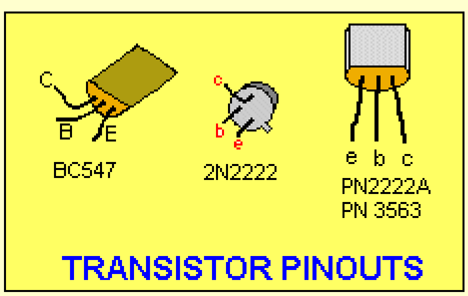
PARTS LIST
2 - 2k2 1 - 33k 1 - 47k 1 - 100k 1 - 220k 1 - 47p ceramic 2 - 100pceramics (101) 1 - 22n ceramic (223) 1 - 100n ceramic (104) 1 - 10k mini trim-pot 1 - 100k mini trim-pot 1 - BC 547 transistor 1 - PN 3563 RF transistor 2 - 1N4148 diodes 1 - 13t enamelled wire 3mrn dia coil 1 - 15t enamelled wire 3mm dia coil 1 - 12v lighter battery 1 - 25cm enamelled wire 1 - SPDT mini slide switch 2 - paper clips **1 - FIELD STRENGTH METER PCB**
Extras:
1 - multimeter (0v -10v range)



Field Strength Meter MkI PCB

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 arid 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 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 silt 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 be cause 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:

RF Stage:

Collector: 6.1v
Base: 5.8v
Emitter: 5.2v

DC stage:

Collector: 0.2v
Base: 0.65v
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 CR0, 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.
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.
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.

FIELD STRENGTH METER Mk II

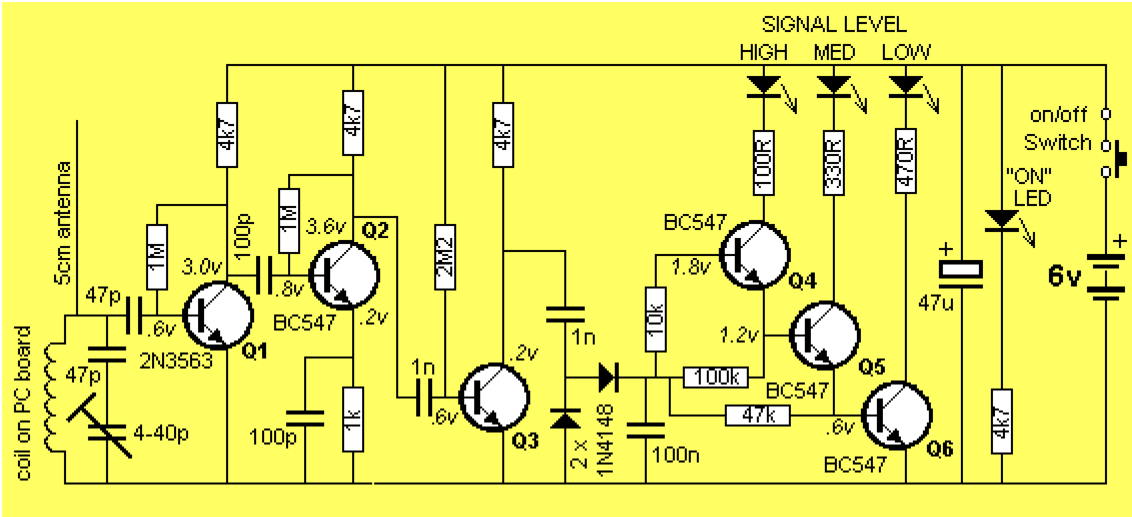
Kit of parts: $16.45 USD
Postage $4.50 USD
pay by PayPal
contact Colin Mitchell
email: talking@tpg.com.au
for details on paying for kit

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.

SUMMARY
• Checks the output of low-power transmitters
• 3 LED readout
• Detects from 75MHz to 140MHz

Note: the pointer is not soldered to the trimmer correctly. When the plates are fully disengaged, the pointer should point to 75MHz.
Note: The bottom 3v lithium cell should be insulated from the holding wires so that the cells do not "short-circuit." Put tape around the bottom of each wire.

Field Strength Meter Mk II



Field Strength Meter MkII circuit

This project has 3 features.

1. It's 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.

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.

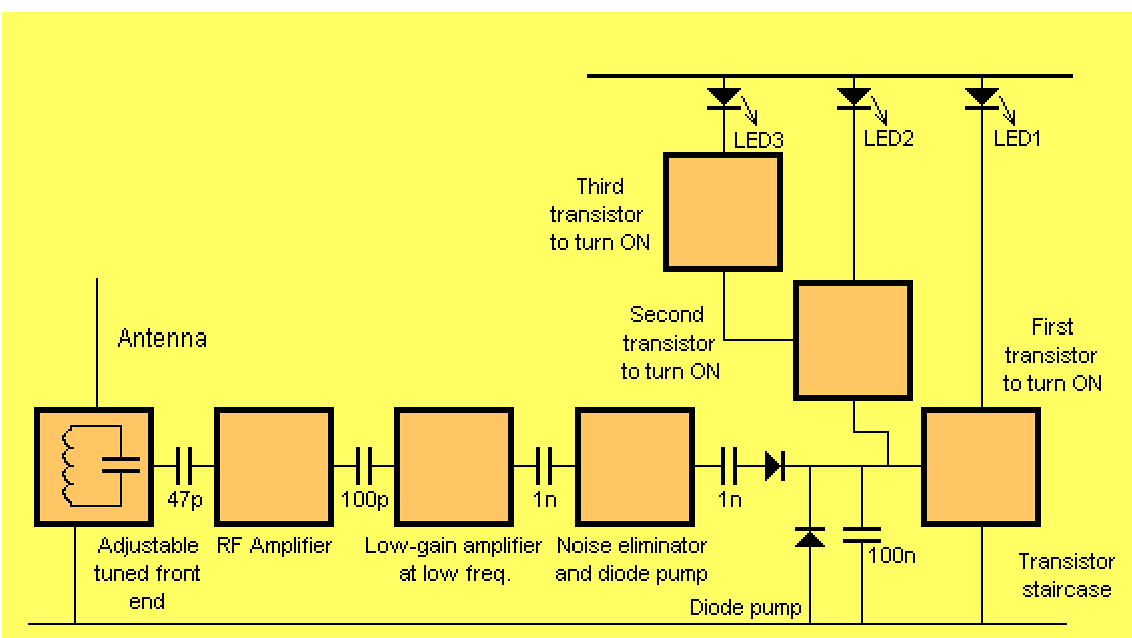
This project differs from our Field Strength Meter MkI in that it is a stand-alone unit and does not require connection to a multimeter.

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 transmission 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.

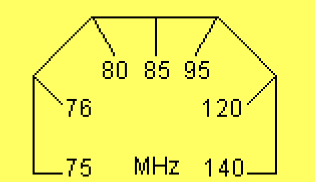
One of the most-often asked questions is "How much power is a particular transmitter producing?" This is very difficult to answer but a simple rule of thumb is to allow 30% of consumption from the supply as the output power.
One of our designs consumes 7mA @ 3v has an output of about 7 milliwatts. Another design 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.
Its output would be less than 1 milliwatt and this is shown by the fact that the output is barely detectable on the LEDs.
The output difference between our highest and lowest transmitter 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 weakest transmitter 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, 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.
As we have said, it is an adaptation of Field Strength Meter MkI 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. It is able to detect 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!



Field Strength Meter MkII block diagram

HOW THE CIRCUIT WORKS

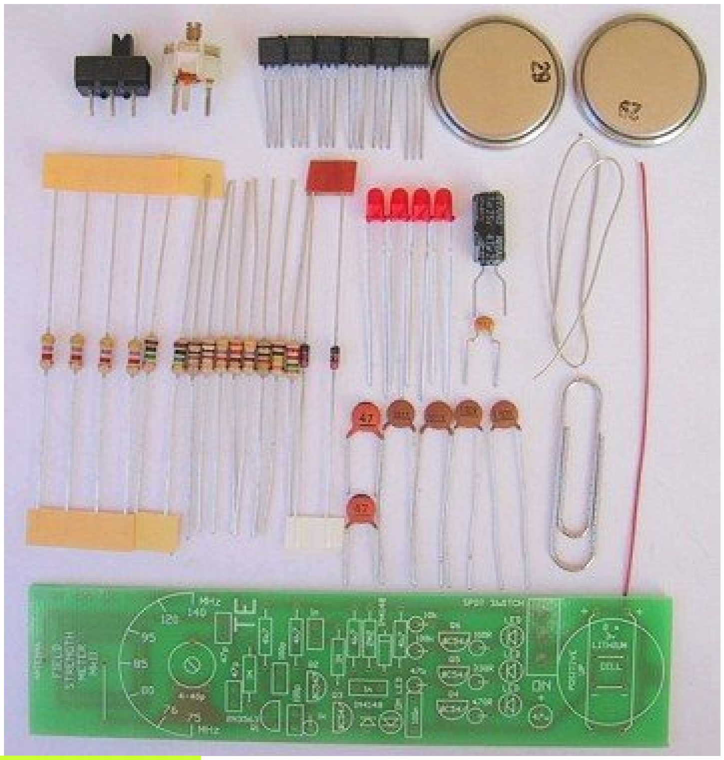
The circuit consists of a tuned front end, an RF amplifier, two further stages of amplification, a diode pump and a transistor staircase.
The circuit picks up RF energy on its 5cm antenna and passes it to a tuned circuit where all the frequencies, EXCEPT ONE are lost in the coil:capacitor combination. 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. Q2 is biased in a standard self-bias configuration while Q3 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 Q3 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 (Q4) 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 04 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 (Q5) 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 (Q4), turns on FIRST and as the voltage on the reservoir capacitor increases, Q5 then Q6 turns on. Without this, you will not be able to understand how the circuit works.



Field Strength Meter Mk II Kit

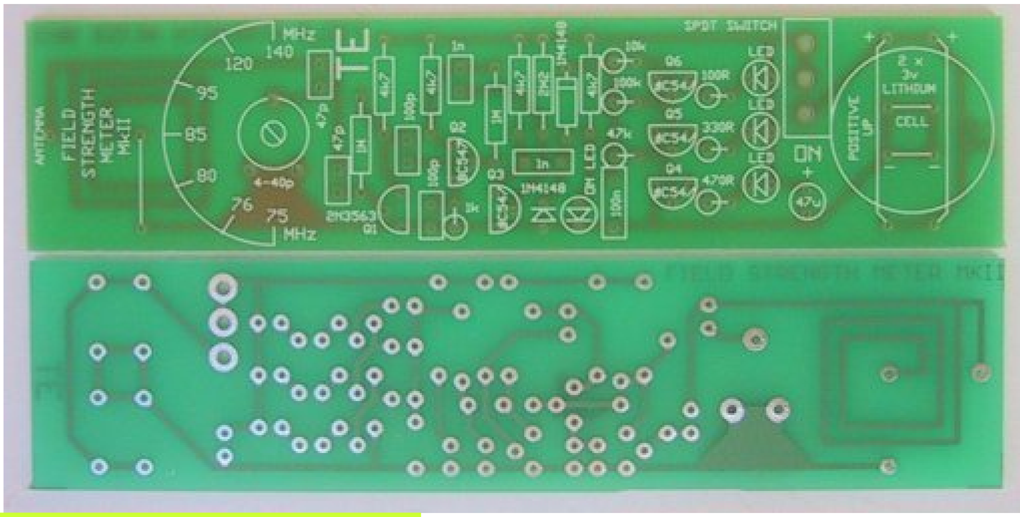
PARTS LIST

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 mono-block capacitor
1 - 4 - 40p air trimmer
1 - 47u 16v PC mount electrolytic
2 - 1N 4148 diodes
5 - BC 547 transistors
1 - PN 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

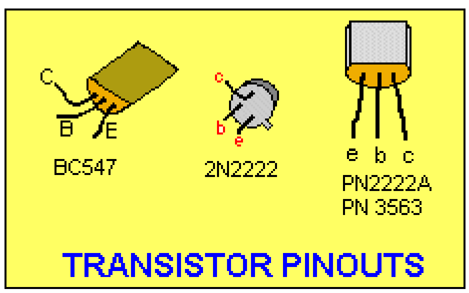
1 - FSM MkII PC board



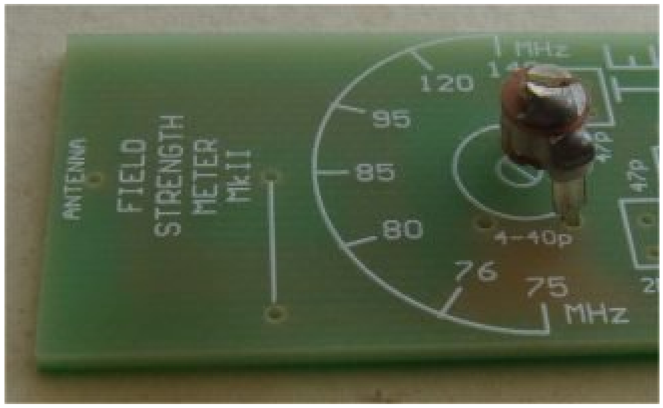
Field Strength Meter MkII PC board

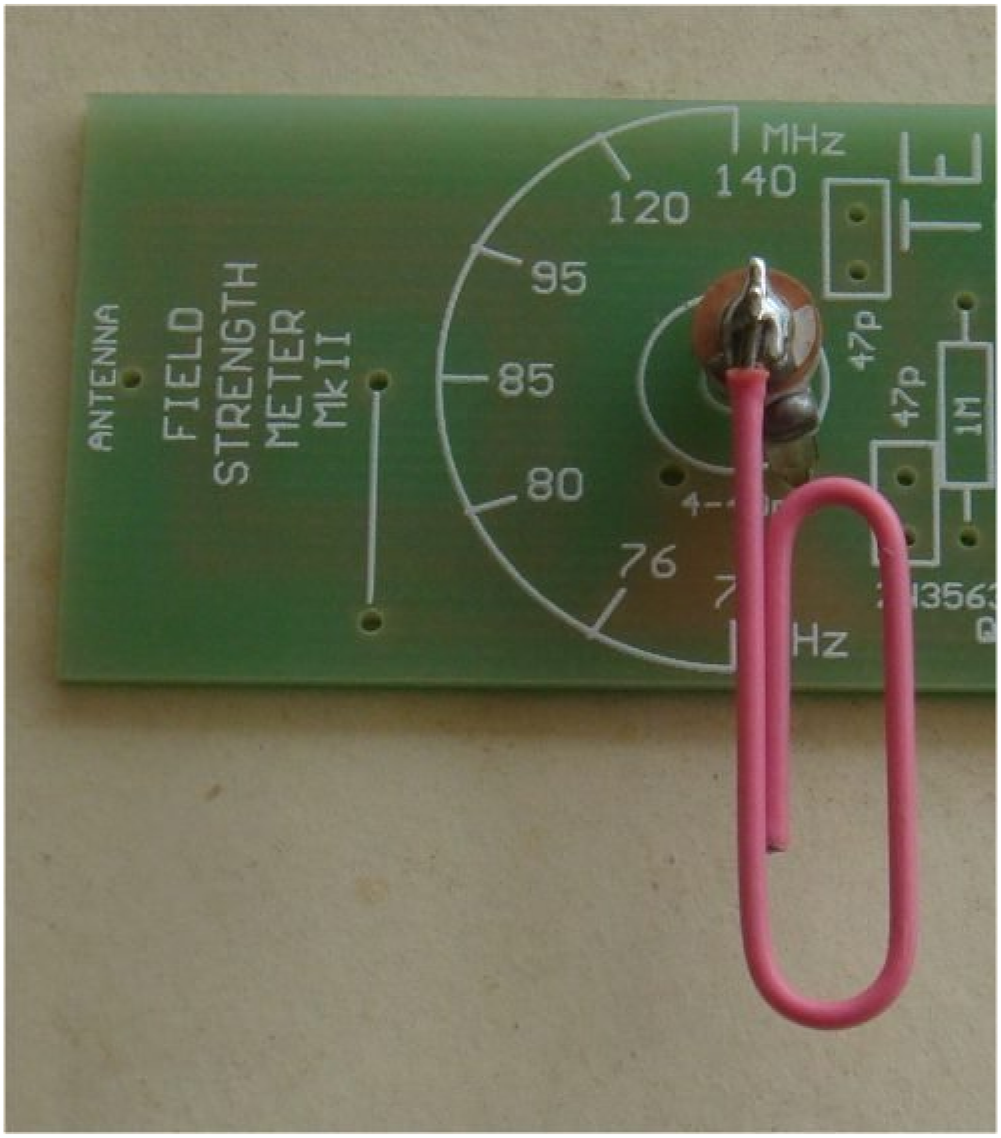
CONSTRUCTION

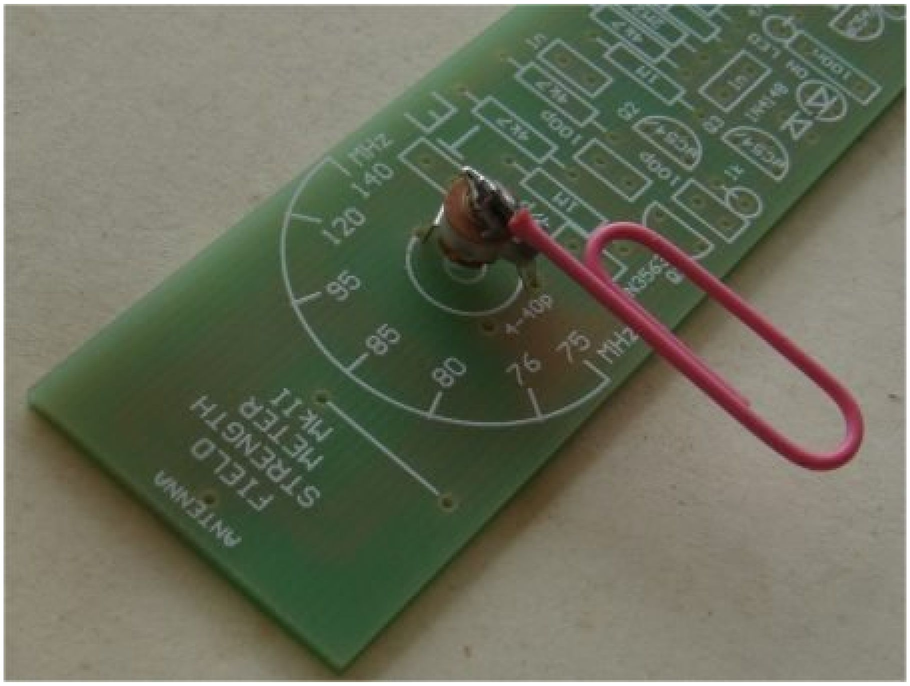
All the components fit on the board, with the two lithium cells at the end.
The overlay shows where the parts are placed and it's a simple matter to fit everything close to the board. If the leads of any of the components are left too long, the circuit will give a different gain to our prototype and 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.



The air trimmer (pointer) is now a ceramic air trimmer and the following photos show how it is soldered to the board and the the pointer soldered to the top when the air trimmer is turned so the moving vane is on top of the stationary vane. This position gives the air trimmer the maximum capacitance and now the pointer can be soldered as shown in the images.


ANTENNA
FIELD
STRENGTH
METER
MkII
MHz
120
95
85
80
76
75
MHz
4-40p
47p
47p


ANTENNA
FIELD
STRENGTH
METER
MkII
MHz
140
120
95
85
80
76
47p
47p
1M



The pointer is now in the correct position for the 75MHz frequency.
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.

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 Q4, Q5, Q6, 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 Q4 (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 (Q5) 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 (Q6) 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 CR0 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 $1,000 - $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.

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.
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.

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 Q2?
4. Why is Q3 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 3p5 - 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, (1 MHz etc) the 100p will have a high reactance and thus the gain of the stage will be the ratio of the 4k7 to 1 k or about 5. Thus the stage will not amplify all the hash and noise of the low frequencies.
4. Q4 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.

THE END

This is not the end.
Talking Electronics has over 200 more projects and you can only learn if you start to put things together.
Reading a book is only part of the experience. The other 90% is gained from ACTUAL CONSTRUCTION.
All the prices in this publication have not increased since the year 2000. That's because Talking Electronic is now a SERVICE COMPANY and supplies everything at cost because no-one wants to pay the real price.
All the kits are now packed "in-house" and this has reduced our costs.
All the kits cost LESS than buying the components separately and some of the items are not available from electronics wholesalers, so you need the kit.

But the real issue is this: You have to build things to get the knowledge. The author still builds and designs and gets PCB's from China and there is a back-log of more than 10 projects waiting to be finalised.
That's the only way to operate. Keep yourself busy.
You can be fully engrossed in electronics your whole life and one project will spark another and after a few years your whole workshop will be filled with projects.

If you look at the range of Talking Electronics projects, you will see lots for the Model Railroad enthusiast and lots for the hobbyist wanting to learn about microcontrollers.

The whole point of having a hobby is to keep your mind active and even sharing your ideas with others on ELECTRONICS FORUMS.

That's where the internet comes in. It is absolutely filled with electronics data, circuits and helpful advice and you can access Talking Electronics website at any time and join the other 7,000 visitors who click on the site every day.

PRICE LIST

All prices are USD plus $4.50 USD postage for a single kit.
2 kits to 5 kits – add $6.50 USD
Use PayPal. It is the quickest and most reliable way to pay.

Use your Paypal account and send to
TALKING ELECTRONICS.com by using Talking Electronics PayPal account: talking@tpg.com.au

Colin Mitchell
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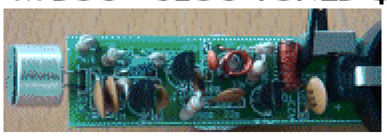
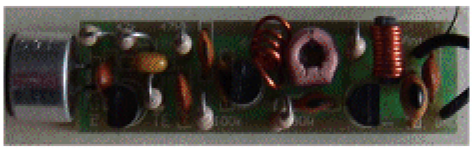
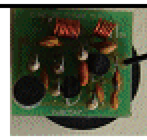
Payment is AUD for the kit and AUD for postage.

FM BUG - SLUG TUNED \$8.00 
THE FLY \$10.80 
CUBE OF SUGAR \$14.05 
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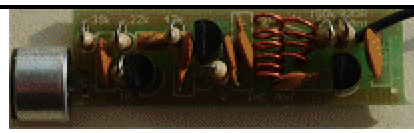
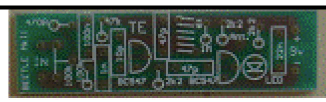
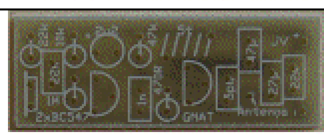
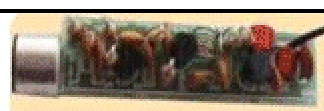
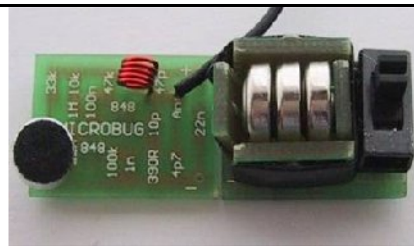
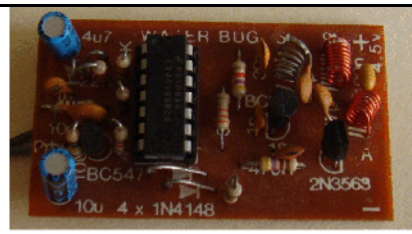
THE ANT \$10.60 
BEETLE MkII \$16.25 
THE GNAT \$10.50 
THE AMOEBA \$11.60 
HIKERS ALARM \$20.35 
VOX MKIV with beep \$25.80 
WALL BUG \$11.60 

MICRO BUG $14.50

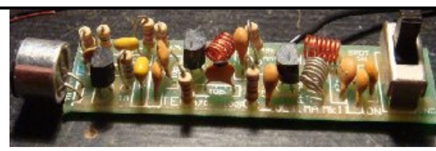


VOYAGER MkII $12.90

WATER BUG $20.35



ULTIMA MkII $15.50



FIELD STRENGTH METER MkI $10.80

FIELD STRENGTH METER MkII $16.45