

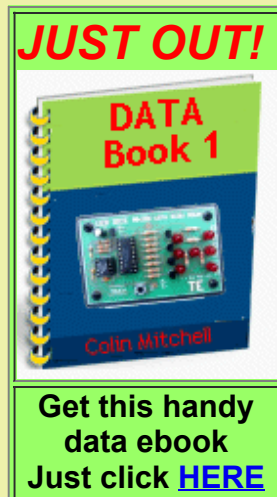
Spy Circuits

P1 [P2](#) [P3](#) [P4](#) (fox hunt)

Note: All the circuits described in this article must be used for experimental purposes only and must not be used for any illegal activity.

These circuits are very powerful, in that they are very hard to detect and will pick-up the slightest whisper and transmit the information 3km and more. Because of this, government laws are very strict and will come down very heavily on any mis-use.

The purpose of this article is to compare different circuits and explain the features that contribute to a good design. Some of these circuits (the best of each design) are available from Talking Electronics in kit-form and/or ready assembled. See the [Talking Electronics](#) website for the list of kits and devices.



FM TRANSMITTERS

The first group of circuits we will discuss are **FM TRANSMITTERS**. They can be called SPY TRANSMITTERS, FM BUGS, or a number of other interesting names. They all do the same thing. They transmit on the FM band in the range 88MHz to 108MHz.

Most of them can be adjusted to transmit above or below the band and you need a radio that will pick up these frequencies, to detect them.

Since the FM band is almost entirely filled with radio stations, we will be providing details on how to adjust a radio so it will scan EITHER above the band or below the band. Most radios can only be adjusted 10MHz above or below but this will be enough to provide a "blank" space for your transmitter.

FM transmission provides perfect quality and when one of these transmitters is used in a house and received on a good quality radio, you cannot tell if the person is actually talking in the next room or via an FM link, through a radio.

This means all the FM bugs have the same perfect audio, but some circuits will detect fainter sounds and others will transmit further. Some circuits can be handled without drifting off-frequency and others are designed to be very small or fit on top of a 9v battery.

By building these circuits you will learn an enormous amount about high frequency, audio and getting the maximum output with the least current.

This is the main aim of this article. It will add a number of "building blocks" to your understanding of electronics.

Before I start, there are two things that particularly annoy me. The first is a circuit diagram with C1, R1 etc and a parts list identifying the values. Circuit diagrams like this are obviously drawn by a non-electronics person. The whole concept of looking at a circuit diagram and seeing the values gives the reader an indication of how each section will work. A section may be

operating very lightly with high value components or it may be working very hard with low value components. The whole idea of providing a circuit diagram with marked components is to give the reader an immediate understanding of how the circuit is operating.

The second thing that annoys me is the labelling of parts on a PC board as R1, C1 etc. Again, the board has been designed by a non-technical person.

Why design a board without component values? Do they think the values will change? How can you assemble a board without referring to a circuit diagram?

The whole purpose of well-designed PC board is to build it without referring to any other data. Keep this in mind when designing your own boards. Also, don't name your boards "A51/834-2." Give them a name you can remember or one that refers to the application it will perform.

Let's start:

1 TRANSISTOR CIRCUITS

There are a number of 1 transistor FM transmitters on the market in kit-form and already assembled.

These circuits are interesting to look at but do not really perform very well.

1. They do not have a good transmitting range.
2. They do not detect low-level sound, and
3. They do not operate very well on 1.5v. No transmitter can be expected to operate very well on 1.5v. If you want to use a single cell, use a lithium cell as it produces 3v.
4. Some have a coil etched on the PC board. No FM transmitter will perform very well with a coil etched on the board.

Why use 1.5v?????

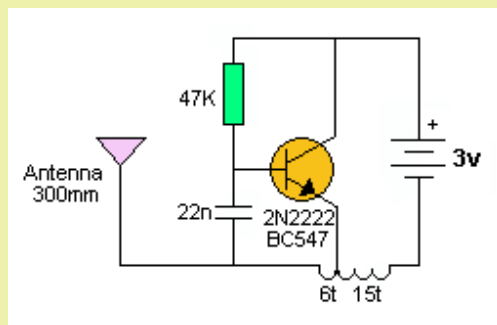
Transistors do not operate very well below 0.9v and the collector load resistor needs a small voltage so it can perform its task (the same applies to an emitter resistor) and thus the lowest voltage for a circuit is 1.5v. If only a single cell is used, there is no allowance for a voltage-drop as the cell becomes depleted. Always use 3v as the lowest supply voltage.

THE SIMPLEST CIRCUIT

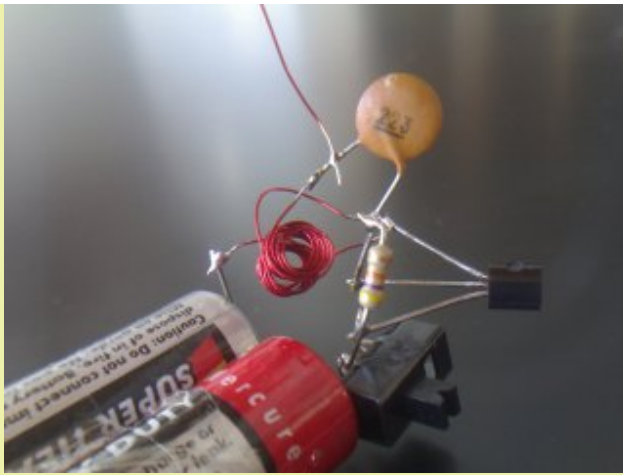
The following circuit is the simplest FM circuit you can get. It has no microphone but the coil is so MICROPHONIC that it will pick up noises in the room via vibrations on a table.

The circuit does not have any section that determines the frequency. In the next circuit and all those that follow, the section that determines the frequency of operation is called the TUNED CIRCUIT or TANK CIRCUIT and consists of a coil and capacitor. The transistor and components surrounding the tuned circuit simply keep the tuned circuit operating at its RESONANT FREQUENCY. This circuit does not have this feature. The transistor turns on via the 47k and this puts a pulse through the 15 turn winding. The magnetic flux from this winding passes through the 6 turn winding and into the base of the transistor via the 22nF capacitor. This pulse is amplified by the transistor and the circuit is kept active.

The frequency is determined by the 6 turn coil. By moving the turns together, the frequency will decrease. The circuit transmits at 90MHz. It has a very poor range and consumes 16mA.



THE SIMPLEST BUG



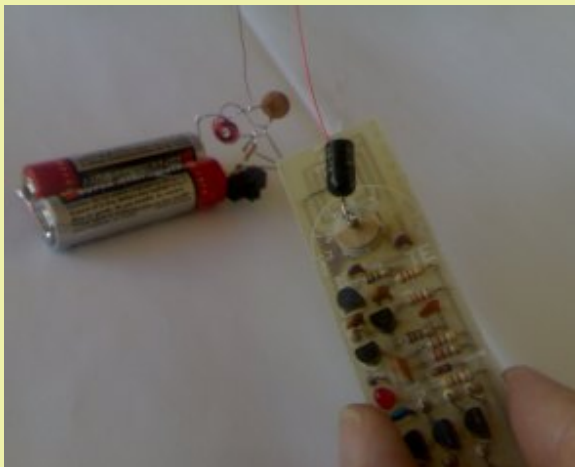
The components soldered to the 2 cells



Rear view of the simplest bug

After making a transmitter, you will want to know if it is transmitting. In the case above, the circuit will only produce a carrier and this will be heard on the radio as a "quiet spot." Rather than chasing up and down the dial, **Talking Electronics** has produced a piece of test equipment to let you know the bug is transmitting and the approx frequency of transmission. It is called [FIELD STRENGTH METER MkII](#).

The photo below shows the **Field Strength Meter** near the bug. The plastic knob on the trimmer allows adjustment without affecting the detecting circuit. Simply turn the knob (with the two antennas near each other) and the 3 LEDs on the project will illuminate.



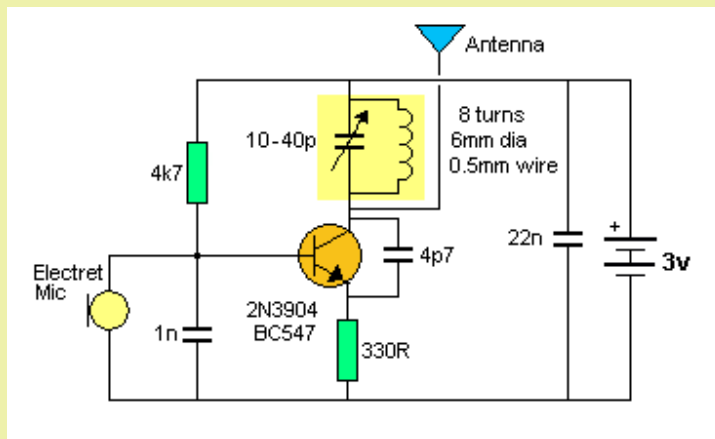
Field Strength Meter and Bug

So far we have seen an unstable circuit in action. Placing a finger near the bug will change the frequency. This is totally unsuitable.

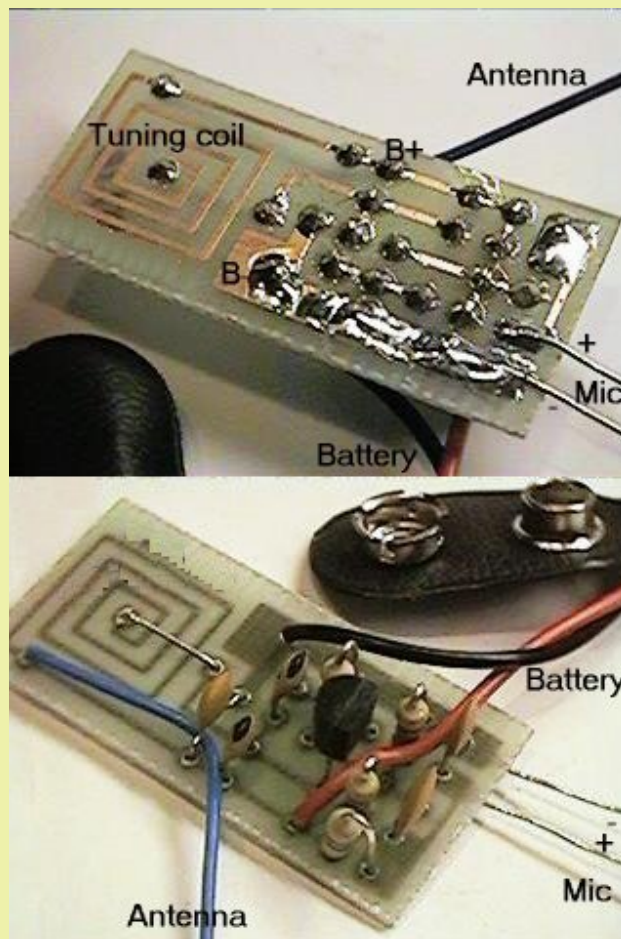
A ONE TRANSISTOR CIRCUIT

The next circuit uses a TUNED CIRCUIT or TANK CIRCUIT to create the operating frequency.

This is clearly shown in the diagram. For best performance the circuit should be built on a PC board with all components fitted close to each other. The photo below shows the circuit using a coil etched on the board. This type of coil is totally unsuitable. It does not have a high "Q" and the range is very poor. The board cannot be touched as the capacitance of your body causes the circuit to drift. A wound coil will improve the stability considerably. See photos below for the details of a wound coil.

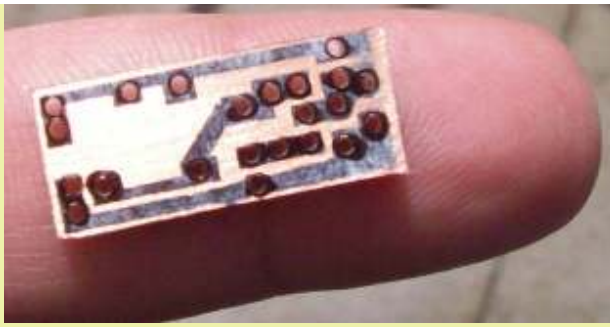


A one transistor circuit

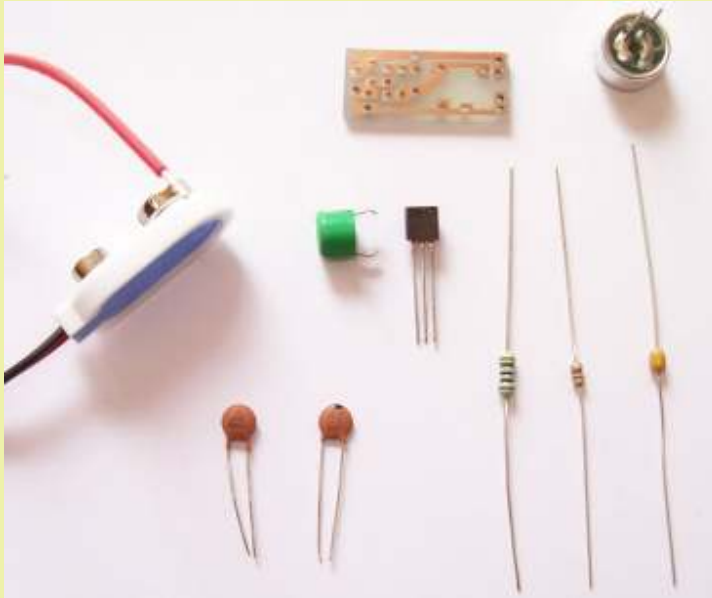


Do not use an etched coil

Here is the 1-transistor circuit produced by Darren Dazaro on a home-made PC board and heat-shrunk so the air-trimmer is adjustable via a small hole.



The PC board drilled ready for fitting the components



The 10 components (plus heatshrink, battery and wire)



The components mounted on the board



The board ready for fitting into heatshrink



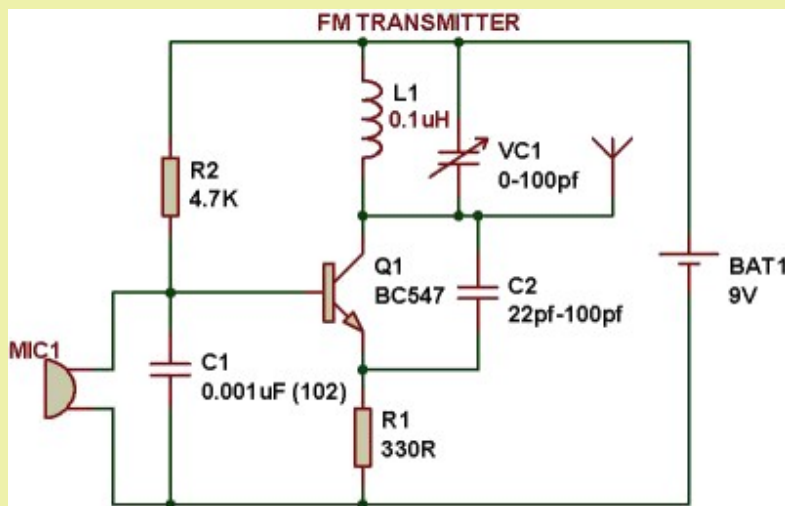
The finished bug with "studs" for the battery and a cut-out for the air trimmer

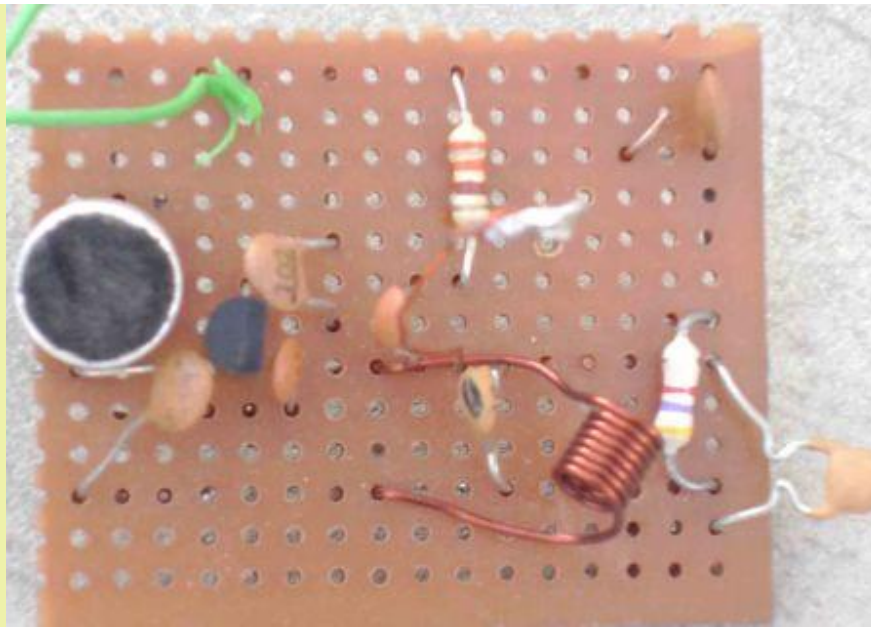
BAD LAYOUT

Here is a circuit with a very bad layout. The circuit may work but it relies on a "Q-factor" from the coil and capacitor in the tank circuit to produce a high voltage. This high voltage gives the circuit a good range.

Firstly the coil and capacitor in the tank circuit should be near each other. The coil should not have long leads. and a 22nF capacitor should be across the supply to give the circuit better performance. The value of C2 is too high. It should be 10pF. The coil should be 5 turns. The electret mic should not be connected directly to the base of the transistor. As you can see, the circuit is full of faults.

You can learn a lot from other people's mistakes.





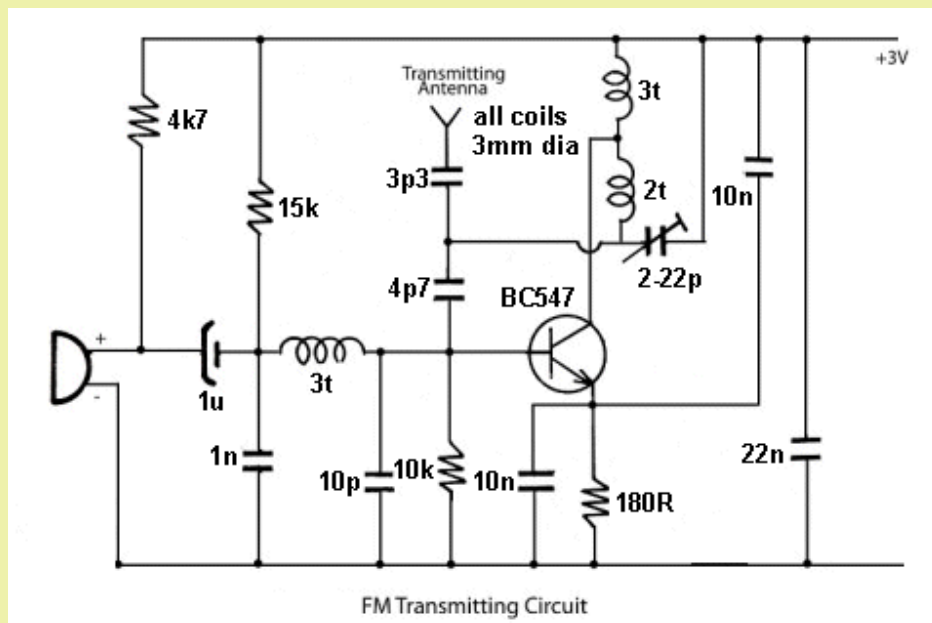
A BAD DESIGN

This circuit is completely different to all the other designs in this section. It is a common-emitter design, whereas all the circuit we are presenting are common-base designs. The circuit has not been tested and you can build it and compare the output with some of our designs.

Two mistakes on the circuit are:

The top 10n is not needed as the emitter is held rigid by the lower 10n.

10p on the base does nothing.



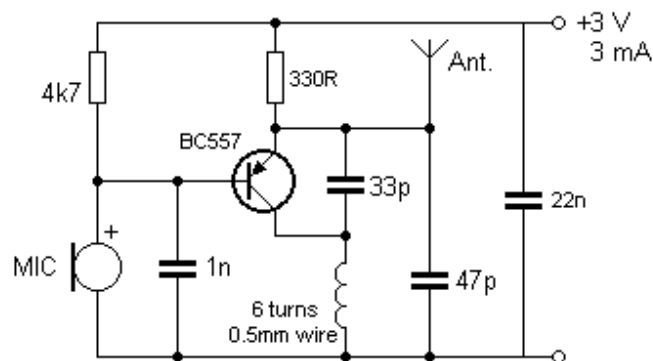
A PNP DESIGN

Before we go to an improved design, here is an unusual circuit using a PNP (BC 557) transistor. Firstly, PNP transistors do not work as well as NPN transistors. I would reverse the 4k7 and electret mic as the voltage between base and 0v rail is very small and the 4k7 is not biasing the transistor - it is not needed! The range will be 50 to 100 metres and the current is about 3mA.

Note: A reader built this circuit. It did not work!!

Try putting the 47p across the coil. The 33p may need to be reduced to 10p.

It is just a BAD design, but a good challenge to see if you can get this type of design to work.

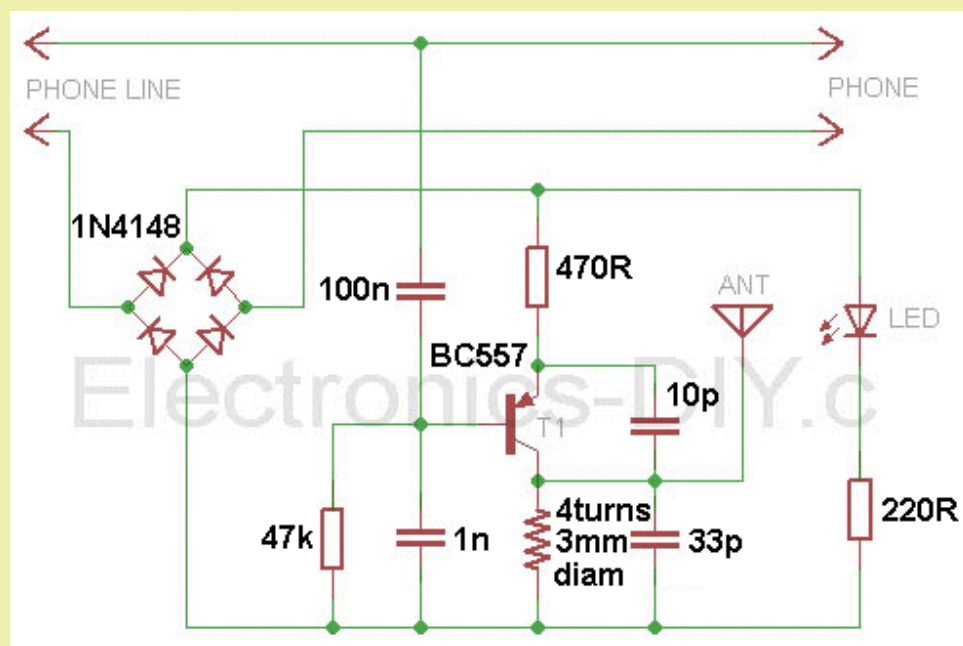


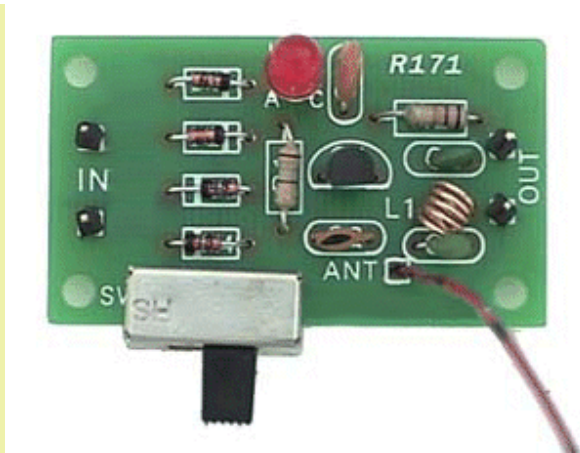
Simple 1 transistor FM Transmitter



The 22n is not shown. This is a later addition.

Here is a 1-transistor PNP circuit that transmits the phone conversation:

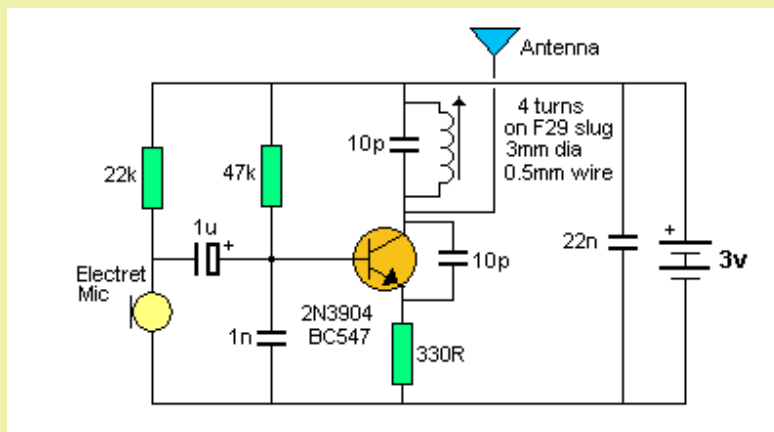




AN IMPROVED DESIGN

This design uses a "slug tuned coil" to set the frequency. This means the slug can be screwed in and out of the coil. This type of circuit does not offer any improvement in stability over the previous circuit. (In later circuits we will show how to improve stability. The main way to improve stability is to add a "buffer" stage. This separates the oscillator stage from the output.)

The antenna is connected to the **collector of the transistor** and this "loads" the circuit and will cause drift if the bug is touched. The range of this circuit is about 200 metres and current consumption is about 7mA. The microphone has been separated from the oscillator and this allows the gain of the microphone to be set via the 22k resistor. Lowering the resistor will make the microphone more sensitive. This circuit is the best you can get with one transistor.



THE COIL

I have particularly avoided mentioning the actual value (inductance in microhenry) of the coil because it is less than 1uH and is about 0.65uH. That is 65nH (65 to 80 nano Henry). A coil of this inductance will be very hard to measure on an inductance meter, but if you want to measure it, here is the secret:

Place a 1uH inductor on the inductance meter and read the value. Now add the 65nH inductor and the reading will increase to 1.65uH.

But a few turns of wire and a few circles of trackwork on a Printed Circuit Board will produce the same 65nH reading but the coil will produce a much better result in the transmitter.

This is all to do with a term called EFFICIENCY or "Q" of the coil and in the controlled conditions of these oscillators, the best coil will "deliver back" nearly 100% of the energy it is supplied. This results in a waveform in the antenna of nearly twice the voltage of the supply. The other secret in producing a good output is to have the capacitor and coil "match" each other.

In other words, the energy delivered back from the coil is the same as the energy delivered back from the capacitor.

That's why the capacitor should be 39p and the coil 5 or 6 turns.

You can use 47p and a coil of 5 or 6 turns.

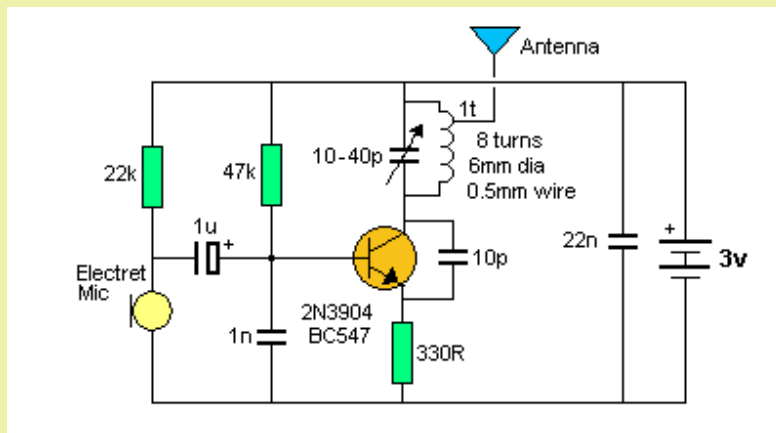
Stretching the coil reduces the inductance and this is how the two are matched together and produce a frequency somewhere in the region of 85MHz to 110MHz.

For 39p and 65nH the resonant frequency will be 100MHz from a calculator. But this may be different in a circuit due to the effect of the transistor.

For 47p and 70nH the resonant frequency will be 88MHz.

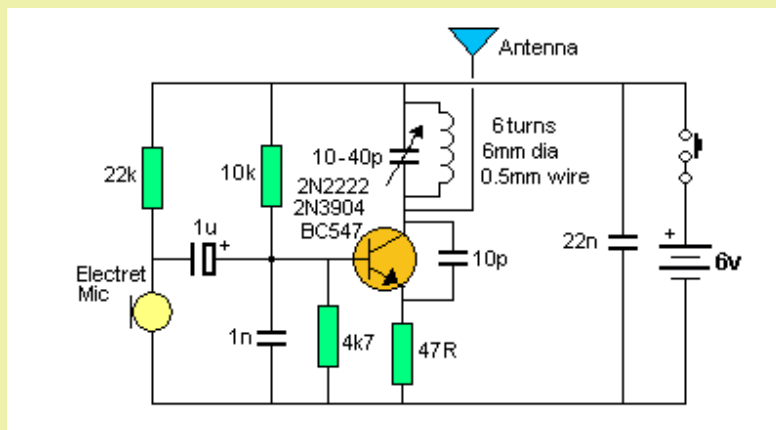
MORE STABILITY

If you want more stability, the antenna can be tapped off the top of the tank circuit. This actually does two things. It keeps the antenna away from the highly active collector and turns the coil into an auto-transformer where the energy from the 8 turns is passed to a single turn. This effectively increases the current into the antenna. And that is exactly what we want. The range is not as far but the stability is better. The frequency will not drift as much when the bug is held. As the tap is taken towards the collector, the output increase but the stability decreases.

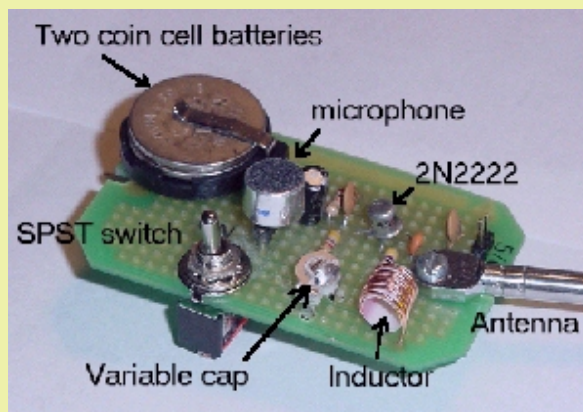


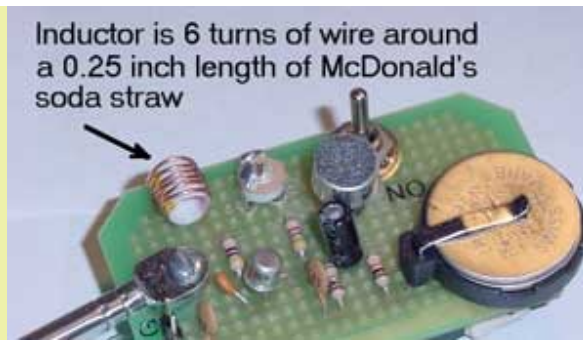
LOW-VALUE EMITTER RESISTOR

The next circuit has been picked out for its low emitter resistor on the oscillator. This resistor does not have to be a very low value as the transistor is working at its maximum potential, due to the high frequency and a low emitter resistor will simply consume more current without improving the output.



The emitter resistor is too low

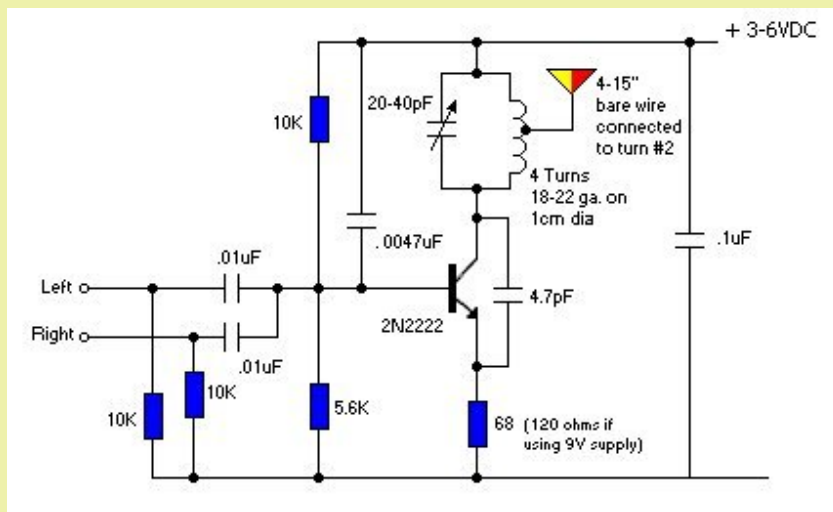




Two photos of the bug

STEREO TO MONO

To combine two channels to a mono output, the following circuit can be used:



INDUCTOR

Some time soon you will come across a circuit with an inductor in the emitter. This can be in a transmitting circuit or receiving circuit.

Let's look at what it does and how it works.

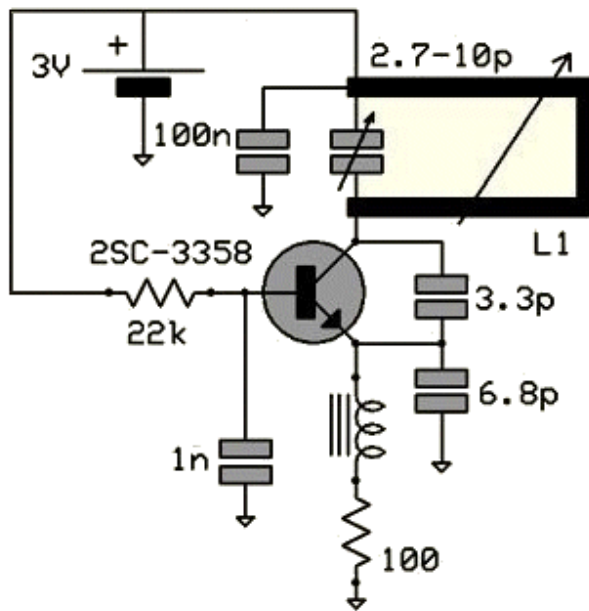
The following circuit is a common-base COLPITTS circuit and oscillates at 303MHz.

The components that set this frequency are: the length of the track on the PC board (shown in thick black) and the value of the capacitor across this track.

The component that makes this a "common-base" circuit is the capacitor on the base.

The 1n has a capacitive reactance of less than ONE OHM at 303MHz!

This means the base will not move up and down during the time when the stage is oscillating.



The circuit turns ON via the 22k resistor and this is because it puts a voltage on the base that is 0.7v higher than the emitter. The current delivered by the 22k can now turn the transistor ON a certain amount - BUT it is not allowed to turn the transistor ON fully. If it did, the other components in the circuit (that turn the transistor ON - by an increased amount) would not be needed and there would be no components in the circuit to turn it OFF.

So, we have the first part of the cycle where the 22k starts to turn the transistor ON.

Before we go any further, we have to mention the second way a transistor can be turned ON. If we hold the base of a transistor rigid and "pull" the emitter lead towards the 0v rail, the "gap" between the base and emitter will increase and although this increase may be only a few millivolts, it will cause the transistor to turn on MORE.

Now, there is one more thing we have to cover.

When the voltage on the collector falls, due to the transistor turning ON, the energy in the 3p3 will be passed to the emitter to reduce the voltage on this lead.

But there is more to this. When the transistor turns ON, the relatively high voltage across the 3p3 will be converted to a much lower voltage to push the emitter lead a few millivolts lower but the current it will deliver will be considerable.

The emitter lead is considered to be a very low impedance lead and it requires a considerable current to move it lower.

Let me explain the capacitor phenomenon again:

You already know about this phenomenon, but have forgotten.

If you take a large electrolytic and charge it on a 12v battery with a resistor in series, the capacitor will take a long time to charge and the current-flow will be quite small.

Now take the electrolytic and short the 2 leads on the shaft of a screwdriver. You will see a bright flash and the screwdriver will be "burnt."

That's because the electrolytic is capable of receiving a low current over a long period of time and releasing a high current for a short period of time.

The 3p3 is doing the same thing.

The low impedance of the "emitter circuit" is due to two things. It is due to the junction inside the transistor and the 100 ohm resistor.

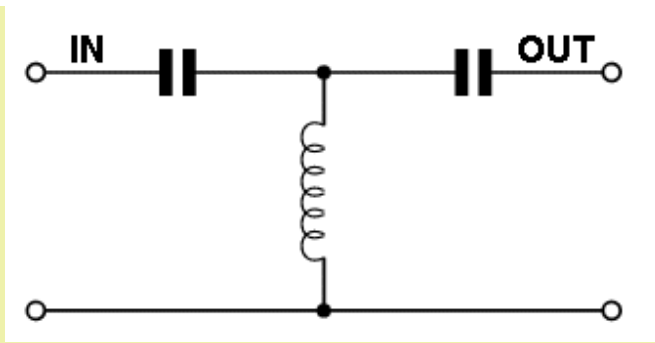
If we were able to remove the 100 ohm resistor, the impedance of the "emitter circuit" would increase - but obviously the circuit would not work.

If the impedance of this part of the circuit is increased, the 3p3 will be able to turn the transistor ON more and thus the overall amplitude of the circuit will increase.

That's exactly what the inductor does. It effectively moves the 100 ohm resistor away from the emitter lead so the 3p3 sees the "emitter circuit" as a higher impedance.

How does it do this?

Firstly you have to understand how an inductor works when placed in this type of circuit.



The circuit above is called an LC HIGH PASS FILTER.

It only allows high frequency signals to pass through the filter.

The signal enters from the left and the left lead of the first capacitor rises and falls and passes this action to the right plate.

The incoming signal is not reduced by the capacitor if the signal has a high frequency.

This means the incoming signal appears on the top of the inductor with very little attenuation.

When the signal rises, a small amount of current enters the inductor and produces magnetic flux. This flux is called EXPANDING FLUX and it cuts all the other turns of the "coil" and produces a voltage in these turns that is of opposite polarity to the incoming voltage. Say the incoming voltage is 10v. The inductor will produce a voltage of 9.999v and this means only 1 millivolt is available to deliver a current into the inductor.

The end result is this: only a very small current will flow into the inductor.

Exactly the same thing will happen when the voltage is falling.

The inductor will have very little "grip" on the voltage and it will allow the voltage to "pass over" the inductor without reducing its amplitude.

The "out" capacitor will pass the amplitude without reducing it and so the incoming waveform will pass through this circuit without being effected.

If the waveform has a low frequency, the first capacitor will attenuate it and the inductor will reduce it and the "out capacitor" will reduce it. The output will be almost zero.

Now, how does the inductor in the 303MHz circuit work?

It allows the signal from 3p3 to enter the emitter lead and have very effect on attenuating the amplitude.

If the inductor were just a short length of wire, it would not have the same effect and a lot of energy from the 3p3 would be passed to the 100 ohm resistor.

I know the two circuits are not identical, but the basics are still the same.

The addition of an inductor DOUBLED the range of another transmitter circuit we were testing in the laboratory and when you realise the extra power needed to do this (about 8 times), its effectiveness is very impressive.

Look at it this way: Pretend the signal from the 3p3 is a waveform going down a large pipe that has sticky honey on the top and bottom of the pipe. As the waveform hits the top and bottom, it get stuck to the honey and eventually its amplitude is reduced.

Now replace the honey with a bright shiny pipe. As the wave reaches the top and bottom of the pipe it bounces off with very little loss and the amplitude is hardly affected. It will get to the end with very little attenuation.

Unless you can see the operation of a circuit as things that "move" you will not be able to diagnose or improve these circuits.

It's because most lecturers don't understand these circuits, that they cannot impart a visualization that the students will remember.

One very clever lecturer said to the class: DO YOU KNOW? DO YOU KNOW THAT YOU KNOW?

In other words, half-understanding is: NO UNDERSTANDING.

2 TRANSISTOR CIRCUITS

The next progressive step is to add a transistor to give the electret microphone more sensitivity. The electret microphone contains a Field Effect Transistor and you can consider it to be a stage of amplification. That's why the electret microphone has a very good output.

A further stage of amplification will give the bug extremely good sensitivity and you will be able to pick up the sound of a pin dropping on a wooden floor.

Many of the 1 transistor circuits over-drive the microphone and this will create a noise like bacon-and-eggs frying. The microphone's used by Talking Electronics require a load resistor of 47k for a 6v supply and 22k for a 3v supply. The voltage across the microphone is about 300mV to 600mV. It will produce an audio waveform of about 2-20mV.

Only a very simple self-biasing common-emitter stage is needed for the audio amplifier. This will give a gain of approx 70 for a 3v supply. The next circuit shows this audio amplifier, added to the previous transmitter circuit. This circuit is the best design using 2 transistors on a 3v supply. The circuit takes about 7mA and produces a range of about 200 - 400metres.



1. The tank circuit has a fixed 39p and is adjusted by a 2-10p trimmer. The coil is stretched to get the desired position on the band and the trimmer fine tunes the location.
2. The microphone coupling is a 22n ceramic. This value is sufficient as its capacitive reactance at 3-4kHz is about 4k and the input to the audio stage is fairly high, as noted by the 1M on the base.
3. The 1u between the audio stage and oscillator is needed as the base has a lower impedance as noted by the 47k base-bias resistor.
4. The 22n across the power rails is needed to keep the rails "tight." Its impedance at 100MHz is much less than one ohm and it improves the performance of the oscillator enormously.
5. The coil in the tank circuit is 5 turns of enameled wire with air core. This is much better than a coil made on a PC board and is cheaper than a bought inductor. The secret to long range is high activity in the oscillator stage. The tank circuit (made up of the coil and capacitors across it) will produce a voltage higher than the supply voltage due to the effect known as "collapsing magnetic field" and this occurs when the coil collapses and passes its reverse voltage to the capacitor. The antenna is also connected to this point and it receives this high waveform and passes the energy to the atmosphere as electromagnetic radiation.

When the circuit is tightly constructed on a PC board, the frequency will not drift very much if the antenna is touched. This is due to the circuit design and layout as well as the use of large-value capacitors in the oscillator. If low value capacitors are used, the effect of your body has a greater effect on changing the frequency.

THE VOYAGER

The only way to get a higher output from two transistors is to increase the supply voltage. The following circuit is available from Talking Electronics as a surface-mount kit, with some components through-hole. The project is called [THE VOYAGER](#).





Voyager on a 9v Battery

All the elements of good design have been achieved in this project. The circuit has a higher output than the 3v circuit above, but most of the voltage is lost across the emitter resistor and not converted to RF. The main advantage of this design is being able to connect to a 9v battery. In a technical sense, about half the energy is wasted as the stages actually require about 4v - 5v for maximum output.

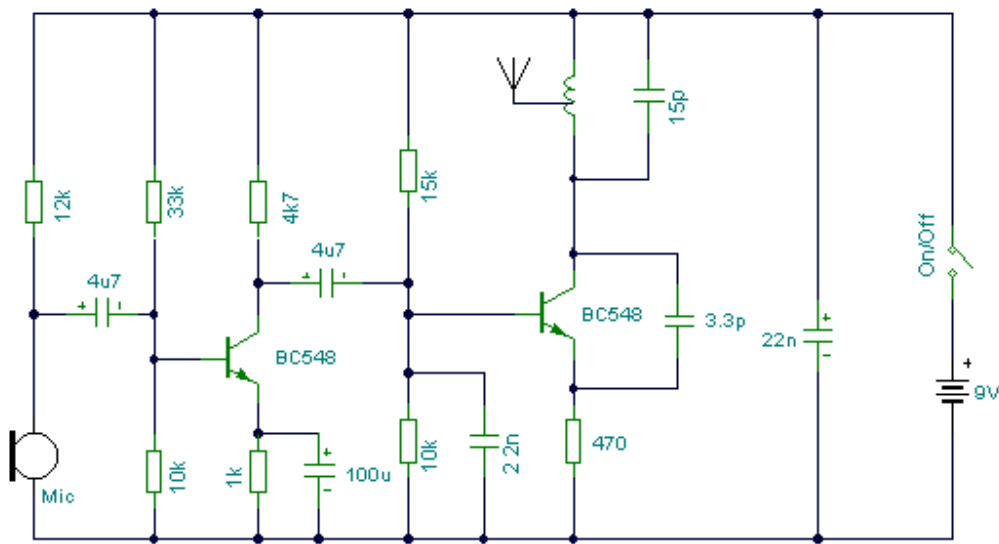
The Voyager has been copied by many kit-makers but none has surpassed its performance. Here is a "knock-off" of our older design. It is mounted flat on a 9v battery:



Here are 2 more two-transistor circuits using a 9v supply. We have also included the technical limitations of the circuits:

DAVID'S DESIGN:

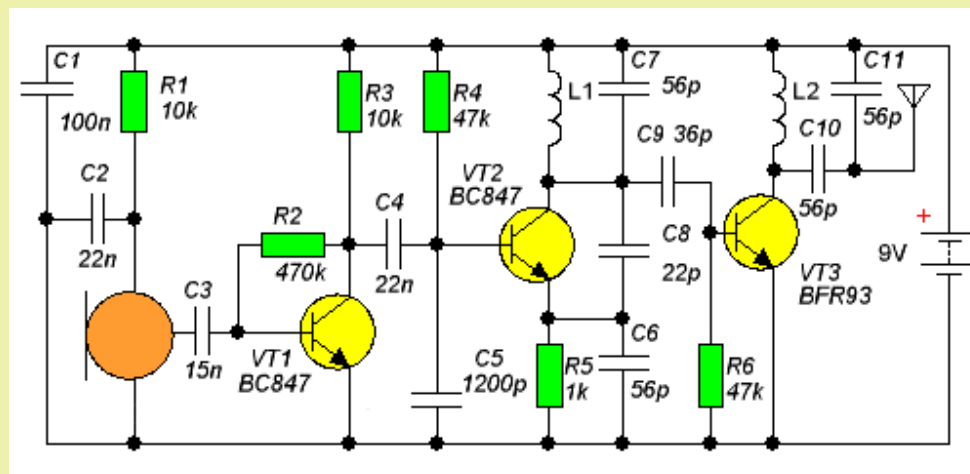




Faults with this circuit:

1. Very low microphone load resistor.
2. 4u7 not needed from microphone. 22n is sufficient.
3. 3p3 is very low for BC 547. May need to be higher. - 10p preferred.
4. Bridge biasing of audio stage is not needed. Simple biasing is adequate.
5. Base biasing of oscillator is very wasteful in current.
6. 22n is very high for base bias of oscillator - restricts incoming audio.

EMITTER CAPACITOR

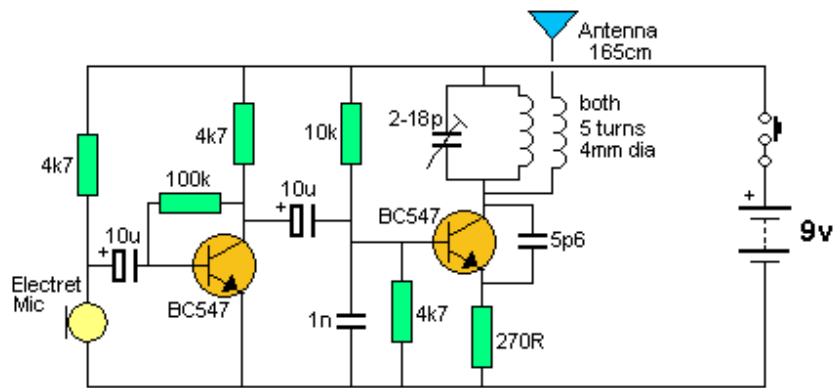


The circuit above has a 56p on the emitter. This capacitor has no effect on improving the operation of the circuit and merely requires the capacitor connected between the collector and emitter to be increased to counter the losses delivered to the 56p.

The two 56p on the output do not improve the performance as they are equivalent to 28p across L2 and this forms a tuned circuit. The aim of the output stage is to be untuned so that any frequency can be selected for the oscillator. If the output is "tuned" it will only have gain at one particular frequency and will have to be re-tuned every time the main frequency is altered.

A BIRD'S NEST DESIGN





Faults with this circuit:

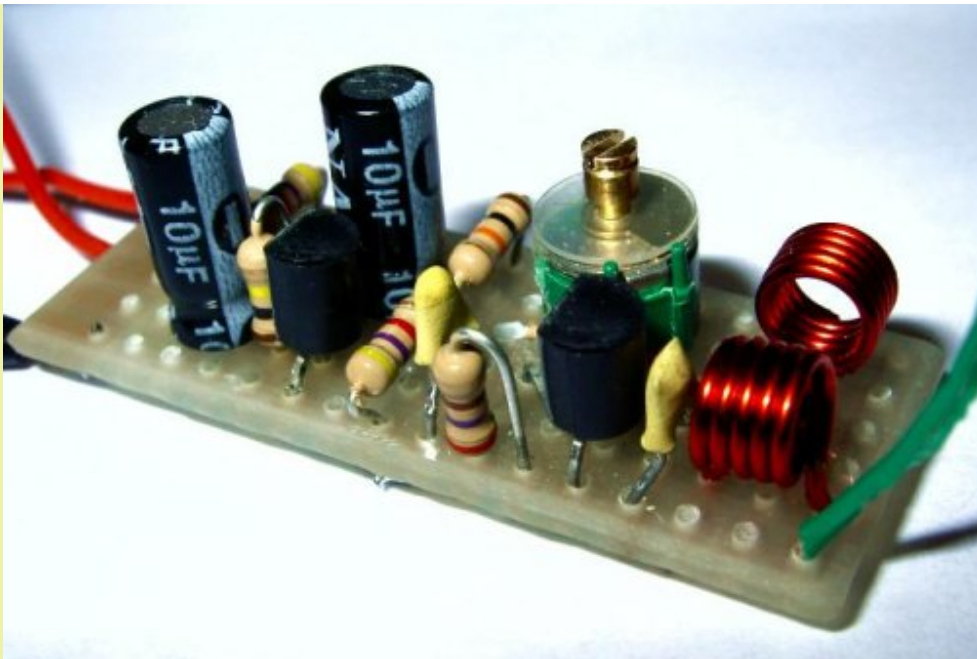
1. Load resistor for microphone is very low - should be 47k
2. 10u on output of microphone is not needed - 22n is sufficient.
3. Current through audio state is very high. Load resistor should be 47k
4. Base biasing of oscillator very wasteful.
5. Load resistor for oscillator (emitter resistor) is very low
6. Feedback capacitor for oscillator should be 10p.
7. No ceramic in tank circuit. Adding a ceramic makes it easier to adjust the trimmer capacitor.
8. No capacitor across the battery.

See the layout below:



Birds-nest of above circuit showing how tight the circuit can be made.

There is nothing wrong with a bird's nest. It is very easy to experiment with components and wiring that can be seen and changed without having to work on a PC board. The only problem with the bird's nest above is the lack of an earth plane. When you have an earth plane, the signal can push against the large mass of an earth rail (or battery) so that it can push the signal out the antenna.



The circuit on proto-typing board - a quick way to build a project.
The oscillator components must be kept near each other,
otherwise the circuit will not oscillate!

Making a long range spy bug FM transmitter



Some of the videos show how to build the Voyager MkII FM transmitter and other transmitters in our series of Spy Circuits.

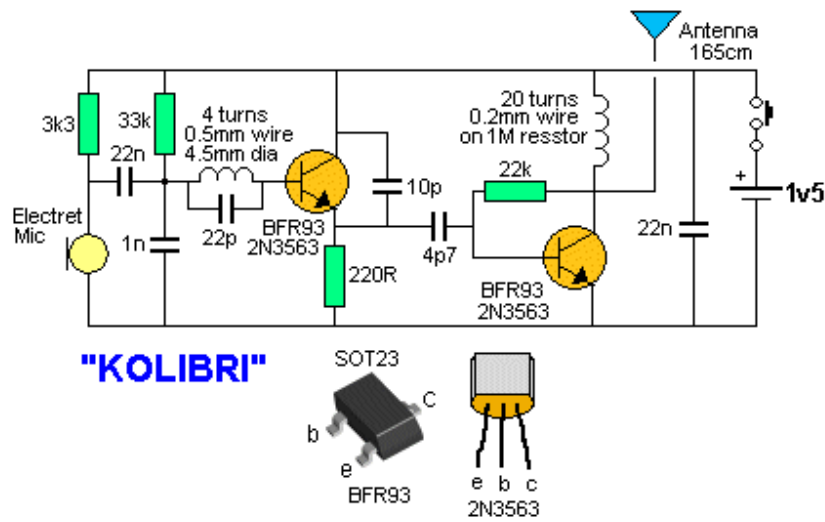
One supplier of kits has **STOLEN** our design and marketed it as his own, claiming to have sold over 6,000 units. At least the design has proven to be a "best-seller."

You will find some of the circuits are very poorly laid out and others just barely work at all. Most are a good example of how **NOT TO DESIGN** an FM circuit and you will be able to learn a lot from these faulty designs. The secret to a good design is compactness. A "tight circuit" is a much-better performer.

The circuits we have discussed so far demonstrate the maximum output that can be achieved from a 3v to 9v supply and the maximum sensitivity from the microphone.

The next stage in the development of a better circuit involves a **BUFFER STAGE** so the oscillator is not driving the antenna. This will give the circuit more stability and more output.

The following circuit comes from Russia. It has an unusual oscillator section with a conventional **BUFFER STAGE**.

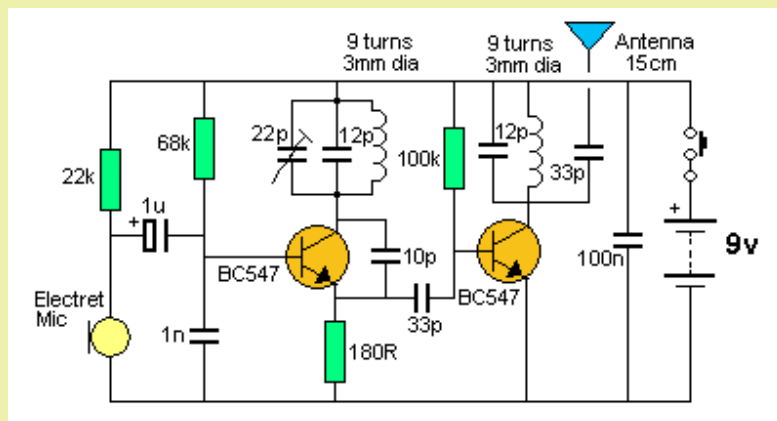


The designer of "Kolibri" circuit claims the output is similar to 3v designs and works down to 0.8v. It's an interesting circuit to put together and test, to see how it performs.

The next circuit uses a BUFFER output to provide stability so the circuit can be handled:

HAND-HELD MICROPHONE

The following circuit is suitable for a hand-held microphone. It does not have an audio-amplifier stage but that makes it ideal as a microphone, to prevent feedback. The output has a buffer stage to keep the oscillator away from the antenna. This gives the project the greatest amount of stability.



To get good **audio amplification**, and a stable **oscillator** and the ability to **handle the circuit** without it drifting, we need 3 transistors. These circuits are on the following page.

THE TANK CIRCUIT AND "Q"

Before we go to 3-Transistor circuits, there is one factor that needs mentioning. It is the most important part of the circuit. The **TANK CIRCUIT**.

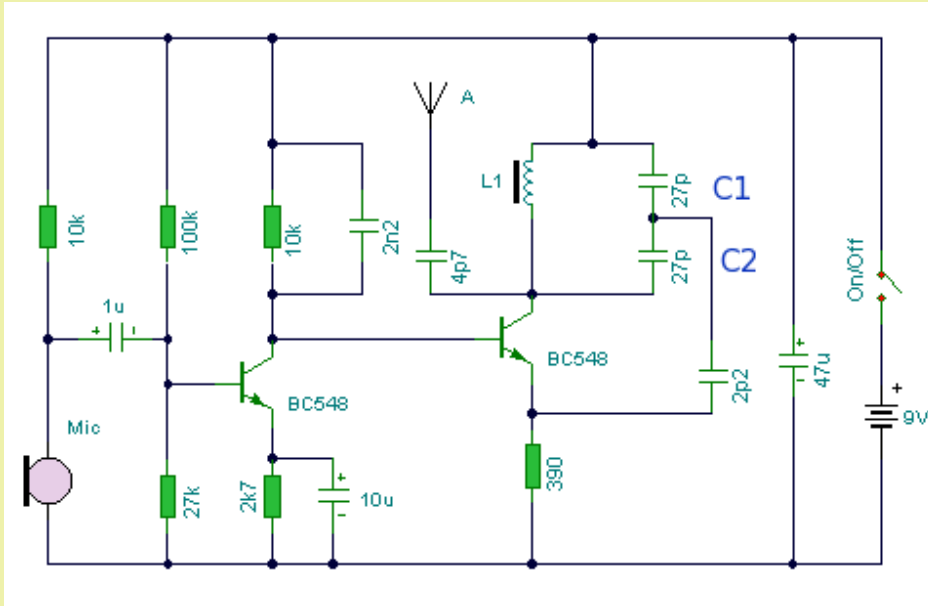
This is the coil and capacitor in the collector of the oscillator transistor.

Even though these two components are classified as "passive" - and do not amplify, when they are connected in parallel, they form a circuit known as a **TANK CIRCUIT** and actually produce a waveform that is larger than the supplied voltage. These two components set the frequency of the circuit and when they are operating correctly, the output will be a maximum. A lot of experimentation has gone into the size of the inductor and by making it 3-4 times longer than the diameter, using the thickest wire possible and spreading the turns, the inductance will provide the maximum amount of energy to pass to the capacitor. Not only does

the value of inductance and capacitance have to be correct to achieve the desired frequency, but the energy from the inductor must match the energy from the capacitor, to get the maximum output.

All this is done to achieve a high output and when a tank circuit is lightly loaded it will oscillate at one and only one frequency. When this happens and when we measure the output and compare it to the supply voltage we get a value called the "Quality Value" or "Q" value. This value is not known for these circuits but the result of a good tank circuit can be seen by testing the circuit with a Field Strength Meter or simply detecting the output of the bug at a distance.

ANOTHER POOR DESIGN



The image has 2 coils but the circuit has only one, so I don't know where the other coil is located on the circuit.

But the general poor design is in the component values. Some are widely different from the expected value and there is no 22n across the battery. The 47u had no effect at 100MHz and

the 22n is needed.

But it's best to build the circuit and compare its performance with the suggested circuits above and make our own assessment.

Page 2 continues with 3-TRANSISTOR CIRCUITS:

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3/1/2017