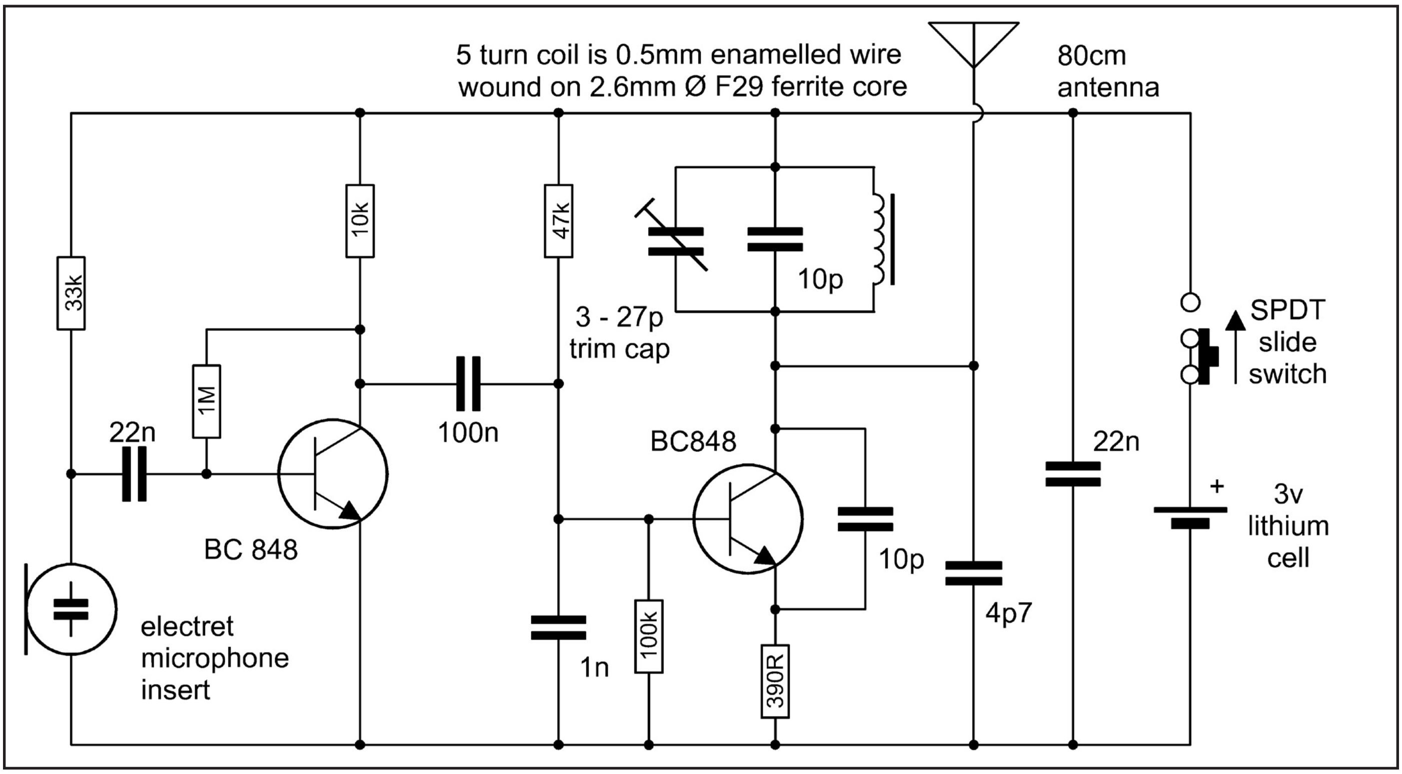
SILVERFISH

The thinnest bug to ever be presented - 100metre range



SILVERFISH CIRCUIT

This must be the world's smallest bug to be presented in kit form. As Small as a credit card and as flat as a couple of coins stacked on top of each other. It's flat enough to fit into the binder of a book or even between the pages of a novel on a bookshelf.

Other inconspicuous places for it to be placed would be; to stick it under a desk with tape or behind a large object like a television or a picture frame on a wall.

The Spy Bug was the original circuit. It was designed long ago. making the PC board layout and circuit undesirable. The battery was held down by an elastic band, and the tank circuit was tuneable by screwing a delicate ferrite core in and out of the RF coil, just these two factors made the final layout unpractical.

Now we have a new CAD board for the circuit and have gone about the design in a very user friendly and compact way, this has radically improved the hardware functionality.

We came across the name silverfish because the meaning for the word defines it as an insect or bug that feeds on starchy materials such as wall paper and books.

The circuit follows our standard two-transistor arrangement as seen in the Voyager, with the resistor values changed to suit the lower voltage and the capacitor values adjusted to suit those readily available in surface-mount form. It also employs a built in small electret microphone and a wafer-thin 3v lithium cell. It could be hardly recognised as a bug!

We have finally designed a bug thin enough and reliable enough to call the silverfish. The design has allowed the use of what we call "circuit board component sinking", where a shape is cut into of the PCB, the same size as the component, making it possible for the part to be counter sunk into the PCB. This relieves the final height of the components, which are already quite small, to minus a few millimetres, while providing strength to the connections of those external parts.

A surface-mount BC 847 (identified as '1k') has been used for the audio stage and the RF stage as a standard transistors would have exploded the overall size.

At a casual glance the bug appears to consist of 5 parts: a battery, microphone, trip cap, coil and PC board with a short length of hook-up wire for the antenna. It's only after very close inspection that the surface-mount components can be detected on the underside of the board.

And that's the way we want it to be.

Show the bug to anyone not familiar with the capabilities of electronics and they won't

PARTS LIST

1 - 390R	(marked 391)
1 - 10k	(marked 103)
1 - 22k	(marked 223)
1 - 47k	(marked 473)
1 - 100k	(marked 104)
1 - 1M	(marked 105)
1 - 5p6	surface mount
2 - 10p	surface mount
1 - 1n	surface mount
2 - 22n	surface mount
1 - 47n	surface mount

2 - BC 848 surface-mount '1k'
1 - Mini Electret microphone
1 - 20cm 0.5mm enamelled wire
1 - Ferrite core 2.6mm x 6mm, F29 material
1 - 1cm x 4cm Mylar strip for switch
10cm tinned copper wire
5 cm x 3.5 cm wide heat-shrink
1 - 3v lithium cell
2 - Paper clips for battery holder
1 - 80cm hook-up flex for antenna
1 - 30cm length 0.7mm solder
1 - SILVERFISH PC Board

believe something this small is capable of transmitting with such clarity over a range of 100 metres or so.

Before I go into the design of this project, I must make one stipulation. It's not for the beginner. It uses chip components (including chip transistors) and requires a fair degree of skill in construction.

This is the second bug from this series of FM transmitters and you should build some of our previous models, such as the Ant, Amoeba or Voyager, to gain experience in construction.

The aim of this series is to bring you in line with modern technology while building something worthwhile.

Many of the technical features we have described in previous articles also apply to this project and it is an improvement over the previous bugs by having surface mount components and a ferrite inductor to give a stable frequency and a trimmer capacitor that allows the frequency to be precisely adjusted via a screw-driver, to be set between 70MHz and 110MHz.

This is the first time we have incorporated a slug (in our case a slug is a length of screwed ferrite material) in the inductor (an inductor is a coil of wire) and you will be able to compare the effectiveness of a slug tuned coil over an air cored coil.

When a piece of ferrite is introduced into a coil it has the effect of concentrating the lines of magnetic flux. In other words it is capable of storing more magnetic energy than the same volume of air and this gives the coil greater inductance.

With this, you will be able to understand the next point:

When a slug is introduced into a coil in an oscillator circuit, the frequency will decrease. If you wish to increase the frequency to the original value, the tuning capacitor (the capacitor across the inductor) must be decreased.

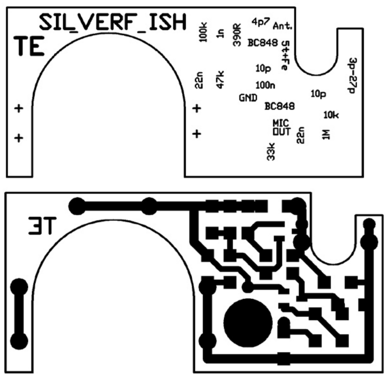
Maximum inductance is obtained when the ferrite is in the middle of the coil and equal amounts protrude from each end. For example; if the slug is screwed in either direction the inductance decreases and the frequency of the circuit increases.

But there is really no need to do this because we have introduced the trimmer capacitor for this purpose.

Ferrite slugs are very brittle and should not be adjusted when inside the coil.

This means the slug should be positioned directly in the centre when setting up the circuit so that the frequency is at the same value as when we designed it.

In the air-cored design of the Ant, Amoeba and Voyager, the frequency was adjusted by squashing or separating the turns of the coil. When the coil is stretched, the effective inductance is reduced and the frequency of the tuned circuit increases or moves up the band. When the turns are squashed together, the inductance increases and this



The full size CAD artwork for the silverfish printed circuit

means the coil will deliver more energy to the capacitor. The capacitor will take longer to charge and thus the frequency of the circuit will decrease.

When adjusting the frequency, it only requires a very slight rotation of the trim cap to get a shift of 1MHz or more. Some constructors found adjusting the frequency via an air coil, very touchy and wanted a "fine tune" arrangement to set the frequency exactly.

This was one of the limitations of our previous designs and has been overcome to a certain extent by the trimmer cap tuning arrangement.

The reason why we have not concentrated on setting the frequency exactly is due to the shift that occurs with these simple bugs as the battery ages.

The frequency of transmission depends partially on the supply voltage as well as a number of factors including the loading effect of the antenna.

Thus any advantage of fine tuning can be swamped by the general drift due to these other influences.

The Silverfish fits into the category of "place and forget" These are bugs that are intended to be placed "in-situ" and not moved. The circuit is not classified as "tight" and the frequency will drift if it is touched or handled. It is not intended to be dropped into a handbag or pocket and in a later project we hope to have a more sophisticated design for this purpose.

The short-term stability of the bug, however, is exceptional and once the frequency is set it will not fluctuate or drift unless the antenna is touched or the supply voltage falls apreciably.

Our tests showed that the slug tuned coil improved the output about 25% and this is due to the "Q" factor of the ferrite. You may be expecting a Q value of 100 or more but as the frequency of a circuit increases, more energy is lost in the core material. We are operating at the upper limits of the ferrite and also drawing most of the energy from the circuit via the antenna. Thus we are not allowing the full effect of the ferrite to be realised.

SLUG TUNED COIL
Vs
AIR CORED COIL

Many constructors of our FM transmitters have requested a variable frequency so that they can tune the bug into an unused portion of the band.

Some wanted it to sit between radio stations while others wanted to be at one end of the band or even slightly off the band.

This project allows any frequency between 70MHz and 110MHz to be selected. Firstly you must decide which end of the band you wish to use. For the low end, use 6 turns and for the high end use 4 turns.

If you were to screw the slug in and out of the coil with a plastic screwdriver you would be able to tune about 10MHz across the band. Doing this may damage the core so we have introduced a trim cap for this adjustment. But the question at the moment is: What is the advantage of the ferrite core over an air cored coil?

In practical terms we can say the improvement is small. Our tests showed an increase of about 20% to 50% in output power but the overall performance was little better than the ANT due to the size of the lithium battery being smaller than 2 AAA cells and thereby not providing as large a ground plane.

Theoretically, the energy that can be stored in ferrite material is up to 100's of times greater than air but as the frequency of the circuit increases, the losses in the ferrite increase too.

For this reason, high frequency ferrites are available but at 90MHz, the losses start to approach the "quality factor" (Q factor) of the coil.

At a lower frequency the introduction of a ferrite material may increase the performance 1,000% or more whereas our tests showed an improvement of only 120% to 150%.

We have explained that the inductance of the ferrite coil is about 5 times that of an air cored coil and this means the tuning capacitor must be reduced accordingly.

The main advantage of a slug tuned coil and the trim cap for trimming is the ease of changing the frequency. This is especially important in countries like the US where the FM band is already crowded and to find a blank spot on the dial requires careful tuning.

A ferrite inductor can be made much smaller than its air counterpart due to it being able to store a higher flux density.

Finally, a ferrite inductor is not as susceptible to outside capacitance effects as an air inductor as the magnetic flux is contained within the coil.

HOW THE CIRCUIT WORKS

Sounds are picked up by the electret microphone and its output is heavily dependent on the current supplied by the feed resistor (load resistor). The microphone supplied in the kit is a high sensitivity device and will produce very good results.

As you will have learnt in our previous discussions on electret microphones, they contain a Field Effect Transistor and a sheet of very thin Mylar material that has been charged during manufacture and will hold this charge for the life of the device. These are the only two parts in the unit!

Sensitivity is a result of controlling the charge on the Mylar film and a sensitive device will detect sounds better than the human ear. The only problem with high sensitivity devices is the generation of background noise and if too much gain is attempted, this noise can be quite disturbing. Microphone gain is achieved by lowering the load resistor.

In our circuit we have struck a balance between the two while achieving a result that can pick up whispers at 3 metres.

When the microphone is in circuit, a small voltage will appear across its terminals and the current flow will be as low as 100 micro-amps. The FET inside the case does all the work and its gain could be as high as 100, 500 or even 1,000 - we have no way of determining this except to say the output is very high for the sound pressure being picked up.

The output will be less than 1mV for a faint sound and about 30mV for a loud whistle at 1 metre and the output is passed to a single audio amplifying stage.

This stage has a gain of about 50 to 70 and the output is fed into the base of the RF oscillator via a 22n capacitor.

The oscillator is a standard Hartley configuration with the tuned circuit at the collector.

The secret of the operation of the RF stage is the transistor. This must switch off for part of the cycle so that the resonant circuit (the coil and capacitor) can provide a waveform that is basically a sine wave.

This waveform can be larger than the supply; this phenomenon will be covered later.

The importance of the tuned circuit is to set the frequency. The transistor is capable of operating at a very high frequency and we require a component or a set of components to set the frequency to about 88MHz. In essence, the trimmer capacitor the 10p and the 5 turn coil does this. It sets the frequency by taking time to transfer the electromagnetic energy stored in the coil, to the capacitor. While this transfer is taking place, the transistor is switched off by the 10p connected to the emitter. How it does this, will be explained later.

The fact that such a small capacitor can be used to do this is due to the high frequency of the circuit.

When the transfer of energy is complete (or nearly complete) the transistor switches ON again and both the tuning capacitor (the capacitor across the coil) and transistor, supply a burst of energy to the coil.

The 10p connected to the emitter assists by transferring the change in voltage (at the collector), to the emitter and turning the transistor ON.

Let's look at how the 10p does this:

The transistor is turned ON by increasing the voltage between the base and emitter. In our circuit, the base is effectively held at a constant voltage by the 1n capacitor. At the frequency of operation, the 1n holds the base very rigid and thus the transistor is not turned off by altering the base voltage.

Instead, the emitter is allowed to move up and down and this causes the transistor to turn on and off. The 10p between the collector and emitter does this.

The frequency of the circuit is set by adjusting the trim cap. This adjusts the inductance of the coil and determines the amount of energy stored by the inductor.

???As the trim cap adjusted, the inductance is reduced and thus the time it takes to transfer this energy to the capacitor is reduced. The net result is the frequency of the circuit is increased.

The antenna is connected to the active end of the resonant circuit and some of the energy is passed into the antenna for radiation to the surroundings. This is the energy we pick up on a receiver.

Not all the energy can be removed as this will kill the circuit and so a short fine wire is used for the antenna to limit the transfer. The 22n across the power rails serves an important function of maintaining stable rails so that the transistor can turn on and off fully.

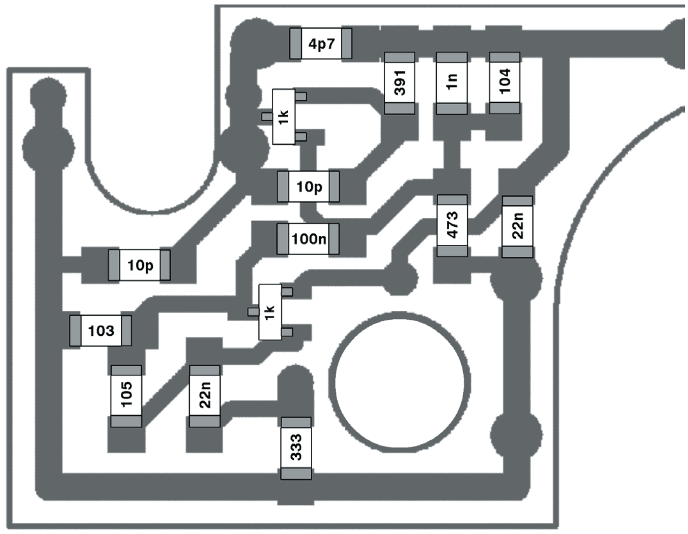
We have used a thin 3v lithium cell to create the smallest bug ever and this cell has more than 5 times the energy of an equivalent "dry cell".

Here's a good way to compare capacities. A 9v transistor battery of the standard "dry cell" type has a capacity of 150mAhr per cell. The alkaline version has 500mAhr and the latest lithium design has 1200mAhr. Each cell in this new lithium battery weighs 10gm making the energy/weight ratio 120mAhr per gram. The lithium cell used in our project weighs 3gm so let's say it has a capacity of 160mAhr, to be on the safe side. If the circuit takes 2.5 - 3mA, the life of the cell will be about 55 hours.

The on/off switch is fabricated with a strip of mylar. When the strip is pulled out, the bug is turned on.

As we have said, the circuit will operate for about 55 hours on a single lithium cell and to replace the cell, the heat-shrink must be removed, if you decide to cover the circuit, for protection.

A new cell is then fitted and the bug re-heat-shrunk for another 80 hours of monitoring.



Enlarged view of the underside of the board to show the placement of the surface-mount components.

ABOUT THE PC BOARD

The approach we have follow with this bug is a one of a kind with any of our designs and by the looks of things it hasn't been done before.

The PC board for this project has been designed on a CAD package and once you know your way around the controls, the time you can save is incalculable.

CONSTRUCTION

The kit contains surface mount components for all of the resistors, capacitors and transistors so that the final size of the product is reduced to a fraction of the size, as if it were built from standard components.

Prepare your workbench by clearing a work space; you don't want to work amongst a clutter because the surface-mount parts are so small that seeing them is hard enough, so you wouldn't want to go searching for them.

With surface mount, the resistors are one of the only packages which have a relative value or code printed on them that identifiable, the others like the capacitors and transistors have no way of being identified not even the colour or the shape can be a factor in there identification.

Size is not always an indication of capacitance as some are single layer devices while others are multi-layer.

Take the kit and empty the contents onto your workbench, take a few minutes to study and become familiar with all of the parts and even the markings on the PCB.

The resistors and the capacitors both come housed in separate carrier strips. The carrier strip for the capacitors and the resistors both have a black line on one end, this end should be on your immediate left. Starting from the left and working to your right we have compiled the values in the strip in an ascending order. Take our word for it that we have arranged the two strips in this order because we have taken into account the people who want build the kit, but obviously do not have the eye-sight capable of seeing the code markings. The order of the components also make the building a little lest time consuming.

Especially, with the strip of capacitors take note; DO NOT EMPTY THE STRIP onto your workbench until each part is required.

Carefully pealing back the plastic one at a time take a capacitor, find its position on the PC board, and following the article that has instructions for surface mount soldering in this book, solder the component into place.

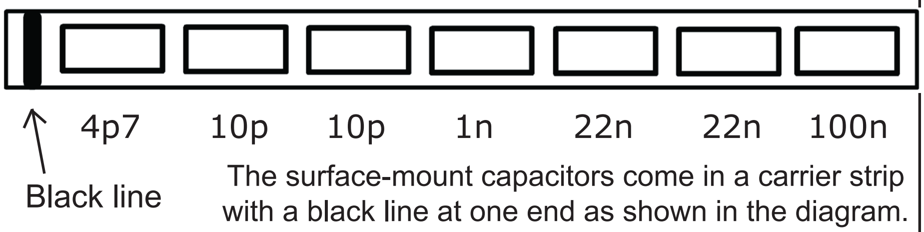
We have included with this article, an enlarged view of the overlay of the PCB. This will assist in the swift and corrected completed product.

Remove the next capacitor in the strip find its position and solder it into place. Repeat this step until all of the capacitors are fitted.

The second strip which are resistors are ready to be soldered into place one-at-a-time, until again, the strip is empty.

The two strips of components, have to be the first parts fitted because of their size, they are the smallest. This will help with the overall neatness of the soldering.

So the next parts in the size and height scale are the two transistors. Take note of the soldering surface mount pages for transistors and commence.



The surface-mount capacitors come in a carrier strip with a black line at one end as shown in the diagram.

The two transistors are noticeable because they have a three-leaded package and they are black, the marking on the package will be '1k' not that it really resembles anything because like mentioned earlier the markings change from manufacturer to manufacturer.

The next best thing to do would be to take the paper clips and make the battery holder. Fold the paper clips out straight, so that there are no kinks from the original bends. The straighter the better.

Follow the templates FIG. 1 on this page for the correct folding dimensions of the paper clip.

DO NOT cut the paper clips with your side cutters as the metal is very hard and will damage the cutters. Use heavy duty metal cutters or a file to score a dint into the metal, allowing you to bend it back and forth untill it snaps into two. Be Quick when Soldering clips because the Coating will peal off and then there will be no tin to solder to.

The trim cap or the trimmer capacitor has its leads bent outwards close as possible to the casing. Insert the trim cap in its position up through the PCB. Turn the PCB upside down and solder the bent leads of the trip cap to the board.

Prepare the enamelled wire coil for insertion by scraping the red enamel off the leads with a hobby knife or blade. Another way is to use the heat of the iron. Apply a generis amount of solder to the iron and with a gently scraping motion wait a few seconds until the enamel bubbles off. Once the two leads are rid of the enamel you can fit the coil. The coil is part of the circuits 'tank circuit' this is an RF oscillator for the FM transmission frequency. If the coil isn't mounted so that it is close as possible to the PCB then the electromagnetic flux produced by the coil while in operation will not be effective due to the low 'Q' factor implied.

Straigten two paper clips and cut three pieces to length.

With two paper clips that you have straightened cut them to size. bend them as shown in the diagram.

There are two pics of the negative rail. The first is viewed from the top and the diagram to the left is a side view showing how to bend it appropriately.

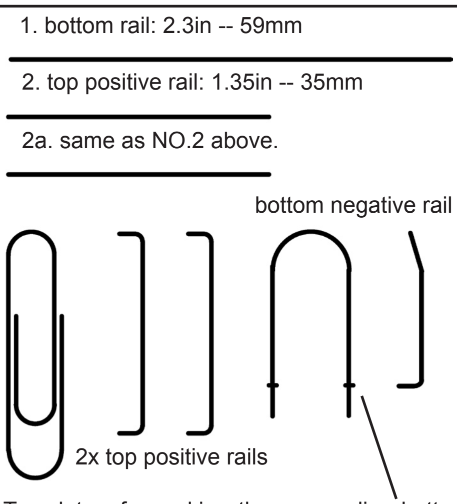


FIG. 1: Template , for making the paper clips battery holder. Note: May not be to scale.

THE MICROPHONE

Two types of electret microphone may be supplied in this kit. Both are electrically the same but look different.

The small electret is a 2 leaded type and has two solder lands on the back to take 2 leads.

A microphone is a polarised component, this means that when connecting it to a circuit there is only one correct way. After inspecting it very carefully you will see one land connects to the case with hair line tracks and this is called the EARTH or NEGATIVE land. Identified on the PCB as a '-'. The other is the ACTIVE or OUTPUT land. Refer to the accompanying diagram to see how the microphone is connected to the PC board. FIGURE??

Solder two short lengths of tinned copper wire to the lands and note which goes to the case. This is the negative lead and must be fitted to the negative terminal of the board.

Place the microphone down the 0.300 inch marked hole on the board and while holding it in place turn the microphone around until the negative lead is closest to the negative land on the bottom of the PCB. Bend the two leads outwards at 90º.

Solder the two leads quickly to prevent them de-soldering from the microphone. Trim the leads as short as possible to prevent them from making a short circuit between the other components and track work.

WINDING THE COIL

The coil is wound on a ferrite slug and must be done neatly and as tight as possible, there are groves on the slug which you can use a guide when winding the coil. Though take note of the direction that the coil is wound around the slug, because if it not wound correctly then it will not attach to the PCB correctly.

The slug must not be allowed to rattle or move by itself, as this will cause the frequency to drift.

For the moment, the job is to wind the 10 turns neatly on the slug. To make it easy, start in the middle of the slug and start wind-

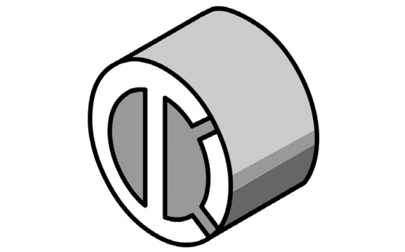


FIG.2 The Microphone

ing outward in both directions.

The turns are wound in a clockwise direction and to make sure you are winding in the right direction, check with the holes on the board. If you run out of former, screw the slug into the coil and continue winding.

"ten turns" is determined by 10 loops of enamelled wire at the top. Straighten the ends of the wire and cut them off at 1cm. Scrape the ends with a razor blade or file to remove the enamel coating and tin the ends with a soldering iron.

THE SWITCH

To save space, an ingenious switch arrangement has been used.

The idea came from a musical card in which the opening and closing of the card pushed a thin strip of plastic between two contacts to turn the chip on and off.

In our arrangement a piece of Mylar is placed between the negative of the cell and a contact on the PC board. When the strip is pulled out, the bug is turned on.

During construction, you should be aware of how the switch operates and make sure the cell is pressed against the contact so that reliable operation will take place.

A paper clip over the battery connects the positive terminal of the cell to the board and the same applies to the negative terminal. A slight up-wards bend in the negative paper clip will give it enough pressure against the positive terminal paper clip to keep the battery cell in place.

Final tension will be provided by the heat-shrink but this should not be added until the project has been checked and tested.

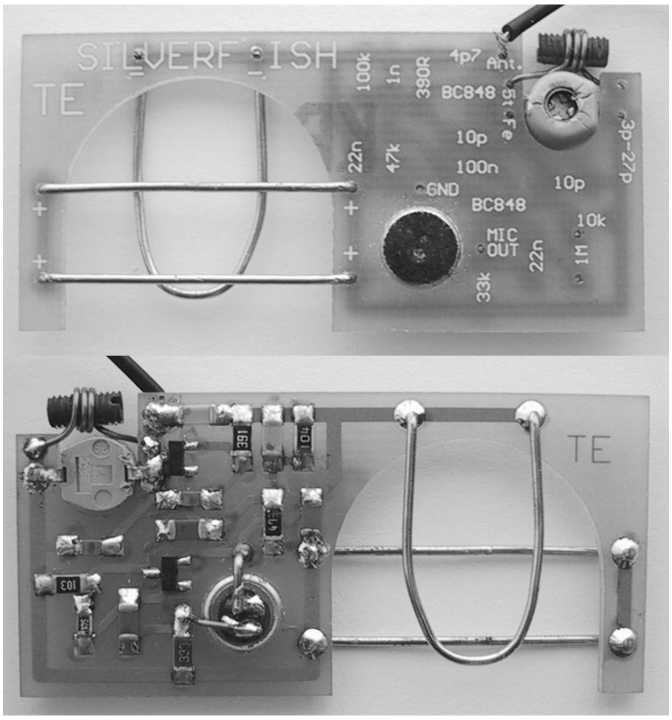
Cover it with the Mylar strip and place the lithium cell in position under the tinned copper wire and keep it in place with the elastic band.

Lastly the antenna is soldered to the antenna point on the board and the job's done.

You can now try the bug by pulling out the Mylar strip so that the negative terminal makes contact with the paper clip and adjust the trim cap until a feedback whistle is detected on a nearby FM radio.

Many of our readers say their bugs worked first go and we plan it that way.

We have already built many models of each bug before we offer it in kit form and the bugs (sorry!) are already ironed out.



If you don't get a feedback whistle, go to the If It Doesn't Work section. If you get a whistle, you can add the heat-shrink as shown in the photos so that it keeps the cell in place and protects the components from damage.

We have supplied special low temperature heat-shrink and you can use a hair-dryer or candle to shrink it in place. Don't use too much heat as this will only damage the plastic.

A "TIGHT" CIRCUIT DEFINED

We mentioned the word "tight" in our introduction. Here's some further notes:

The Silverfish bug has been designed to be placed 'in-situ' and left to transmit. It should not be moved around or handled like a wireless microphone as the circuit has been designed for high activity and high output, not "touchability."

If stability when handling is required, the circuit would need to be "tight" and by this we mean the oscillator must be a low amplitude arrangement so that it is not affected by outside capacitance.

To further improve stability, the antenna should be decoupled from the oscillator with a buffer transistor so that the varying loading effect of the antenna does not alter the frequency of operation.

Refer to the Ant circuit to see how this buffering is achieved.

In a future design we will incorporate a stable oscillator with high output and achieve a bug called a "drop in."

These bugs are designed to be dropped into a pocket or handbag and allowed to monitor events while being carried around.

A CIRCUIT AT RESONANCE

Another statement we made was the amplitude of the oscillator could be higher than the supply voltage.

In a parallel tuned circuit, such as we have in the Silverfish, the amplitude of the waveform can be theoretically very high. The size of the waveform is due to the quality of the material in the inductor and the speed with which the energy in the inductor is allowed to collapse.

In our case this voltage is reduced by the loading effect of the antenna and the voltage peaks flow into the antenna to be radiated as electromagnetic energy.

IF IT DOESN'T WORK

If the circuit doesn't work, you have 3 options.

1. Try to fix it yourself,
2. Send it in for repair or
3. Put it aside and build another kit.

The third option is not as silly as it sounds.

With the next kit you will take more care and the chances of it working will be greater.

You can then compare the parts and layout of the non-working model with the model that works.

This project provides a fair degree of challenge as the components are very small and some of them (the capacitors) are not identified. The size of a surface mount capacitor does not indicate its value but since there are three different sizes and you can use the process of elimination to determine the values.

Fortunately there is a simple test you can make to separate the circuit into two halves - the RF section and the audio section.

Using the Field Strength Meter or LED Power Meter (described in the LED power meter article), you can determine if the oscillator section is working by connecting the antenna point to the meter.

If RF is being produced you will get a deflection on the meter and you can now test the audio section by positioning an FM radio about 2 metres away and adjusting the trim cap until a carrier or squeal is detected on the radio. If the background noise disappears but no squeal is produced, the RF section is working but the audio section is not.

Checking through a surface mount project is much more complex than a standard project as the surface mount components are easily damaged during soldering.

Once you have the project ready for testing, check all the components to make sure they are in the correct positions.

This is especially important with the capacitors as they are unmarked and you can only go by the fact that there is one 4p7, two 10p's, two 22n's, one 1n and one 100n.

Next measure the resistance of each resistor, with a multimeter. The bug should be off during this operation. If you get an incorrect reading, reverse the probes and try again. All the resistors should read their correct value. An open resistor will be very easy to detect and is quite on the cards. The end terminations can easily break from the resistive substrate during soldering. If this is the case, you can buy another pack of resistors to replace the faulty part or parts.

The capacitors are more difficult to test and I would venture to say that I would not trust checking them with a capacitance meter while they are in circuit - especially the 10p capacitor, as the surrounding components will influence its value appreciably.

On the other hand it will not tolerate being removed from circuit, tested and replaced.

So we have a dilemma. My choice is to move to checking the current (2.5 -3mA) and testing the voltage at all points on the circuit. Use the low range on the multimeter to measure these.

Next measure the voltage across the 390R (1v) and the voltage on the base of the RF transistor (1.65v). This will show the transistor is turned ON and if no RF is being produced, we can conclude the stage is not oscillating. This could be due to the transistor being faulty; the 10p being open circuit; the in on the base being open or the 22n across the battery being open.

RF is detected by using the Peaking Circuit or LED Power Meter (as mentioned in the Ultima article) connected to the collector of the RF stage and any movement at all on the multimeter will show that RF is being produced.

Once you are satisfied RF is present, you should adjust the ferrite slug to get either a squeal or blank spot on the radio.

This will bring the frequency of transmission into the 88-108MHz band.

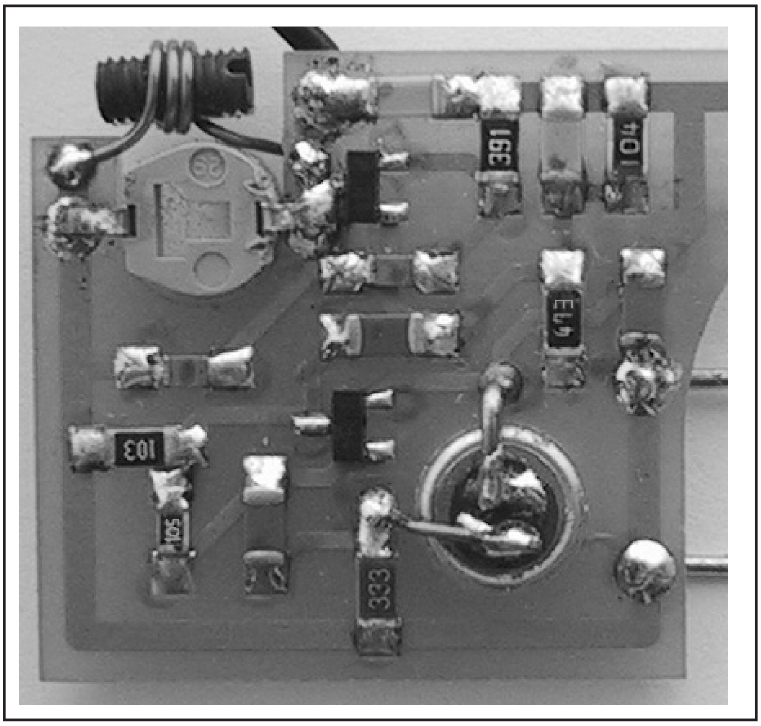
If only a blank spot is detected, the audio stage is defective and will require checking the surface mount transistor and its associated components, as well as the electret microphone, load resistor and 22n coupling capacitor.

The voltage on the active lead of the electret microphone can be anywhere between 70mV and 0.9v, and other than proving a voltage is present, we cannot do any more at the moment.

The voltage on the collector of the audio transistor should be 1v and the base voltage should be about 0.65v. This will show the transistor is turned on but it can still be damaged due to overheating and not providing any amplification.

One of the ways to prove the microphone is working, and the audio stage is amplifying, is to test the circuit with a CRO.

By whistling into the microphone and checking the audio section, you will be able to see the amplitude increase as you advance across the circuit. Set the CRO to a low mV reading (say 10mV/cm) to detect the output of the microphone and set the horizontal sweep to 0.2mS/div.



Keep the whistle intensity low (about 1mV p-p) for the final test and compare the amplitude on the base of the audio transistor with that on the collector. You should see a gain of about 50-70.

If you don't have a CRO, you can build a small amplifier such as the Mini-Bench Amplifier (featured in issue 5) and probe the output of the microphone to see if it is operating. Next probe the base of the audio transistor to see if the signal is passing through the 22n and then the collector to see if the transistor has amplified the signal.

CONCLUSION

If you have followed through our discussion and assembled the bug as described, you will have created one of the smallest bugs on the market.

For the final test, lay the bug on the table and stretch the antenna to its full length.

You will need a radio with a signal strength meter (or the Field Strength meter MkII described in this issue), for this.

The top looks very simple. It appears the bug consists of just 5 parts. But we know better!

After the bug has been tested it is heat-shrunk to protect it from damage.

Switch the bug ON and measure the output. Cut 2cm from the antenna and measure the output again. Continue until the antenna is about 10cm long and from your readings determine if the antenna length affects the signal strength. You may find the signal strength does not diminish appreciably until the antenna is about 10cm long and you may find certain lengths are more effective than others.

Throw away the pieces of antenna and fit a new 60cm length. Heat-shrink the bug and make sure the switch works freely.

This completes our project and I hope yours works as well as ours.

Look for the next chapter in this bug series and be ready for a big surprise.>