In this discussion we cover 27MHz transmitters and receivers as found in remote control cars, aeroplanes, walkie talkies and some of the older-style garage door openers.
We have provided a number of circuits so you can work out the best type for your application and these circuits will also help you understand which components are critical and which components can be changed.
It's a matter of looking at each circuit and seeing the general layout, and comparing it to the other circuits. In this way you are building up a concept of "building blocks" and this is the basis to learning electronics.
Talking Electronics does not provide any kits for these circuits as the products (toy cars, wireless doorbells etc) are readily available in toy shops, hobby shops and many of the $2.00 "junk Shops." You cannot buy many of the special components and the cost of the completed item is less than buying the components!

Let's start:

6 bands (or frequencies) were allocated for the 27MHz band,

Channel	Frequency
1	26.995
2	27.045
3	27.095
4	27.145
5	27.195
6	27.255

and these were very popular for transmission - especially in countries where transmitting was strictly controlled.
Both 27MHz and 49MHz circuitry produced very low cost devices and they are still available. But you must be careful as some of the latest types are much more sophisticated (and sometimes cost less than the older types).
We will investigate how they work and how they can be modified.
Very little is available on how these circuits work and this article will cover the "building blocks."
When we use the term "building block" we mean a group of components making up a circuit that carries out a particular function and can be connected to another circuit to achieve a final result. In this way you can create your own project without having to design each of the sections. A typical example is the 5-channel remote control circuit we have modified to produce an on-off action from two of the outputs. You can build these circuits from scratch, but **why re-invent the wheel?** If you want a 27MHz or 49MHzlink, the best idea is to buy a toy and modify it.
If you want voice communication, get a walkie talkie. If you want a single on-off operation, get a remote control car.
Some remote control cars have up to 5 channels and sell for less than $20.00. You can get everything you need on 2 printed circuit boards, ready for modification, without having to source the components. Look for 4 function models that require 3v operation for both remote and receiver. The fifth function is "turbo" and is not used in some of the designs. The photo below is the 4(5) function 27MHz remote control car we discussed above:

**5 channel remote control car as discussed
in the text. It uses only 4 of the 5 channels**.

The first two circuits (figs 1& 2) form a single-channel transmitter-receiver link. The second receiver (fig 7) uses a split supply to power a motor in the forward and reverse direction (it uses the same transmitter as shown in fig 1). The third transmitter & receiver, (figs 12 & 22) is a multi-channel design, with a chip in the receiver. Then we cover a 27MHz walkie talkie. This is a 4 transistor model. It uses the same type of super-regenerative front-end as our receiver circuits and injects Amplitude Modulated (AM) audio onto the signal. The result is a very noisy transmission but a very effective way to achieve both transmission and reception with the minimum of components. Most of the parts have a dual function, operating in both transmit and receive mode. This makes the circuit very efficient, component-wise.

Before we start, some of the Japanese transistors have either a very high frequency capability or a very high collector current. These transistors need to have an equivalent for the circuit to work successfully. Here is a list of some of the type you will come across and some equivalents:

Type:		Gain:	Vbe	Vce	Current	Case
2SC3279	NPN	140 to 600 @0.5A	0.75v	10v	2amp	
BC337 BC338	NPN	60 @300mA	0.7v	45v 25v	800mA	
BC547 BC548 BC549	NPN	70 @100mA	0.7v	45v 30v 30v	100mA	
BC557	PNP				100mA	
8050	NPN			10v	1.5A	
8550	PNP			10v	1.5A	
9012	PNP				500mA	
9013	NPN				500mA	
9014	NPN				100mA	
9015	PNP				100mA	
9018	NPN	700MHz			100mA	

THE 27MHz TRANSMITTER

Fig 1 shows a simple 27MHz transmitter producing a carrier.

Fig 1. The 27MHz Transmitter
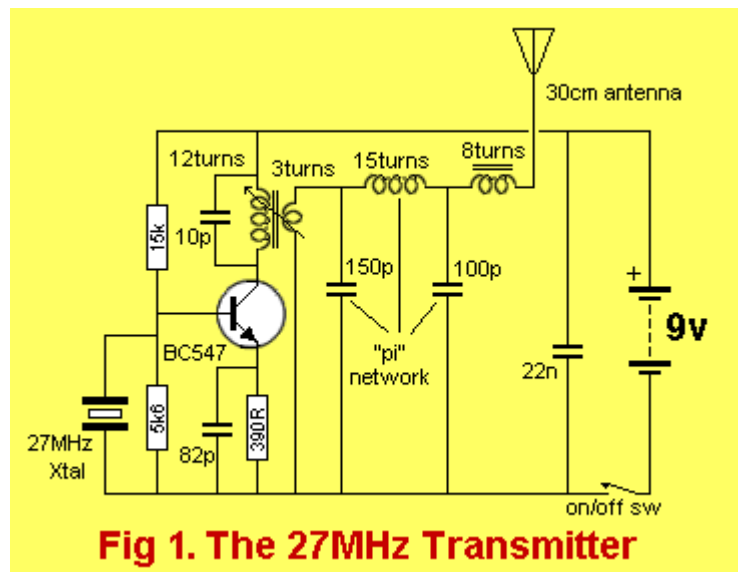
The 27MHz transmitter PC board

This means it produces an unmodulated 27MHz signal and when picked up by a receiver, such as shown in fig 2, the result is a clean, noise-free reception. To increase the output of the transmitter, the 390R resistor is replaced by a 220R. This increases the current from 7mA to 12mA. The resistor could

be decreased to 150R for more output. of this article covers test equipment that can be used to detect the output and the frequency of transmission.
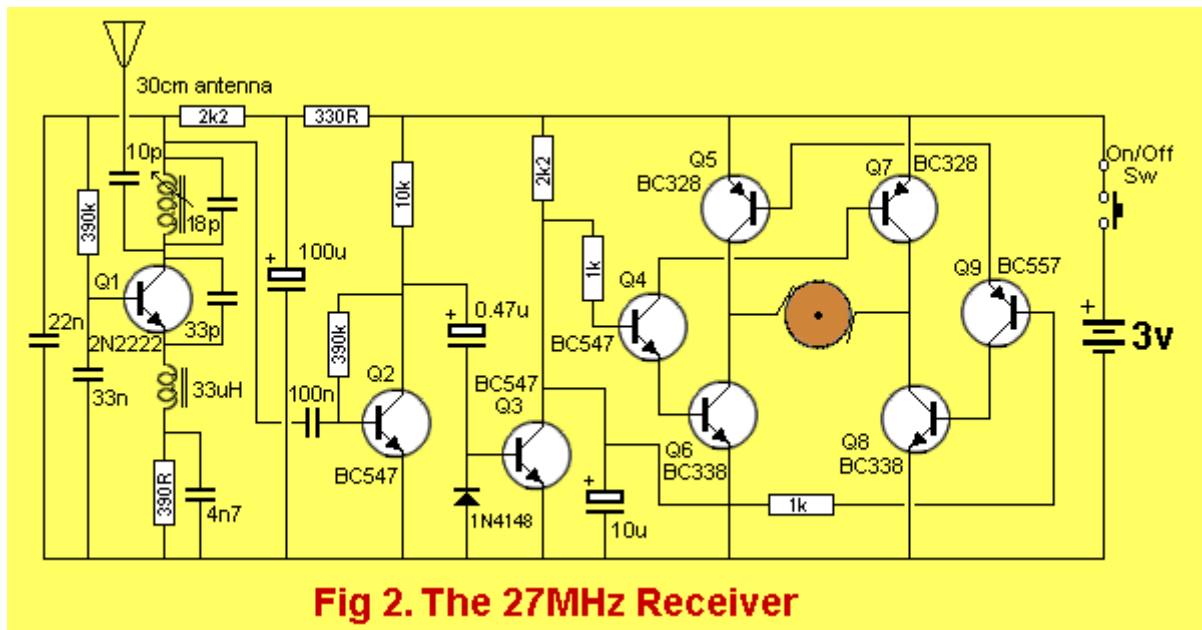

Fig 2. The 27MHz Receiver

When the transmitter is off, the car moves forward. When the transmitter is on, the car reverses and moves in a circular pattern. This allows the operator to guide the car around obstacles. It's a very awkward way to control a car and although it is very simple and clever, it is not really successful in practice. We will not be going into the mechanics of how the car steers, only the fact that the transmitter causes the motor to reverse direction. In place of the motor you could use a relay or two separate motors to carry out a number of functions and we will show how the circuit can be modified to do this.

The receiver works on a "tone," "no-tone" principle but the transmitter doesn't actually send a tone as this would require additional circuitry. What happens is the receiver picks up random noise from the airwaves when the transmitter is not operating and this functions as the tone part of the reception. This random noise is amplified by the second transistor and passed to a 0.47u electrolytic that keeps the third transistor in conduction for the majority of the time. The operation of this will be discussed later. The 10u on the output of the third transistor keeps the output low for the short periods when the third transistor is not low. The motor is connected in a bridge formation via four transistors and these change the polarity of the supply to the motor.

When the transmitter is operating, and the receiver is within range, it picks up a 27MHz carrier that over-rides the random noise and produces a CARRIER. This means the second transistor will not see any noise and thus the 0.47u electrolytic will charge and turn off the third transistor. The 10u will charge via the 2k2 and the input to the bridge will change from a LOW to a HIGH. This will turn on the opposite half of the bridge to supply current to the motor in the reverse direction.

Now we will cover the circuit in detail.

HOW THE TRANSMITTER WORKS

The transmitter is a very simple crystal oscillator. The heart of the circuit is the tuned circuit consisting of the primary of the transformer and a 10p capacitor. These two components oscillate when a voltage is applied to them. The frequency is adjusted by a ferrite slug in the centre of the coil until it is exactly the same as the crystal. The crystal will then maintain the frequency over a wide range of temperature and supply voltage fluctuations. The transistor is configured as a common emitter amplifier. It has a resistor on the emitter for biasing purposes but the 82p across the 390R effectively takes the emitter to the negative rail as far as the signal is concerned. The 390R resistor prevents a high current passing through the transistor as the resistance of the transformer is very low. The tuned circuit operates at exactly the third harmonic (also called the third overtone - an overtone is a multiple of a fundamental frequency) of the crystal so that the crystal will oscillate at its third overtone (27MHz) and in-turn, keep the frequency of the circuit stable. The transformer in the collector of the transistor performs two functions. 1. It matches the impedance of the transistor to the impedance of the antenna, and 2.

Creates a resonant circuit at 27MHz to make sure the crystal oscillates at this frequency. You can see the transformer creates a resonant circuit by the fact that it has a capacitor across the primary winding. These two components create a "resonant" or "tuned " circuit and this is where the circuit "gets its frequency."

The crystal has a fundamental of about 9MHz and it will oscillate at this frequency unless assisted to oscillate at a higher frequency. This is done by the tuned circuit oscillating at 27MHz.

Now we will look at the impedance-matching feature of the transformer.

The impedance of the output of the transistor is about 1k to 5k and this means it is the impedance (resistance) "it works at." In other words, it is the characteristic impedance of the transistor in this type of stage. The impedance of a whip antenna is about 50 ohms and the transformer matches these two by having a TURNS RATIO.

The primary has about 12 turns and the secondary about 3 turns. This provides part of the matching requirement. The `pi' network, made up of the 150p, 15 turn air-cored coil and 100p capacitor assists further in matching the output of the transformer to the antenna. When the power is applied, the transistor turns on fairly hard due to the 82p in the emitter being uncharged.

This puts a pulse of energy through the 10p and as the transistor turns off slightly due to the 82p charging, the energy in the 10p capacitor is passed to the primary of the transformer to start the 27MHz cycle. The action of the emitter rising and falling during start-up, allows the base to rise and fall and this puts a pulse on the crystal to start it oscillating.

The frequency of oscillation OF THE CIRCUIT is generated by the tuned circuit in the primary of the transformer and the crystal merely keeps the circuit operating at exactly 27.145MHz (or 27.240MHz, depending on the frequency of the crystal). The turns ratio of the transformer converts a high voltage waveform (that has little current) from the transistor, into a low voltage waveform with a higher current. This is exactly what the antenna requires. But before the signal passes into the antenna it goes through the pi network, then an 8 turn Radio Frequency Choke. This is 8 turns of enamelled wire wound on a ferrite core and is called a base-load for the antenna.

The result is a 27MHz frequency called a CARRIER. The carrier produces a clean spot on the band that is free from background noise.

HOW THE RECEIVER WORKS

The first thing you have to realize is the receiver is really a transmitter. It's a very weak transmitter and delivers a low level signal to the surroundings via the antenna. When another signal (from the transmitter) comes in contact with the transmission from the receiver it creates an interference pattern that reflects down the antenna and into the first stage of the receiver.

The receiver is a super-regenerative design. This means it is self-oscillating (or already oscillating) and makes it very sensitive to nearby signals. It is much more sensitive than receiving a signal and making it oscillate a transistor.

A super-regenerative design is not universally used because it is much more noisy than conventional reception and is not suitable for voice transmission. However it is used in simple walkie-talkies and this is why they are so noisy - as will be shown at the end of this article. When a signal of the same frequency as the super-regenerative circuit passes near the antenna, the circuit has difficulty radiating a signal.

This means the circuit current VARIES. These variations appear across the 2k2 load resistor as a change in voltage and the signal is picked off via a 100n capacitor and passed to the second and third stages for amplification.

The 22n across the first stage is designed to remove the high-frequency component from the waveform. If this were not present, the circuit would never change state. The receiver is tuned to the frequency of the crystal in the transmitter via a slug-tuned coil in the collector.

When the transmitter is off, the receiver picks up background noise and amplifies it to produce random-noise. This is amplified by the second transistor and passed to the third via a 0.47u electrolytic. This electrolytic is designed to keep the third transistor ON for the major part of the time and it does this in a very clever way. We will assume the supply has just been turned on and the second transistor is not receiving a signal. The 0.47u will be uncharged and it will charge via the 10k collector resistor and the base-emitter junction of the third transistor.

The action of the current flowing through the base of the third transistor will turn it ON but after a short time the electrolytic will be fully charged and the current will cease and the transistor will turn off. A 10u on the collector of the third transistor will then begin to charge via the 2k2 resistor and after a period of time called the DELAY TIME, the output will be HIGH and change the state of the bridge. But if a signal is present on the collector of the second transistor, (in our case this will be background hash), the voltage on the collector will be rising and falling. When the voltage goes low, it takes the

positive end of the 0.47u low and the other end must follow.

The voltage on the negative end will go below the negative rail and at -0.7v it gets clamped by the diode. This means the electrolytic gets discharged very rapidly when the second transistor turns on.

The result is the electrolytic takes a long time to charge and a short time to discharge, even when random noise (hash) is being processed.

The action of the 0.47u is amazing and will be explained in more detail in a moment. During the short periods of time when the third transistor is not turned on, the 10u on the collector will take over and hold the signal low. It's only when a long duration of silence is encountered, that the circuit will change state. This period of silence is when the transmitter turns ON and the time is very short in real terms.

Transistor Q3 is called the switching transistor. It changes between HIGH and LOW to create the forward and reverse direction. The switching transistor feeds two driver transistors, Q4 and Q9. Each of these drives two output transistors. Q4 drives Q6 and Q7. Q9 drives Q5 and Q8.

Follow these transistors on the circuit and you will see how the supply is directed to the motor, firstly in one direction and then the other.

The printed circuit board is quite complex because of the number of driver transistors. But since these cost less than 2 cents when bought in the million, it is not cheaper to use a chip.

HOW THE 0.47u WORKS

The 0.47u electrolytic on the base of the third transistor needs explaining as its operation is very clever.
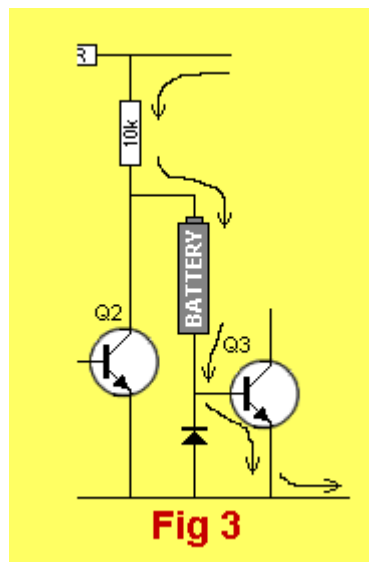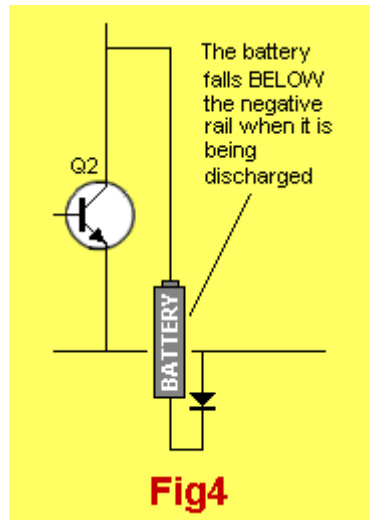

**Charging the 0.47u electrolytic
is represented as a battery.**

The electrolytic is simply a tiny re-chargeable battery and when the circuit first turns on, it is uncharged. The charging current passes through the base-emitter junction of the third transistor and keeps it ON as shown in fig: 3. If the electrolytic is allowed to fully charge, the current will fall to zero and the third transistor will turn off. But the second transistor discharges the electrolytic quickly before it has time to fully charge. It does this by turning ON. How the electrolytic discharges is shown in fig: 4. The only components involved in the discharge are Q2 and the diode. Transistor Q2 is turned on and it will have zero volts (0.3v) on the collector.

Discharging the 0.47u electrolytic.

This means the positive lead of the electrolytic (equivalent to the positive terminal of the battery) will drop from say nearly 3v, to 0.3v. The negative lead must follow and normally it would be at -2.7v. Yes, the negative lead would have a negative voltage on it relative to the 0v rail, if the diode was not present. BUT the diode on the negative lead gets turned on as soon as the voltage on the negative lead falls to -0.7v and prevents it going below -0.7v. As the positive lead falls, the energy in the electrolytic is quickly discharged through the diode and when the second transistor turns OFF, the electrolytic is ready for charging, through the 10k resistor.

LOW RAIL VOLTAGE

One of the problems of a low rail voltage is the voltage lost across each of the output transistors. Each drops about 0.5v across the collector-emitter junction and this leaves only about 2v for the motor. However the supply voltage must not be increased above 3v as there is a very short period of time when the circuit is changing from LOW to HIGH and both halves of the bridge are ON. This is at the mid-point of the change-over and if you work out the various voltage drops across the base-emitter junctions, it leaves about 0.2v for the two 1k resistors. With a 3v supply, the base current is limited to 0.1mA by the inclusion of the two 1k resistors and 10mA for the collector-emitter current. But if the voltage is increased above 3v, the current will increase dramatically and the transistors will be damaged.

CONNECTING A RELAY

Fig: 5 shows how a relay can be connected to the driver transistor to operate when the transmitter is switched on. The change-over contacts on the relay can be used to power any device when the transmitter is off or when it is on.
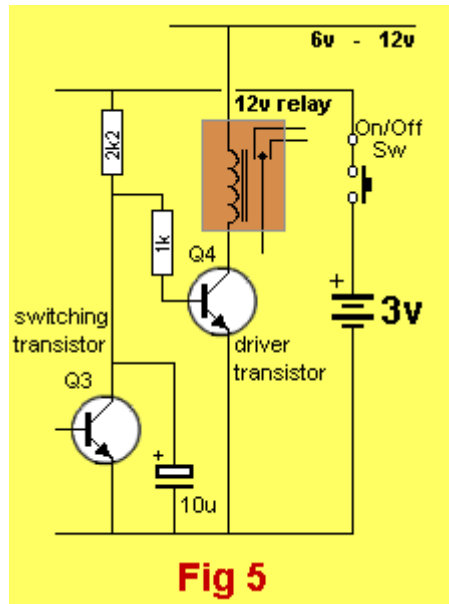
Fig 5

Connecting a relay to the driver transistor. The supply for the relay can be 6v - 12v.

CONNECTING TWO MOTORS

Fig: 6. shows how to connect two separate motors to the circuit. The motors can be connected to any voltage from 3v to 12v and the direction of rotation will depend on which way around they are connected, but transistors Q4and Q7 should be kept at 3v - especially Q9, as it cannot be taken to a voltage higher than 3v, due to the way it is connected in the circuit.
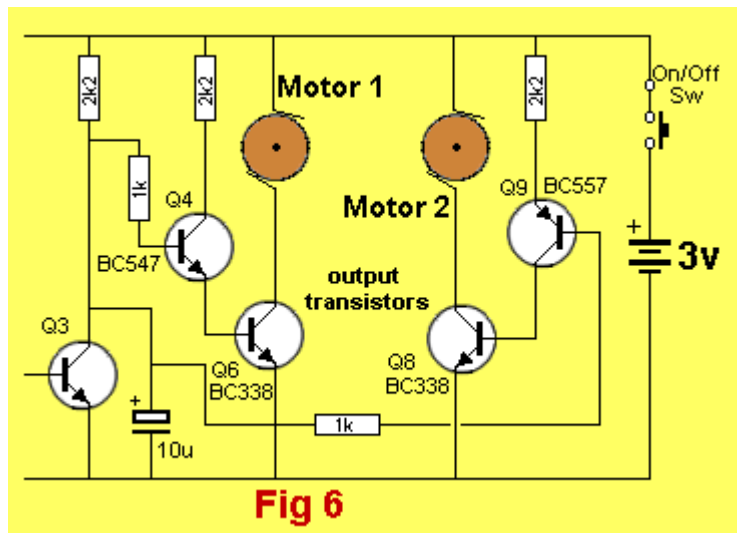

Fig 6

Connecting two motors to the outputs.

A SPLIT-SUPPLY RECEIVER

The second receiver circuit we will study uses more components to do exactly the same job but it may have better sensitivity due to the inclusion of one extra stage of amplification and the use of a higher rail voltage. The higher rail voltage gives some stages a higher gain due to the higher amplitude of the signal. But some of the gain has been lost in the diode pump as this type of pump requires more energy to charge the 10u than a 0.47u. The use of a center-tapped voltage source saves two transistors in the bridge network but necessitates the use of a double-pole switch to disconnect both halves of the supply.
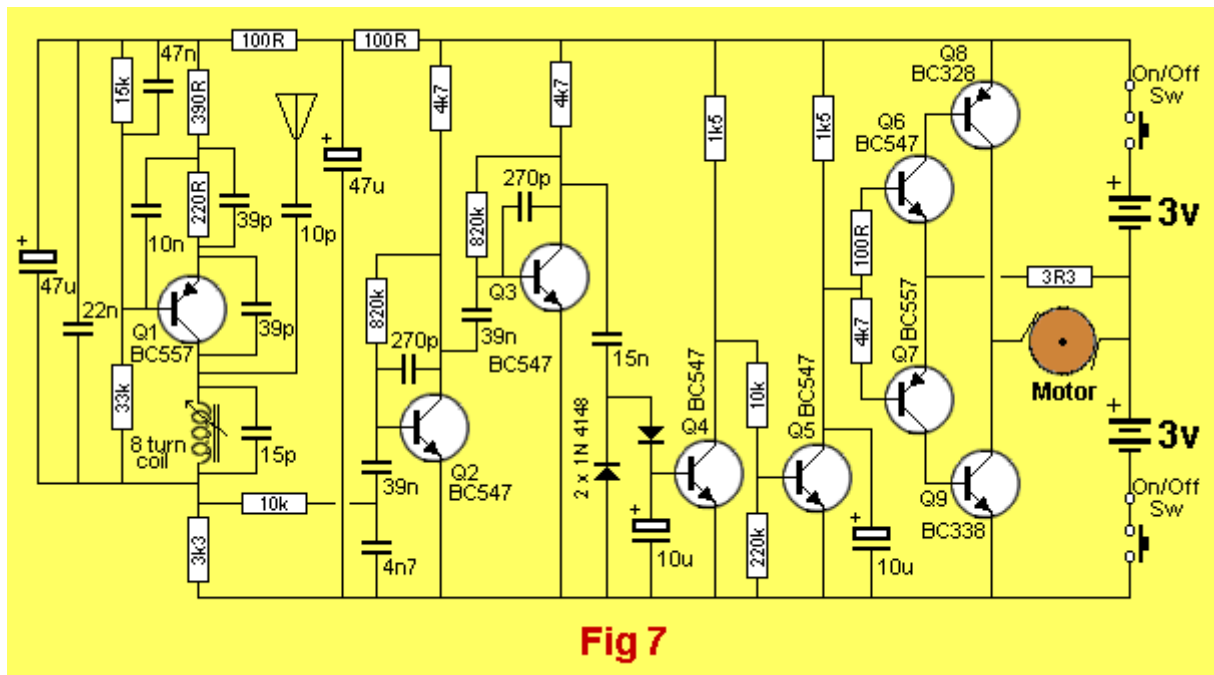
A 27MHz receiver using a split supply

The 27MHz receiver PC board

HOW THE SPLIT-SUPPLY RECEIVER WORKS

The operation of the front end of the split-supply receiver in fig: 7 is identical to the receiver shown in fig: 2. The use of a PNP transistor for Q1has simply turned the circuit up-side-down however the antenna is still connected to the collector and the parallel tuned circuit is also on the collector.
The circuit is turned on by the 33k on the base and the 47n keeps it rigid and turns the stage into a common base configuration. The parallel resonant circuit made up of the 8-turn inductor and 15p,

starts the circuit oscillating and the 39p between collector and emitter provides feedback for the transistor to supply pulses of energy to the tuned circuit to keep it oscillating.

The 220R and 39p are the emitter biasing components, as well as the 390R, 10n and 47n. The 100R and 47u are stage-separating components to remove low-frequency noise from the power rails and the 22n across the first stage tightens up the power rails as far as the high frequency is concerned and allows the low-frequency component to appear across the 3k3. The signal across this resistor is picked off via the 10k/39n combination and passed to two stages of amplification.

The 10k and 4n7 form a filter to remove high frequency pulses. A high frequency pulse will try to charge the 4n7 and most of the amplitude of the pulse will be lost (attenuated) in the 10k resistor. Exactly how this works is as follows: The high-frequency pulse will rise and fall before the 4n7 has time to charge. But a low-frequency will charge the 4n7 and enter the 39n for amplification by the rest of the circuit. Going back to the first stage, we have already mentioned that it is oscillating at 27MHz and the MOST ACTIVE lead of the circuit is the collector and this is where the antenna is connected. The waveform produced by the circuit is passed to the antenna and radiated to the surroundings.

Any other signals of the same frequency will interfere with the circuit's ability to radiate energy and this is reflected down the antenna to the first stage. The result is it takes slightly more and less current according to the intelligence on the signal. The word intelligence means the information that has been added to the carrier.

For a transmitted signal this means voice or music etc. When no transmitted signal is present this is background hash or "noise." The changes in current will see a waveform develop across the 3k3 feed resistor. The 10k will detect this and pass it to Q2 for amplification. Q2 and Q3 amplify the low frequency (audio) or "hash" component.

Any high frequency signals will be removed by the 270p capacitors. They act as negative feedback devices and operates as follows: A rising signal on the base of the transistor turns it ON and the collector voltage falls. The fall in voltage is passed through the 270p (because it does not have time to charge) to the base where it counteracts the original signal.

The capacitor ONLY has an effect on high frequency signals and the low frequency signals are amplified without attenuation. A low-frequency signal will charge the 270p and get lost in the 270p. After two stages of amplification, the signal appears at a diode pump made up of a 15n capacitor, two diodes and a 10u electrolytic.

The charging of the 10u takes quite a number of cycles as the 15n is like a teaspoon filling a glass with water. When Q3 turns off, the 15n is charged via the 4k7, D2 and the 10u. The 15n doesn't take very long to charge and the current flowing through it puts a tiny amount of charge into the 10u. Transistor Q3 turns on and discharges the 15n through diode D1 in exactly the same manner as explained previously. When Q3 turns off, the 15n is ready to charge up again. This keeps happening for hundreds of cycles, each time the voltage on the 10u gets slightly higher.

At a voltage of 0.65v, the base of Q4 begins to turn on. Below this value the base does not see anything, and does not have any loading effect on the electrolytic. But at exactly 0.65v a tiny amount of current begins to flow into the transistor to turn it on. The electrolytic keeps charging and as the voltage rises to 0.66v, 0.67v, 0.68v, 0.69v, the transistor turns on more and more. At 0.7v, the transistor is fully turned on and any voltage over this simply spills into the base and is passed to the negative rail via the base-emitter junction. This means the voltage on the 10u does not rise above 0.7v.

To keep the transistor turned on requires a small amount of current into the base and the electrolytic supplies this current. In doing so, the energy in the electrolytic gets used up and the voltage across it reduces.

As the voltage falls, the transistor gets turned off. When the voltage drops below 0.65v, the transistor is fully turned off and does not see any voltage below this. This means the operating voltage for the electrolytic is between 0.7v and 0.65v. Q4 feeds Q5 and when Q4 is turned on, the voltage on the base of Q5 is below 0.65v and it is turned off. The 10u on the collector of Q5 charges via the 1k5 and when it is above 3.7v, driver transistor Q6 turns on and output transistor Q8 operates the motor. There are two outputs. One drives the motor in the forward direction and the other drives it in reverse.

THE TRANSISTORS IN THE FORWARD DIRECTION

There are two transistors for the motor in the clockwise (forward) direction, as shown in fig: 8.
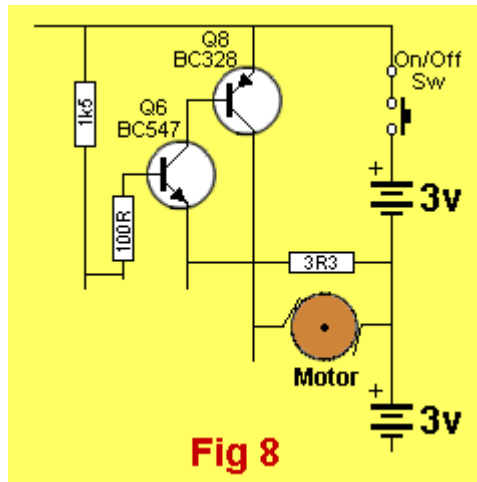
Fig 8

You will notice the turn-on resistor(s) on the base of the driver transistor is lower than for the reverse direction and this will allow a greater current to be delivered to the motor to give it full speed in the forward direction.

THE TRANSISTORS IN THE REVERSE DIRECTION

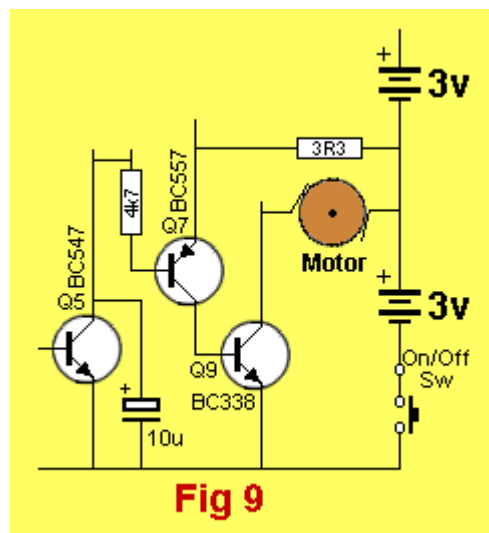There are 3 transistors driving the motor in the reverse direction, as shown in fig: 9.

Fig 9

These are the switching transistor Q5, the driver transistor Q7, and the output transistor Q9. The reason why a driver and output transistor are need is to provide a high current for the motor as it needs a high current at start-up or when under load. A motor may take only 50-150mA when not loaded but the current will rise to 300-500mA when loaded. It the motor does not receive this high current, it will appear the car has no power. For the output transistor to deliver this high current, the base must receive a current according to the gain of the transistor.

The gain of a transistor varies enormously, depending on the current flowing through the collector-emitter circuit. The DC gain of a transistor is generally specified as between 100 - 450, but this is under ideal conditions and is determined at a collector current of about 1mA! When the current is increased, the ability of the transistor to amplify decreases. For a small signal transistor, this may decrease to a gain of 75 for 50mA or as low as 10 or 20 for 250 - 500mA.

That's right, the transistor may only have a gain or 10 or 20 when passing a heavy current. This means the base must receive a current of 25mA to 50mA to make certain the transistor will deliver 500mA. When the transistor turns on fully, the voltage between the collector and emitter is only about 0.2v to 0.5v. If the base is not supplied with sufficient current, the transistor will not turn on fully and the voltage across the collector-emitter leads may be 0.6v or higher.

This is how the transistor limits the current to the device it is powering. For our application we do not

want any extra voltage to be lost across the transistor and so it must be fully turned ON. So we want the driver transistor to deliver 50mA. This will be a low-current device and 50mA will be its maximum rating. We can allow a gain of 100 for this device so that it requires a current of 0.5mA into the base to turn it on fully.

The turn-on resistor is the 4k7 and when you take off the voltage drop across the collector-emitter of the switching transistor and the base-emitter junction of the driver transistor you have about 2v remaining from the 3v supply. This gives a base current of 0.4mA.

This is not enough to supply the motor with full current and thus the motor goes slightly slower in the reverse direction.

THE ADVANTAGE OF A SPLIT SUPPLY

With the split-supply design there is no part of the cycle when both outputs are on at the same time. This makes it a much safer design than the receiver in fig: 2. The section of the circuit we are looking at, to see if both outputs are on at the same time, is shown in fig: 10.
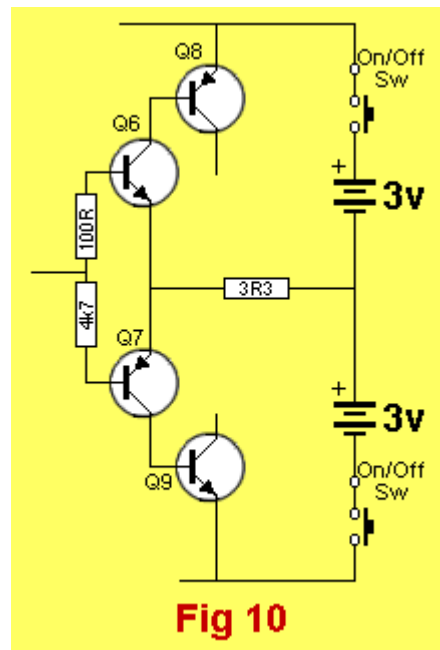

Determining if both outputs are on at the same time.

When the switching transistor (Q5), in fig: 7, is changing from high to low, there is a gap of about 1.2v where both outputs are off. Driver Q6 is tuned on when the input line is above 3.6v, and driver Q7 is turned on when the input line is below 2.4v.

SIMPLIFYING THE SPLIT-SUPPLY CIRCUIT

There are some unnecessary components in the circuit of fig: 7 and by clever re-designing, these can be eliminated. This seems surprising for a mass-produced item but sometimes the designer has not carried out the final step of a design. This is to look at each component and say "Is this part necessary?" If you are not sure, remove it and check the operation of the circuit. If the circuit operates ok, the component may not be necessary. There are 10 components in the circuit of fig: 7 that can be removed and a further 5 can be changed in value when a re-design is carried out. The result is shown in fig: 11.
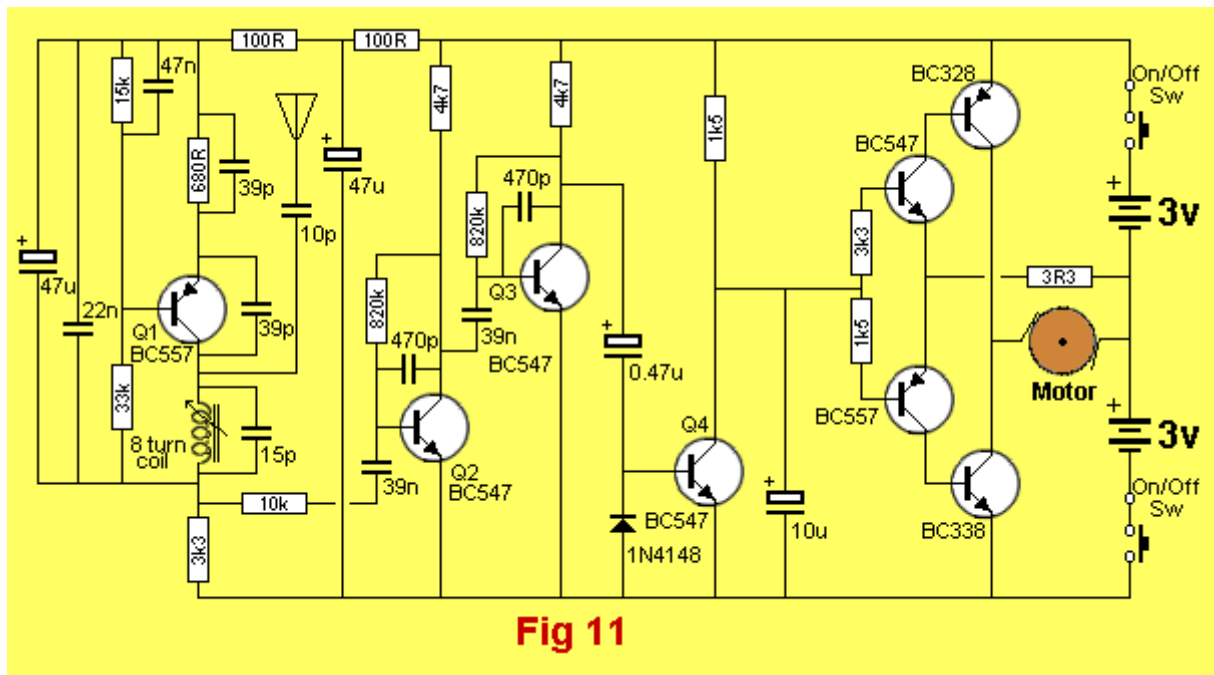
**The 27MHz single-channel receiver with the author's modifications.**

The first two components to be removed are the 390R and 10n on the emitter of the first transistor. The 220R is increased to 680R as shown in fig: 11 to produce the same biasing. The reason why the 10n can be removed is because it is effectively across the 390R (via a 47n) so that the join of the 220R and 390R is effectively at rail impedance to high frequencies.

This means the 39p can be connected to the positive rail and the 390R can be incorporated with the 220R. By using 470p as the high frequency filtering component in each of the two audio amplifier stages, the 10k and 4n7 filtering components can be eliminated. It may also be possible to remove one of the audio amplifier stages when the 0.47u electrolytic is used as it is much more effective than the 15n charging the 10u.

The 15n and one of the diodes is not needed when the charging electrolytic is 0.47u. The switching transistor Q5 is not required, however it does invert the signal so that when it is removed, the resistors to each of the driver transistors must be changed so that the output driving the car in the forward direction delivers full power and the reverse output delivers about 80%.

A MULTI-CHANNEL LINK

A multi-channel link is considerably more complex than a single channel design but it offers the possibility of designing a project that has more features. The multi-channel transmitter shown in fig: 12 has forward, stop, reverse as well as left, centre, right steering.

Fig 12
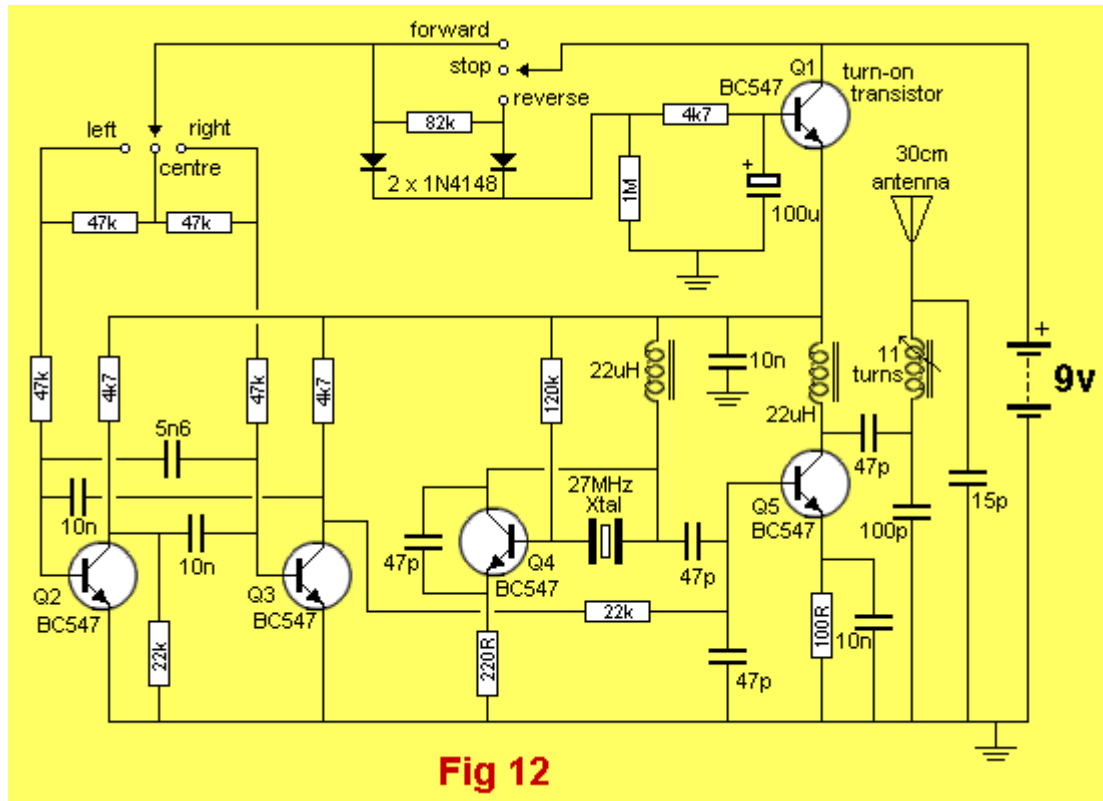
A multi-channel 2MHz transmitter

This represents 6 channels and they are created by changing the mark-space ratio of a square wave oscillator as well as its frequency.
The photo shows the components on the PC board:
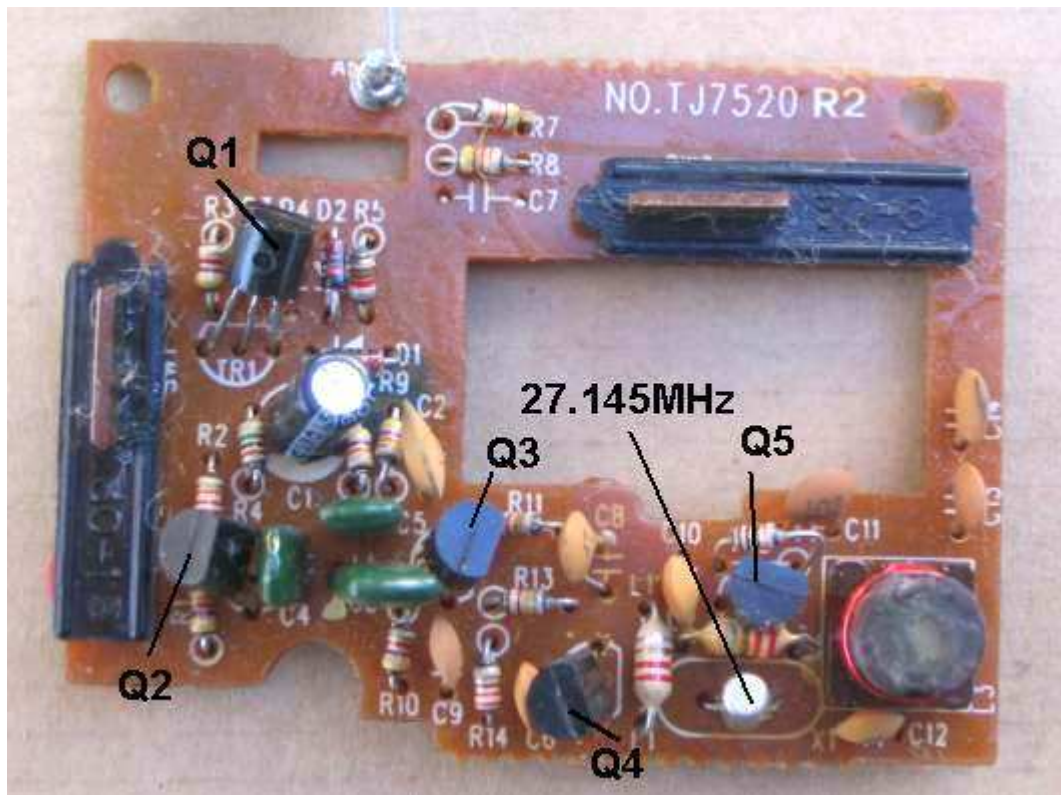
The 6 (4) channel transmitter board

When the transmitter is not operating, the receiver picks up hash (background noise) and no outputs are activated. This represents the STOP function. When the forward function is selected on the transmitter, the square-wave oscillator operates at its high frequency setting, with an equal mark-space ratio.
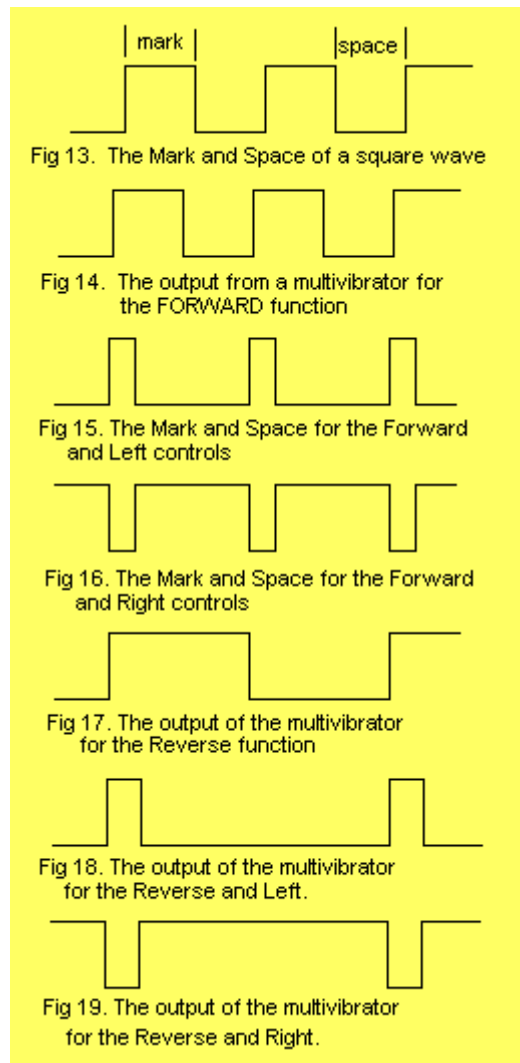
If left-turn is selected at the same time, the mark-space ratio is altered to 1:3 while the frequency remains the same. If right-turn is selected, the mark-space ratio is 3:1, with the same frequency. If the reverse function is selected, the frequency of the oscillator is reduced to half and if the centre steering is selected, the mark space ratio is 1:1. If the left steering is selected, the mark-space ratio is 1:3 and if right steering is selected, the mark-space ratio is 3:1. To understand how the channels are produced, you need to know how a multivibrator works.

HOW A MULTIVIBRATOR WORKS

The multivibrator in the transmitter consists of transistors Q2, Q3 and the surrounding components. This is shown in fig: 20.

Fig 20
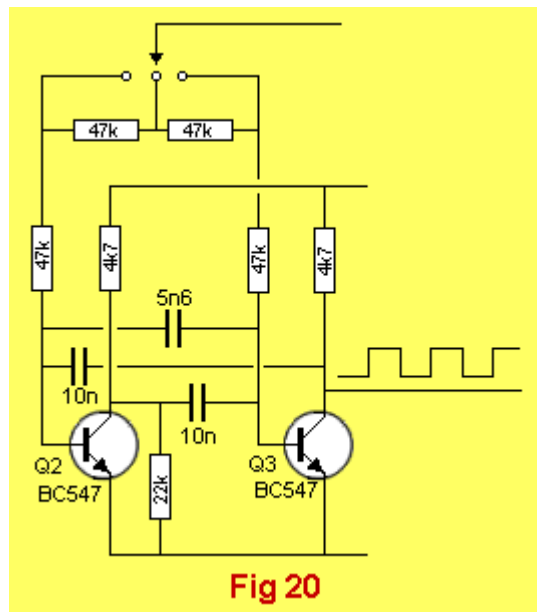
You will notice the symmetry of the circuit and this produces an output waveform that is either HIGH or LOW. The circuit changes from one state to the other very quickly and this produces the fast rise and fall of the waveform and thus its square nature. The HIGH part of the waveform is called the Mark and the LOW is the Space, as shown in fig: 15. A square wave with a 1:1 output has the length of the mark equal to the space.

Fig 13. The Mark and Space of a square wave

Fig 14. The output from a multivibrator for the FORWARD function

Fig 15. The Mark and Space for the Forward and Left controls

Fig 16. The Mark and Space for the Forward and Right controls

Fig 17. The output of the multivibrator for the Reverse function

Fig 18. The output of the multivibrator for the Reverse and Left.

Fig 19. The output of the multivibrator for the Reverse and Right.

For the transmitter in fig: 12, the output of the multivibrator for the Forward function is shown in fig: 14. We can take this as the reference waveform as all the other waveforms will be a multiple of this. For instance, if the left-turn is selected while in the forward direction, the waveform changes to that shown in fig: 15.

Note the short period of time the waveform is HIGH compared to the LOW time. If this waveform is passed into an integrating network, the percentage of time it is high can be determined and an output activated. This is what the chip does in the receiver.

It determines one of six functions and produces outputs to steer the car in the left or right direction and/or drives the car in forward or reverse. It also detects when the transmitter is not operating and stops the car. If the forward-and-right controls are selected the waveform is shown in fig:16.

When reverse is selected, the multivibrator operates at half the frequency due to the 82k resistor added to the base of the two transistors in the multivibrator. The resulting waveform for reverse is shown in fig: 17. If reverse-and-left is selected, the waveform is shown in fig: 18. If reverse and right is selected, the waveform is shown in fig: 19.

THE TURN-ON CIRCUIT

The transmitter doesn't have an on-off switch. It is turned on when the forward-reverse control is moved from the stop position. This switches a diode into circuit. The diode charges the 100u via the 4k7 to turn on the emitter-follower transistor Q1. The base rises to just below rail voltage and the emitter is about 0.7v below this. The emitter becomes the power rail for the rest of the circuit and while the controls are in the forward or reverse direction, the circuit is supplied with voltage and current.
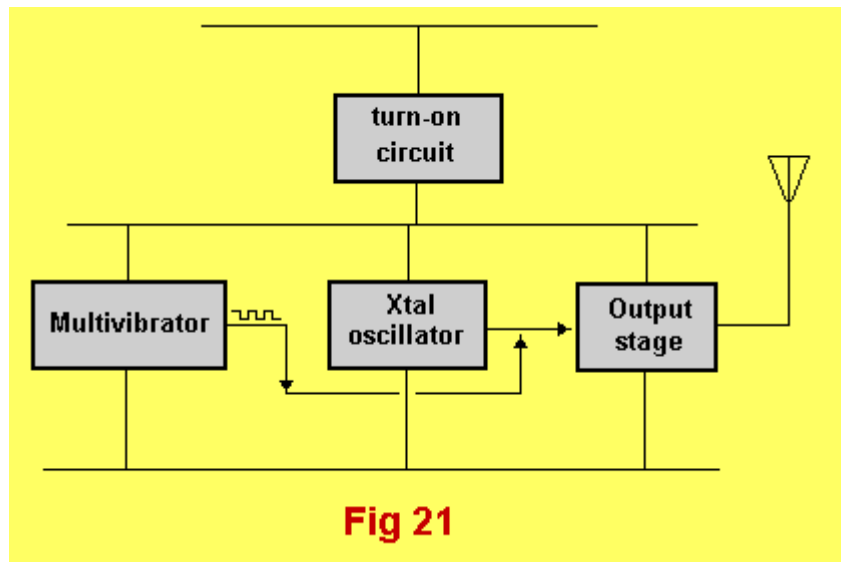
Block diagram of multi-channel transmitter.
The turn-on circuit supplies current to the rest
of the circuit when the controls are activated.

When the control is returned to the stop position (via a spring-return), the current required by Q1 to keep it turned on is supplied by the 100u on the base and as the energy is delivered from the electrolytic, the voltage across it reduces. This reduces the voltage across the circuit but since it is not sending out a signal, this does not matter.

After a minute, the voltage drops to almost zero and the electrolytic is finally discharged completely by the 1M (and 4k7 in series with it). The stand-by current drops to less than 1 micro-amp, the leakage through the collector-emitter junction when the transistor is not turned on.

MORE ON HOW THE MULTIVIBRATOR WORKS

Transistors Q2 and Q3 form a multivibrator and the operation of this is fully covered in our books titled Learning Electronics Book 1 and Book 2. The circuit is basically regenerative in which one transistor turns the other off then the second turns the first off. When the circuit is first turned on, both the bases are pulled high via the 10n capacitors but one of the transistors turns on before the other and robs it of turn-on voltage. But the transistor cannot stay turned on forever as the 10n capacitor becomes charged and as it turns off, it sends a pulse to the other transistor.

The second transistor turns on and completely removes the turn-on voltage from the first transistor. Eventually the second transistor cannot remain fully turned on due to the 10n becoming charged, and starts to turn off. This sends a pulse to the first transistor and it starts to turn on. Each transistor has a gain or amplification factor of about 100 and when we say one transistor begins to turn off slightly, this change is passed to the base of the opposite transistor and the result is magnified 100 times on the collector. This is then passed to the base of the first transistor and suddenly a tiny signal gets passed back as a huge signal. That's why each transistor reacts so quickly and the result is a very fast change from one state to the other. This is shown in the shape of the output waveform.

The rise and fall times are very short and the sides of the square wave are very steep. The frequency of the output is determined by the value of the components on the base. This includes the base resistor and the capacitor connecting to the opposite transistor. In the circuit of fig: 12, the capacitors are fixed at 10n and the resistors are changed.

An increase in resistance causes the capacitor to take longer to charge and decreases the frequency of the circuit. The output of the multivibrator is passed to the base of the RF output transistor where it controls the on/off time for the transmitter. When the transmitter is turned on, a 27MHz frequency is injected into the base of the RF output transistor via a 47p from the crystal oscillator. This crystal oscillator is made up of transistor Q4 and its surrounding components.

The transistor is turned on via the crystal and 22uH inductor. The crystal is equivalent to about 20p and the resistance of the inductor is about 1 ohm. The emitter is held fairly rigid via the 47p and the transistor gets a very short pulse from the crystal. This puts a pulse of current through the coil and the current creates magnetic flux. As soon as the pulse ceases, the magnetic flux collapses and the inductor produces a voltage in the opposite direction and passes the waveform through the 47p to the base of the RF output transistor. It also passes the waveform through the crystal to turn off the

oscillator transistor Q4. When the transistor is turned off, it does not put any load on the inductor and the amplitude of the waveform is fairly large. After a short period of time, this waveform ceases and the transistor gets turned on by the 120k base bias resistor.

This injects another pulse of current into the inductor and the cycle repeats. The inductor creates the time delay for the waveform as it takes time for the current to convert to magnetic flux then back into a voltage in the opposite direction. This time-delay approximates to about 27MHz and the crystal locks it on to the frequency of 27.240 by exhibiting a larger capacitive effect at this exact frequency. This is how the circuit is pulled into line and kept at an exact frequency, even though the supply voltage may decrease or the temperature may rise.

The 27.240MHz waveform is passed to the RF output transistor and the transistor is turned on and off at the frequency of the multivibrator. The transistor is in common emitter mode as evidenced by the 10n on the emitter.

The impedance of this capacitor at 27MHz is very small compared to the 100R and the emitter considers it is connected to the negative rail as far as the high frequency is concerned. The 27MHz waveform on the base is amplifier by the transistor and appears on the collector in magnified form.

The 22uH inductor on the collector prevents the signal passing to the power rail. It does this by producing a "back-voltage." As the transistor turns on, the current through the inductor increases and magnetic flux is produced in the coil that cuts the other turns of the coil and this induces a voltage and current in them that is in opposition to the current being delivered. The result is a reverse voltage is produced that makes it difficult for the forward voltage to enter the coil.

This means the forward voltage gets larger and larger in an attempt to enter the coil and the result is a large voltage appearing on the collector of the transistor. This voltage passes through the 47p to a tuned circuit made up of a 11 turn inductor and 15p capacitor. These are designed to match the high impedance of the output of the transistor to the low impedance of the whip antenna. Matching is required to get the maximum signal to pass into the antenna. This completes the coverage of the sections in the transmitter.
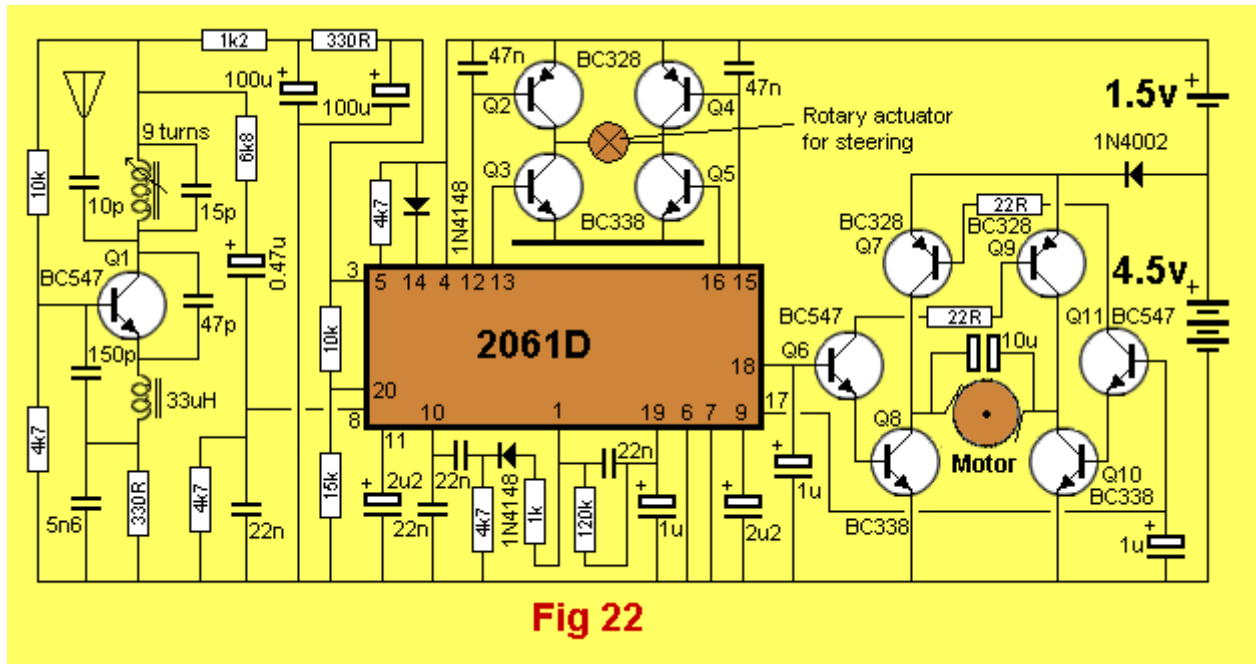
THE MULTI-CHANNEL RECEIVER

The signal from the transmitter is picked up by the receiver as bursts of tone between hash. Viewing the signal on a CRO (Cathode Ray Oscilloscope) will look something like fig: 23.

**The signal from the multi-channel transmitter will consist
of a regular waveform between background hash.**

The receiver is required to pick out the signal from the noise and it does this by a process called integration and differentiation where the signal is detected due to its regular nature and this is used to charge a capacitor.

Another circuit determines the length of time the tone is present and these are combined to determine the nature of the control signal. Most of the circuitry for doing this is locked inside the chip in the receiver and the only components we can see are the external items on pins 10, 1 and 19. These determine the frequency detected by the chip and the length of the "highs," but all the rest of the signal processing is done inside the chip. The chip detects the waveforms shown in figs 14 - 19 and turns on the appropriate outputs.

A multi-channel 2MHz receiver

The 27MHz receiver PC board

Two outputs drive the motor in the forward/reverse direction and 4 outputs drive the transistors for the steering motor. The steering motor is simply a rotary actuator. This is similar to the armature of a motor, positioned inside a circular magnet.

The armature does not need brushes as it will only turn about 45° in one direction and 45° in the opposite direction, depending on the direction of the current. The output of the shaft will be connected to a lever to steer the front wheels.

The chip controls the two diagonally opposite transistors for the clockwise and anticlockwise rotation to get left and right steering. All the rest of the circuit has been previously discussed and the only new feature is the tapping at 4.5v for the motor. A diode on the 4.5v rail drops the voltage to 3.8v and the two output transistors drop a further 1v, so that motor receives about 2.8 to 3v.

Here are some remote control items, shown on the web, by a hobbyist who disassembles devices and makes a new project:

Some of these components were used to build a project and presented on the web.

A 27MHz WALKIE TALKIE

An Overview
Walkie Talkies are the next logical step in this discussion. They show how a crystal oscillator can be used to transmit voice. Transmitting a voice via a crystal locked oscillator is not easy. This is because the crystal is locking the frequency and it is very difficult to shift it. The only way to do it is to add the audio as an amplitude component so that the amplitude of the oscillator rises and falls with the audio signal but its frequency does not change.

The only problem with this mode of transmission is interference. Electrical noise entering the airwaves is also a varying amplitude waveform and the receiver will pick this up at the same time and produce a very noisy result. This is one of the reasons why walkie talkies are so noisy. However it is a starting point for learning about transmission and the circuit in fig: 24 shows how the audio is added to the carrier.
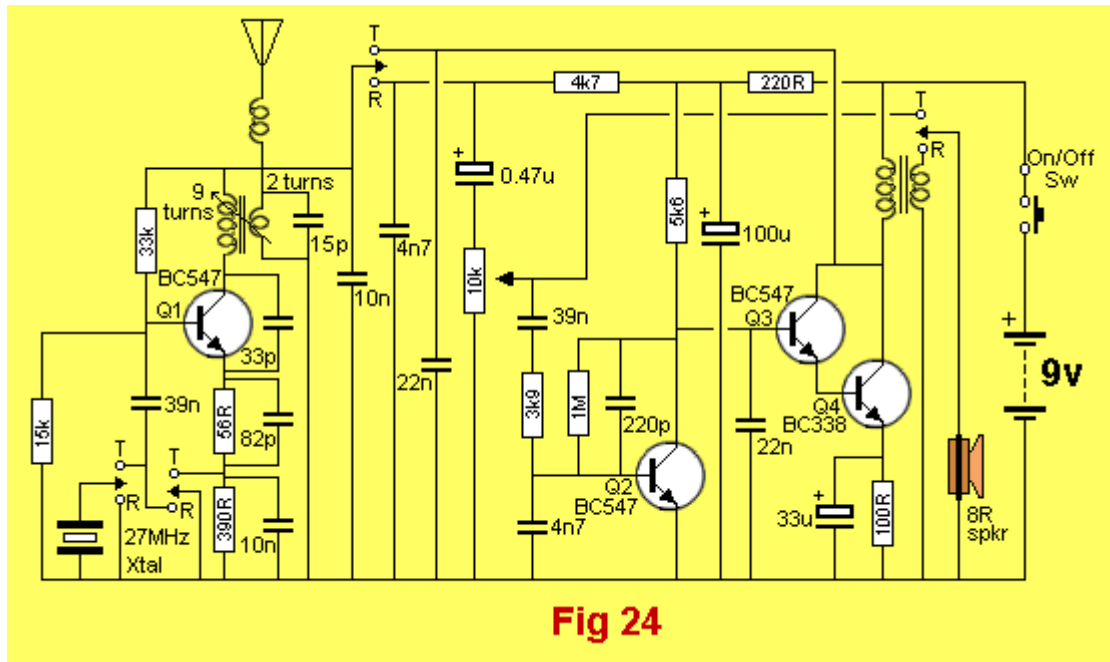
Fig 24

A 4-Transistor Walkie Talkie

Nearly all the components in the 4-transistor circuit are used for both transmitting and receiving. This makes it a very economical design. The frequency-generating stage only needs the crystal to be removed and it becomes a receiver.

The operation of this circuit coincides with our discussion on receiver circuits at the beginning of this article where we said the receiver was oscillating all the time, similar to a weak transmitter. A 390R is added to the emitter of the oscillator stage to reduce the activity and turn it into a receiver. The next section of the circuit is called a building block.

It consists of three transistors directly coupled to produce an audio amplifier with very high gain. The first transistor is a pre-amplifier and the next two are wired as a super-alpha pair, commonly called a Darlington pair to drive the speaker transformer.

The third block is the speaker. This is a separate item because it is used as a speaker in the receive mode and a dynamic microphone in the transmit mode. A speaker can be used in reverse like this and it is called a dynamic microphone because of the coil and magnet arrangement. When you talk into the cone, the movement of the voice coil in the magnetic field produces a few millivolts output. This can be coupled to a high gain amplifier to get quite good results.

When the walkie talkie is in the receive mode, the first transistor is configured as a receiver and the audio is picked off the 4k7 load resistor via a 0.47u electrolytic. It then passes through a volume control and into the three transistor amplifier. The speaker transformer couples the amplifier to the speaker and we hear the result. When the walkie talkie is in the transmit mode, the speaker is placed at the input of the audio amplifier.

The audio is then amplified and the waveform appears as THE SUPPLY VOLTAGE FOR THE TRANSMITTER STAGE. The crystal is connected to the first stage and the gain of the transistor is increased by removing the 330R and only using a 56R for the emitter resistor.

The speaker transformer is not used as a transformer in this mode but as an INDUCTOR to couple the output of the audio amplifier to the power rail and the signal developed across the winding is passed to the transmitter stage as the supply voltage for the transmitter. As the waveform rises and falls, it changes the gain of the first stage and thus the amplitude of the transmitted signal. This is how the signal becomes an Amplitude Modulated (AM) Radio Frequency (RF) signal.

THE WALKIE-TALKIE CIRCUIT IN DETAIL

In the receive mode, the first transistor is configured as a low-level oscillator. The base is tied to earth via a 39n capacitor. This makes it a common-base configuration and the gain of the transistor is high. The input (the collector) is also high, whereas the input (the base) of a common-emitter stage is medium to low.

If this type of stage were used, the antenna would not be as sensitive in detecting up a signal. The feedback for the transistor is provided by the 33p between collector and emitter. The emitter has a

330R and 56R in series to keep the gain low.

The circuit starts up and oscillates due to a tuned circuit on the output of the RF transformer. The transistor detects this oscillation on the primary side of the transformer and passes the signal to the emitter via the 82p, where the gain of the transistor increases the amplitude of the signal to a medium level. If the amplitude is too high, the stage will not be responsive to the surrounding signals.

Any nearby signals of the same frequency will increase and decrease the current taken by this stage and the information on the signal will appear across the 4k7 load resistor as a varying voltage. The 0.47u picks off the voltage and passes it as an audio signal to the volume control and finally the 3-transistor amplifier. The 4n7 between base and ground of the first amplifier transistor is designed to remove any high frequency signals and the output of the transistor goes to a super-alpha pair to drive a speaker transformer.

The speaker transformer matches the output of the transistor to the 8 ohms of the speaker. Matching is done by the transformer having a turns ratio. It has 525 turns for the primary and 75 turns for the secondary. The purpose of the transformer is to convert a high voltage (about 7v), with low current to a low voltage (about 400mV) at high current. This is what the speaker requires. It needs a high current to pull the cone into the magnetic field. The remaining components are biasing components or capacitors to remove the high-frequency signal.

SETTING THE BIAS FOR THE 3-TRANSISTOR AMPLIFIER

The circuit in fig: 25 shows the components that set the bias for the three transistors.
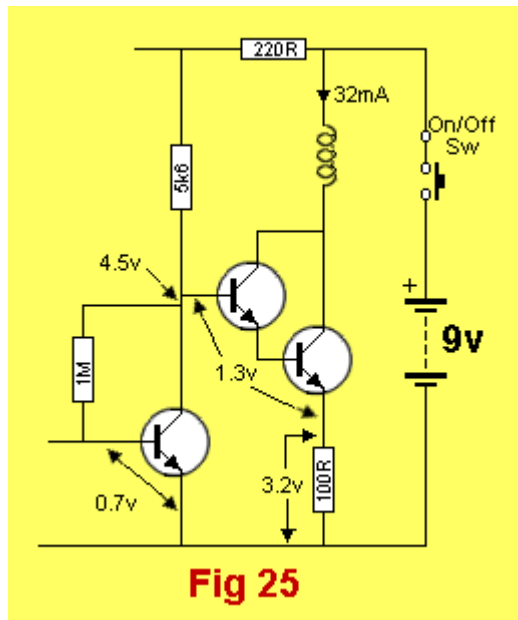

The biasing of the 3-transistor amplifier

All the other components have been left out because they do not determine the DC bias point. The biasing starts at the base of the first transistor. It is turned ON, but not fully, by the 1M resistor until the collector voltage falls to half-rail voltage. The 1M and 5k6 resistors are chosen so that this occurs. This is the ideal set-point so that the pre-amplifier transistor can amplify both the positive and negative excursions of the signal without distortion. The super-alpha pair (the second and third transistors in the 3-transistor amp) drops a total of 1.3v across the base-emitter junctions, leaving 3.2v across the 100 ohm emitter resistor. By ohms law, this will produce 32mA as the idle current (quiescent current) for the audio stage.

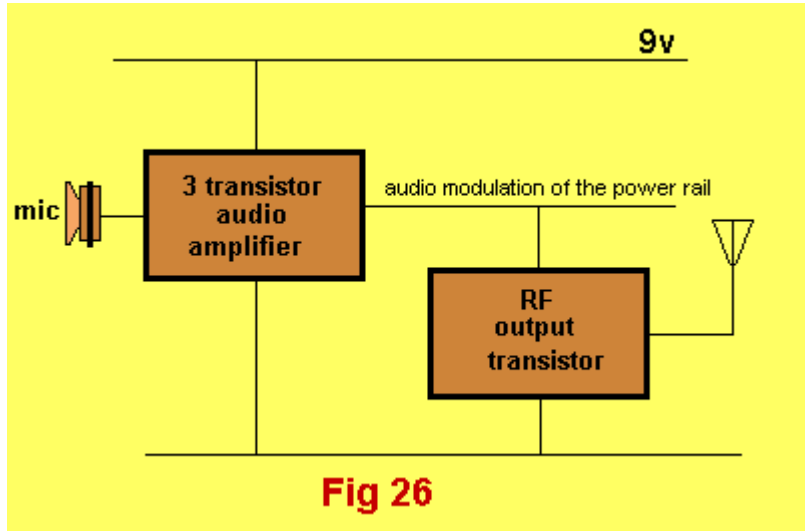Here is a hand-cranked walkie talkie:

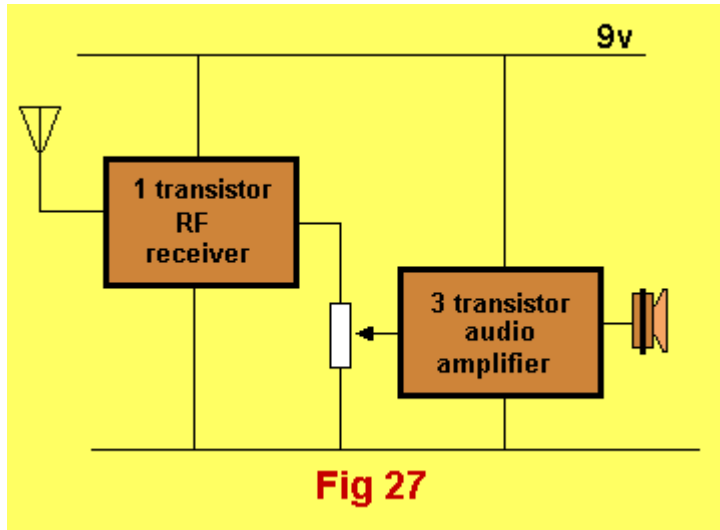**The walkie talkie in transmit mode. The signal passes from the audio amplifier to the RF stage via the power rail**

The walkie talkie in receive mode. The circuit is conventional with the first stage feeding the 3-transistor amplifier via a volume control

THE EMITTER BY-PASS CAPACITOR

The 33u electrolytic on the emitter is called the emitter by-pass capacitor. It connects the emitter to the 0v rail when the stage is processing a signal and the signal by-passes the 100 ohm resistor. To see how the electrolytic works we firstly have to remove it and see why the Darlington pair has NO GAIN. Refer to fig: 25. When a signal is fed into the base of the pre-amplifier transistor it will be amplified about 100 times and appear on the collector. Suppose the collector voltage rises 5mV.
This will be passed to the base of the top transistor of the Darlington pair and since it is almost fully

turned on, the emitter will rise too. The emitter of this transistor is connected to the base of the lower transistor and the base will pull the emitter up too.

The collector voltage will not change and this means the transistors will produce NO gain because the voltage on the emitter is allowed to rise. It we hold the voltage on the emitter rigid, the pair will give us gain. To do this we connect an electrolytic between 33u and 100u. It has the feature of taking a long time to charge (and discharge) - compared with the rise and fall time of the signal.

When the 5mV waveform appears on the base of the Darlington arrangement, the base tries to rise but it is fixed by the characteristic voltage of 0.7v developed across each of the base-emitter junctions. The result is the base rises 0.1v and both transistors get turned on more. The resistance between the collector and emitter of the output reduces and the transistor allows more current to flow through the primary of the speaker transformer.

THE SPEAKER TRANSFORMER

A lot of discussion could be devoted to the operation of the speaker transformer as the design of a transformer is very complex. There are two ways you can design a transformer. One is to calculate the requirements from scratch and the other is to copy an existing design and make modifications until the desired result is achieved. Copying and modifying is the quickest.

If you use the theoretical approach you will invariably have to modify the design to get it working perfectly. The speaker transformer used in fig: 24 is 1k to 8 ohm. These are the impedance values measured at 1kHz. The actual DC resistance of the primary is 42 ohms and the secondary is 1 ohm. The DC resistance of a transformer is different to the impedance value. If the transformer was larger, the wire diameter would be larger and the DC resistance could be as low as 10 ohm and 0.5 ohms. The impedance is the resistance as seen by the transistor at 1kHz. It "sees" a 1k load at 1kHz and a higher impedance at a higher frequency. Energy is transferred from the primary to the secondary via magnetism.

The primary produces a magnetic flux that passes into the magnetic core surrounding the windings. This magnetic flux cuts the turns of the secondary and produces a voltage in it.

The voltage produced is proportional to the number of turns. In our case the primary has 525 turns and the secondary has 75 turns. This is exactly a 7:1 ratio and it means the transformer will theoretically convert a 7v waveform at 10mA into a 1v waveform with a current of 70mA.

A small transformer like this has an efficiency of about 50 - 70% however it is performing a very big task, matching 1k to 8 ohms and the speaker would not work if it were connected directly to the transistor. To directly couple the speaker, the emitter resistor would have to be lower. The circuit would then take 70mA to get the same result as with the speaker transformer. And even then the transformer provides a much better match.

THE TRANSFORMER AS AN INDUCTOR

When the transformer is used as an inductor in the transmit mode, the speaker is not connected and the secondary does not see a load. This means the primary does not see a "reflected" load and the impedance of the transformer is increased considerably. The effect is the transistor sees a higher impedance and this means it finds it easier to develop a signal across the primary.

To give a very simple analogy, the transformer (with the speaker connected) is like a very stiff spring. When the speaker is removed, the transformer is like a very weak spring. The transistor finds it very easy to pull the bottom end of the spring down (the top is connected to the positive rail). When a signal is processed by the Darlington pair in transmit mode, the emitter is held rigid by the 33u and the only thing that can happen is the weak spring gets pulled down.

By referring to the circuit diagram in fig: 24, the bottom lead of the transformer becomes the power rail of the crystal oscillator and as the voltage on the transformer rises and falls, the supply voltage to the oscillator increases and decreases. and affects the gain of the oscillator. Now we come to the difficult part of explaining how a voltage is produced across the primary winding. During the quiescent (idle) mode, about 1.5v is dropped across the 42 ohm resistance of the primary. When a signal is processed by the Darlington pair, the resistance between the collector and emitter is reduced and a higher current flows.

The action of this current increasing creates an expanding magnetic flux in the transformer and this flux cuts the adjacent turns of the primary and induces a voltage in each of the turns in the opposite direction. This means the voltage produced by the transistor has to be greater, in an attempt to pass current into the inductor.

This voltage is picked off the inductor and passed to the first stage in the circuit and becomes the power rail. The fluctuating power rail alters the gain of the stage and amplitude modulates the 27MHz signal to produce audio on the carrier. The result is an Amplitude Modulated (AM) Radio Frequency

(RF) signal.

49MHz WALKIE TALKIES

Two bands have been allocated for walkie talkies and remote control equipment. These are the 27MHz band and 49MHz band. The 49MHz band has slightly better performance due to the short antenna being closer to the wavelength of the signal. The two bands allow more remote control cars to be raced together without interference between the cars.

FURTHER USES

All of these circuit can be found in remote-control toys from your local department store. Simply buy a remote control car and give it to a youngster to play with. After a day or two he will lose interest and you will be able to pull it apart and adapt it to your own use.
To create a private channel, simply replace the crystal with one of a slightly different frequency and retune both the transmitter and receiver coil. The multi-channel receiver has even most possibilities. You can control four different devices directly and even more by gating the outputs. The simple 27MHz link will be used with one of our Talking Electronics FM transmitters to turn it ON and OFF remotely. The 27MHz transmitter will work up to 60ft (20m) and will allow you to turn off a transmitter to give it added security from being detected. The receiver will have to be designed to turn on for 0.5sec every 10 seconds to detect if a turn-on transmission is being sent and the whole circuit will then shut down to conserve power if a reception is not detected.
This means you will have to transmit for at least 10 seconds to be sure the receiver picks up the signal.

CIRCUIT A

Circuit A shows a 27MHz transmitter circuit without a crystal. The main reason for a crystal is to comply with the strict transmitting laws in most countries. A fairly narrow band has been allowed at 27MHz and to keep within this area, a crystal has been used. Since a crystal is not an expensive component when bought in the millions, manufacturers have included them in their circuits to get instant approval.

However the important reason for using a crystal is to get reliable operation.
When a circuit does not have a crystal, the oscillator is said to be "voltage dependent" or "voltage controlled" and when the supply voltage drops, the frequency changes.
If the frequency drifts too much, the receiver will not pick up the signal.
For this reason, a simple circuit as shown in circuit A is not recommended. We have only included it as a concept to show how the 27MHz frequency is generated. It produces a tone and this is detected by a receiver. Q1 sets the frequency of the tone but it actually gets feedback from Q2 to keep the tone being produced. The tone enters the base of Q2 and appears on the collector in an amplified form. It is also phase-shifted. This means a HIGH will appear as a LOW and a LOW as a HIGH. This signal passes through the coil and appears on the right side of the 6n8 capacitor with an opposite polarity to that being produced by Q1. The 100R resistor keeps the signal away from the power rail and the 2n2 does not have a great effect on reducing the amplitude of the signal, as it is such a low frequency. This signal then passes through the 6n8 to keep the oscillator producing the tone. The frequency of the tone is determined by the value of the 6n8 and 1M resistor.
Q1 would also amplify the 27MHz signal except for the fact that the signal is reduced to almost zero by the effect of the 2n2 capacitor. The only remaining "noise" (signal) is the tone frequency. The 2k2 reduces the current into the base of Q2 to allow it to turn-on fully but not overload the transistor as this would consume additional current for no extra output. The tone consists of short spikes, unlike the tone produced by Circuit B, which has an almost even mark-space ratio.
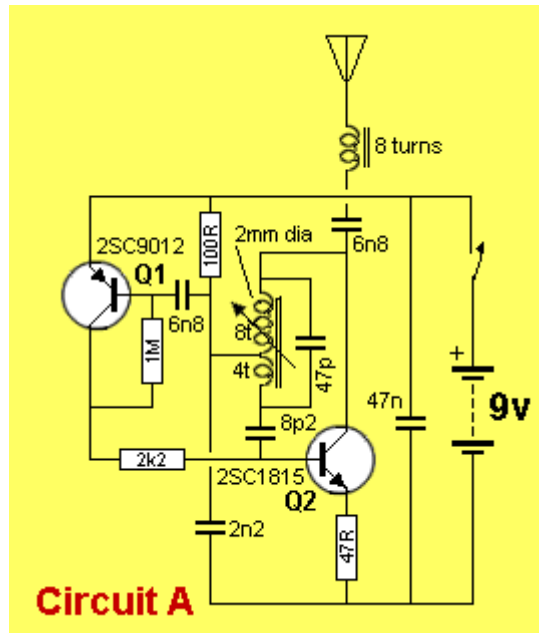
A 27MHz transmitter
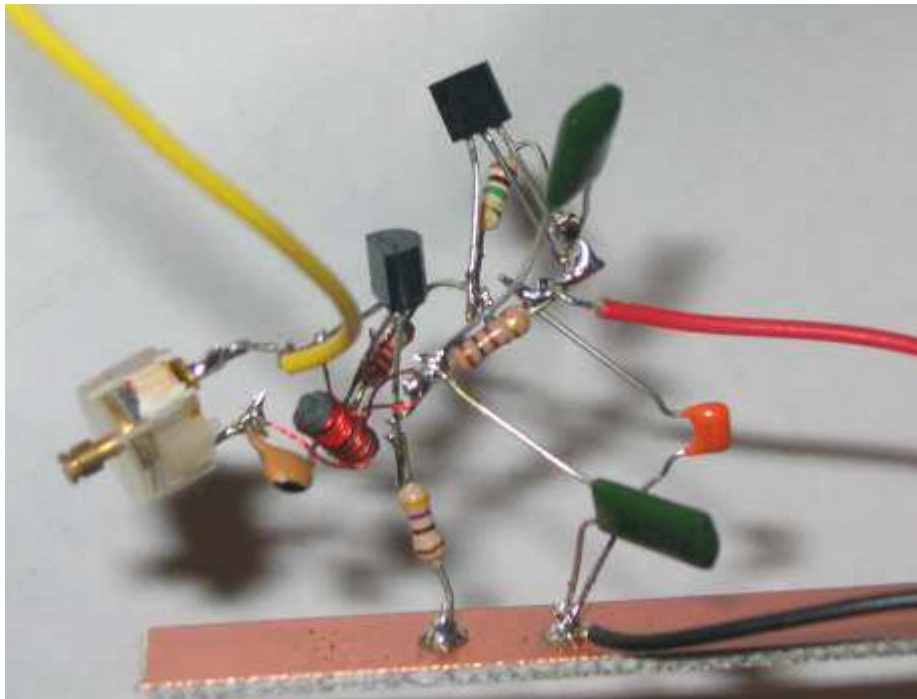
Circuit A - Birds Nest

Circuit A was quickly constructed on a piece of copper board to act as an earth plane and to make sure it worked and to see if any improvements could be made. If a circuit works well in an open format such as this, you can be sure it will work better when constructed on a printed circuit board where the circuit is much "tighter" and the impedances are lower. The layout above is called a "Birds Nest" and allows rapid modifications to be made and you can touch the parts to see if your hand capacitance changes the frequency or stops the circuit working.

CIRCUIT B

Circuit B also produces a tone. But this time two transistors are used in a multivibrator arrangement, in which one of the transistors is used to turn the third transistor on and off.

Circuit A is a very efficient and clever circuit and requires less components. That's why you must study

all types of circuits before producing your own design as simplicity is the secret to success.
The tone is used by a receiver to determine the signal is coming from the chosen transmitter. The receiver can have a detector stage to detect the exact frequency or the tone can be used to change the state of a stage. This is called integration, where the energy from the pulses from the tone are added together to charge or discharge a capacitor.
Circuit B comes from a Russian design, and it uses Philips transistors!
We tested the output with our Field Strength Meter MkII and found it had a good output. Details of Field Strength Meter MkII are discussed below.
But the circuit has some poor features. The poorest feature is the printed-circuit coil. This type of coil has the lowest value of "Q." "Q" is the name for the "Quality factor" for a coil and it effectively determines how much amplitude you will get. Quite often the output of a coil will be higher than the voltage being supplied to it and this gives the value of "Q."
The other poor design is turning the emitter of the third transistor on and off. A better solution is to drive the base as has been done in Circuit A. This allows full voltage to be applied to the stage.
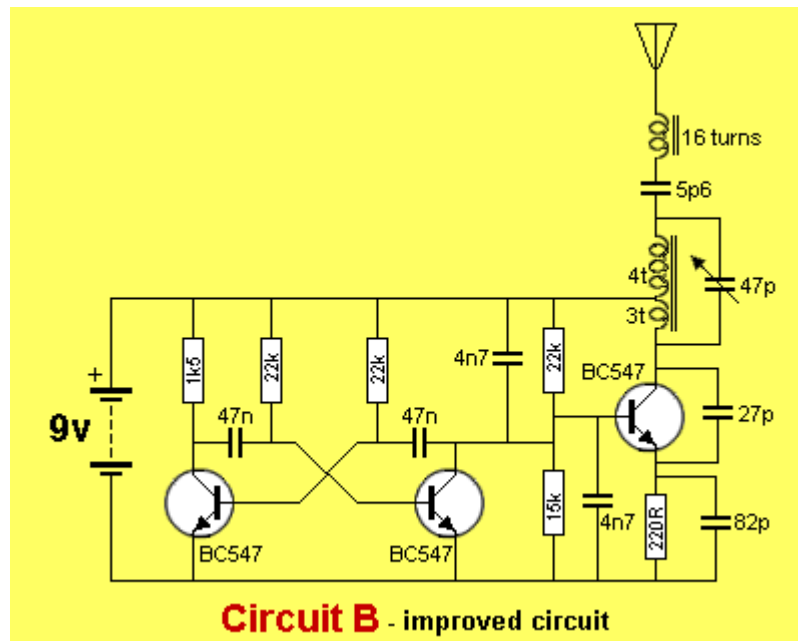Here is the circuit:
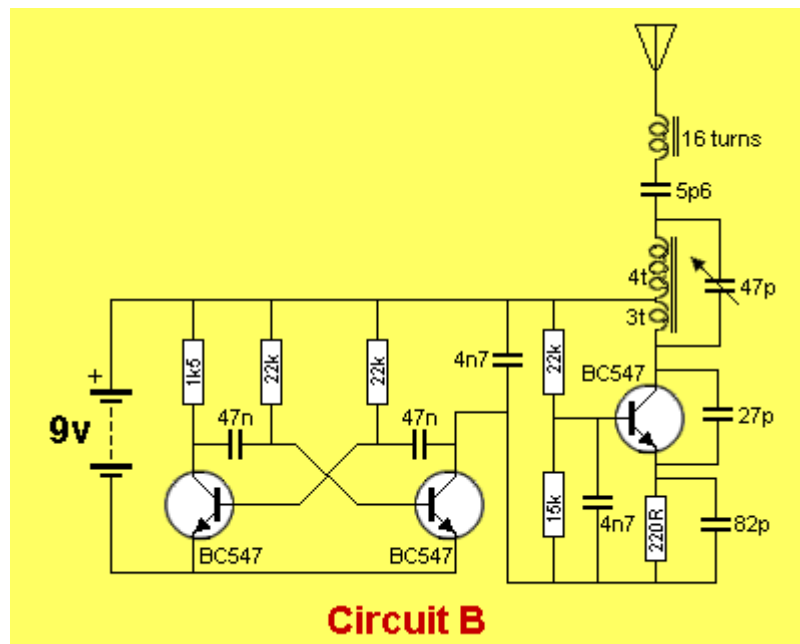
Circuit B

The topside of circuit B
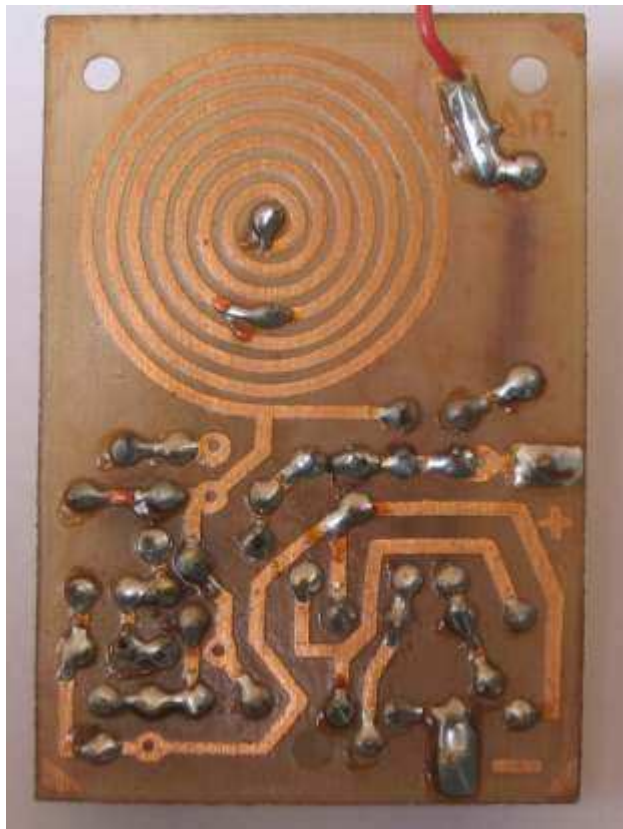
The underside of circuit B

Circuit B - improved circuit

HOW THE CIRCUIT WORKS

Circuit B consists of two blocks. Block 1 is a multivibrator and this has an equal mark/space ratio to turn the RF stage on and off.

We have covered the operation of a multivibrator in the electronics course on Talking Electronics website, in the subscription section.

The only thing you have to know for this circuit is the fact that the middle transistor turns on for 50% of the time and the voltage between the collector and emitter drops to less than 0.3v This voltage is too low for the third transistor to operate and thus the RF stage is turned off.

The second building block is the RF oscillator.

The actual operation of the stage is very complex and beyond the scope of this discussion. However some of the points are as follows:

The feedback to keep the stage operating is provided by the 27p capacitor.

The frequency-producing items are the coil (made up of the full 7 turns) and the 47p air trimmer.

These two items are called a parallel tuned circuit. They are also called a TANK CIRCUIT as they store energy just like a TANK of water and pass it to the antenna.

The base is kept rigid by both of the 4n7's. In other words, the base does not move.

The stage is turned on by the 22k and 15k voltage dividers. A voltage of 5v is produced at the join of these two components. The voltage on the emitter will be 0.6v lower.

This will cause current to flow in the 220R and also in the 3t winding. These turns will produce magnetic flux that will cut the other 4 turns and produce a voltage in them. This energy will pass to the antenna and some of it will charge the 47p and in doing so the voltage on the collector will reduce.

This voltage will be passed to the emitter via the 27p and this will turn the transistor on more. This will continue until the coil cannot produce any more voltage and the transistor will begin to turn off. The collapsing magnetic flux in the 3 turns will cut the 4 turns and produce a voltage in the opposite directions and the other half of the cycle will be produced.

The frequency of the circuit is adjusted by the 47p air trimmer.

TESTING TRANSMITTERS

We are now at the point of looking at test equipment to test the output of a transmitter.
There are four simple pieces of equipment. Three are available from Talking Electronics.

1. LED Power Meter, Detects RF energy and indicates the result on a multimeter set to 2v or 10v scale.
2. Field Strength Meter MkI.   FSM MkI detects RF energy and indicates the result on a multimeter set to 10v scale.
3. Field Strength Meter MkII. FSM MkII has a scale 26MHz to 50MHz. By turning a pointer connected

to an air trimmer, the frequency of a transmitter can be determined.
4. 27MHz Walkie Talkie - purchase from a toy store.

When working with a transmitter, the first thing you will want to do is determine if the transmitter is producing RF.
Talking Electronics has three kits for this. The **LED Power Meter** costs less than $2.00 and connects to a multimeter set to 2v or 10v range or you can use the 0.5mA range. It connects directly to the antenna of the transmitter and a LED illuminates if the transmitter is producing more than about 30milliwatts. If the transmitter is producing less than 30mW, the needle on the multimeter will deflect, but the LED will not illuminate.
The photo below shows the LED Power Meter connected to a mini Multimeter. These are available from "$2.00 shops" for less than $10.00

The multimeter in the photo has a sensitivity of 2,000 ohms per volt. This means the resistance inside the meter is 20,000 ohms when the pointer is on the 10v scale.
This type of meter is called a low sensitivity instrument and is ideal for the job we are doing.
If a high impedance instrument is used, it can pick up stray RF and produce a false reading.
A high impedance instrument can be 20,000 ohm per volt, 50,000 ohms per volt or 100,000 ohms per volt (commonly called a FET meter.)
Digital multimeters can have higher input impedances.

LED Power Meter connected to a mini multimeter

If you want a more sensitive detector, use **Field Strength Meter MkI**.
Once you know a transmitter is producing RF (a signal), you can tune it to a particular frequency.
To do this you will need **Field Strength Meter MkII.**
When FSM MkII has been modified as shown below, it can be calibrated.
This will allow you to set the frequency of any transmitter that does not use a crystal.
To detect a tone from a transmitter, use a 27MHz or 49MHz Walkie Talkie. The tone will be heard in the speaker.
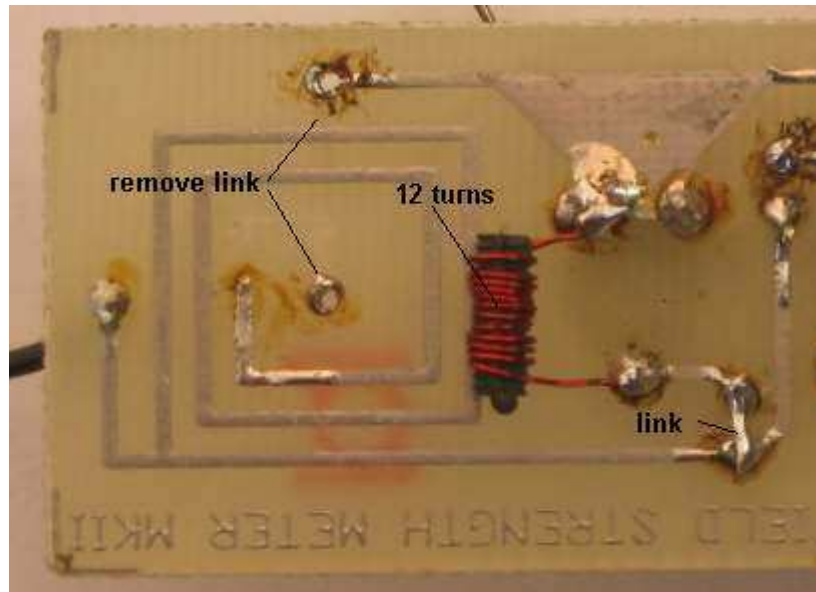
**FIELD STRENGTH METER MkII Modification**

Field Strength Meter MkII can be modified to detect transmitters in the range 27MHz to 49MHz by placing a 12 turn inductor on the bottom of the board. This is made by winding 12 turns of 0.25mm wire on a 2mm x 5mm ferrite slug. The 47p capacitor in series with the 47p air trimmer is "shorted out" under the board as can be seen in the photo above. The link to the coil on the board is removed so that it effectively comes out of circuit. No other parts on the board are changed.
You will need a transmitter with a crystal to calibrate the Field Strength Meter. You can then use the FSM to adjust any of the transmitters that do not have a crystal.
Field Strength Meter MkII can also be used to determine the relative output of each transmitter by using the same length antenna on each transmitter and holding FSM MkII at the same distance from the transmitter. The three LEDs on the PC board will show the relative signal strength.

RECEIVERS
The following receiver matches up with Circuit B above.

27MHz Receiver
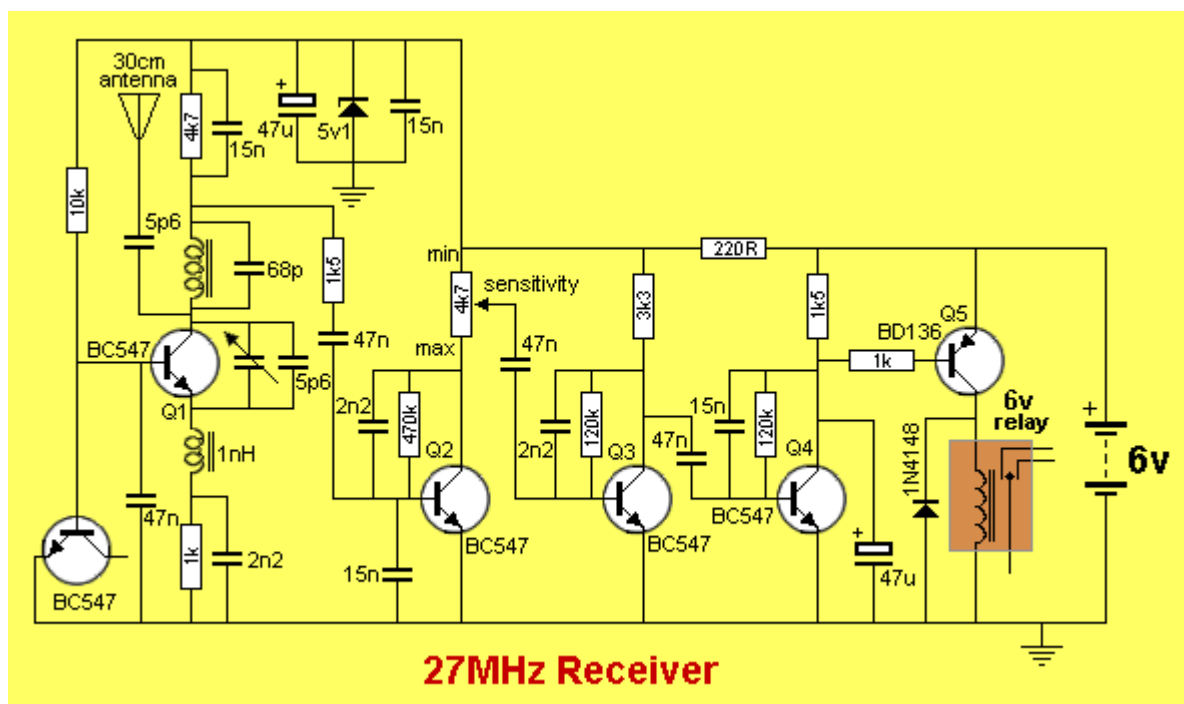
HOW THE CIRCUIT WORKS

The circuit consists of a number of building blocks and these can be identified when a capacitor separates one stage from another.

The first stage is actually a 27MHz oscillator with a very small output due to the 4k7 resistor connecting the stage to the positive rail. This allows very little current to enter the stage and the transistor operates on a very "delicate basis."

When a circuit is oscillating and delivering a signal to the air surrounding the antenna, any other signal entering the same surroundings will cause an interference with the generated signal and the circuit will find it more-difficult to deliver a signal, especially when the signal has the same frequency. This will cause the voltage on the collector of the transistor to alter and produce a signal that can be passed to further stages of amplification.

The 5v1 zener is designed to keep the voltage on the first stage constant as the transistor is oscillating and is a voltage-controlled oscillator.

All the components in the first stage are designed to make it very sensitive to detecting a signal.

Normally, all the surrounding signals upset the clean sine-wave produced by the stage and the result is a lot of "noise" or "hash" or "background noise" at the "pick-off" point.

If the 27MHz signal produced by a transmitter contains a tone, this tone will appear at the "pick-off" point along with the hash.

The frequency of the hash is fairly high and on the second stage there are three components to remove it.

The first is the 1k5 resistor. This, in combination with the 47n, has a slight effect.

Next, the 15n between base and ground will remove high frequencies. And finally the 2n2 will send any amplified signal back to the base for cancellation. This capacitor has a greater effect on canceling high frequencies.

The third and fourth stages also remove some of the high frequency component of the signal and the result is a clean signal with only the tone appearing on the base of the fourth transistor.

This signal has a large amplitude and will turn the transistor on fully.

The transistor normally sits with the collector very close to rail voltage due to the low value of collector resistor and this means transistor Q5 is not turned on.

The 47u gets charged via the 1k5 resistor and the relay is not energised.

When the fourth transistor sees a tone, it turns on at the frequency of the tone and this puts pulses of short-circuit across the 47u and it rapidly discharges.

As it discharges, the voltage on the collector drops and this turns ON Q5 to operate the relay.

When the tone stops, the 47u rapidly charges via the 1k5 and the relay switches off.

The photo below shows a switch added to the PC board and a LED connected to the output of the relay to test the receiver.

The pot in the centre of the board adjusts the sensitivity of the receiver.

Receiver for transmitter in Circuit B

The relay can be latched ON via the following circuit but it cannot be turned OFF remotely. The power has to be disconnected to release the relay. This is only suitable for a "one-shot" operation where a device has to be turned ON only once.
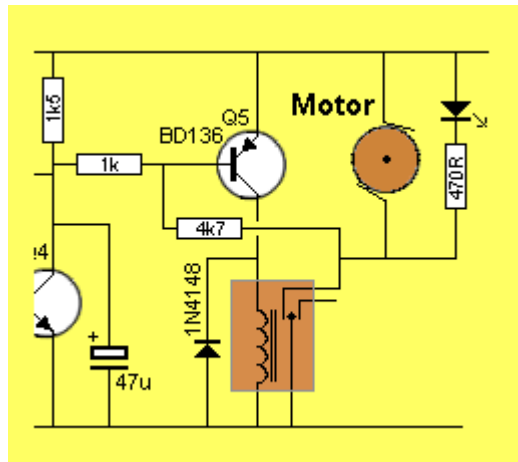
Relay turns ON and stays ON
(Latching Circuit)

If a long tone is required to turn on the relay (to prevent false triggering), the following circuit can be used. The 100u electrolytic takes about 2 seconds to discharge via the 10k resistor, as the 4k7 adds to the time-delay, since it is providing charging-current that the transistor has to overcome.
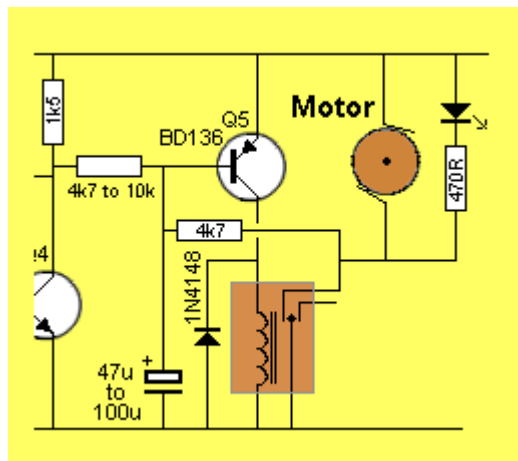
2-second tone to turn relay ON

The following circuit allows a single channel transmitter/receiver to turn an appliance ON and OFF by sending a short pulse to turn a circuit on and a long pulse to turn a circuit off.
This is handy when you cannot see the result of your operation. A simple toggle operation is not suitable as you do not know the state of the output at the start of the operation.
By sending a long pulse, you definitely know the output will be OFF and you can then control the output remotely.
A short pulse is less than 0.25 sec and a long pulse can be any length longer than 1 second.
These times can be adjusted by changing the value of the components.
When a short tone is received, the lower 47u discharges and pulls the base of the BD136 towards the 0v rail and turns the transistor ON. This activates the relay and the contacts take the 4k7 to the 0v rail to keep the transistor ON.
During this time the top 47u charges via the 100k but not enough voltage appears across it to turn on the BC557 transistor.
If the tone appears for a long period of time, the top 47u charges and turns on the BC557 and the voltage between the emitter/collector terminals is less than 0.3v. This voltage is too low for the BD136 to remain on and it turns off.

When the tone is turned off, the BC557 remains on for 1 second and then turns off.
The circuit is then ready to be activated again.
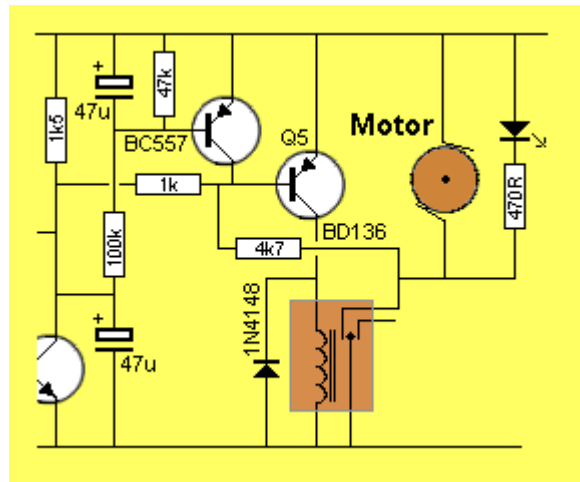

Short tone = ON   Long tone = OFF

The circuit above can be added to many different receiver circuits, thus using only one output to provide an on/off function.

2 CHANNEL TRANSMITTER
The next circuit is a 2 channel transmitter.
This circuit does not use a crystal but has a clever feature of using the two push buttons to turn the circuit on when it is required to transmit.
Click HERE for RX-3 IC datasheet .pdf
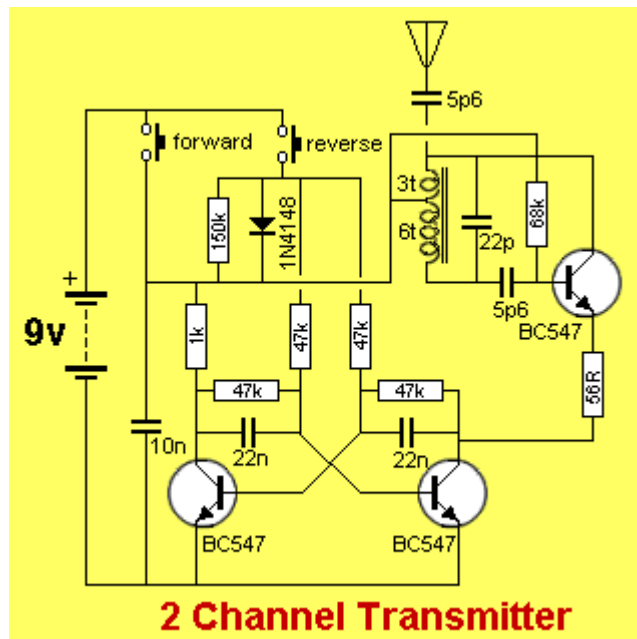
2 Channel Transmitter

We have already discussed the operation of a circuit such as this, with a multivibrator and RF oscillator. The only new feature is the arrangement for producing two different tones.
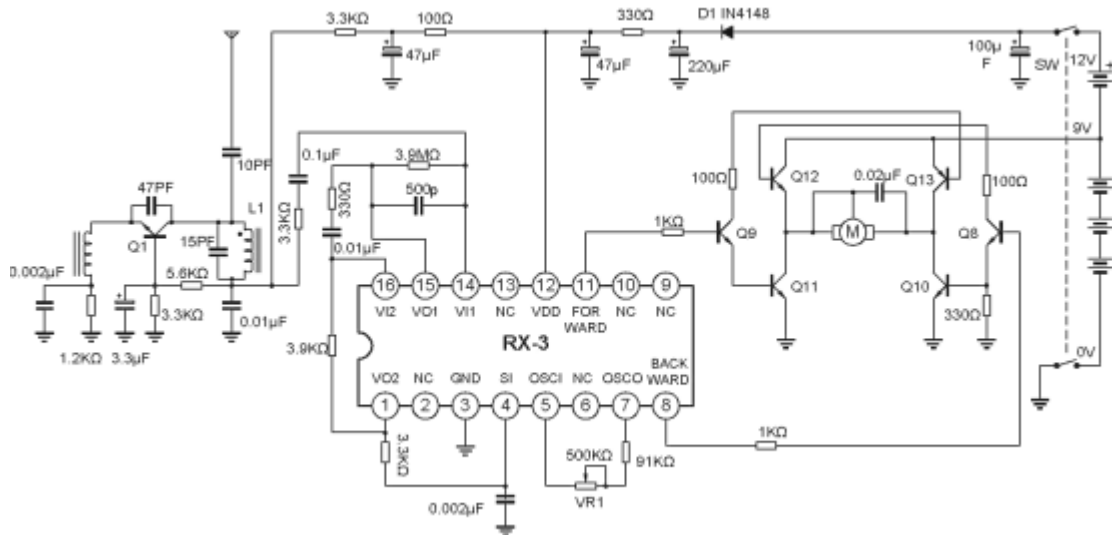The receiver requires a 1kHz and 250Hz tone for the forward and reverse outputs. The frequency of the multivibrator is determined by the value of resistance on the base of each transistor. The multivibrator is driven directly from the supply with the forward button and via a 150k for the reverse

frequency.
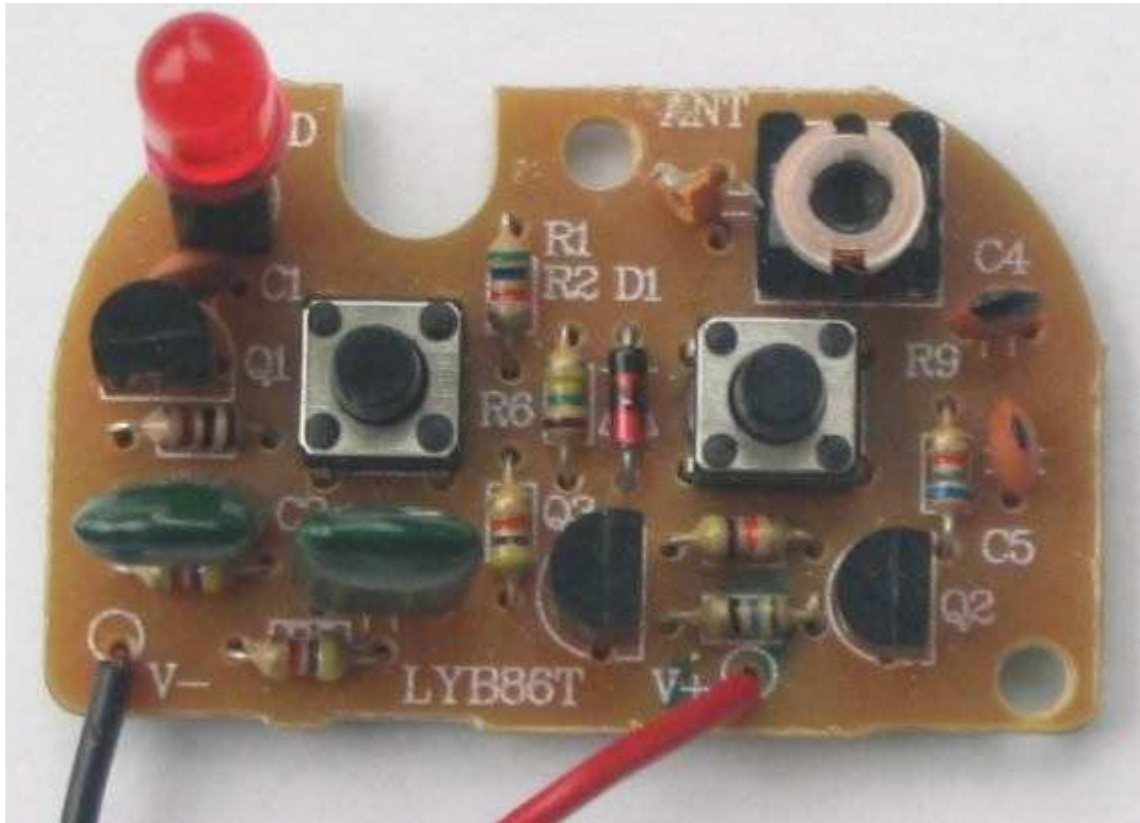
2 Channel Transmitter PC board
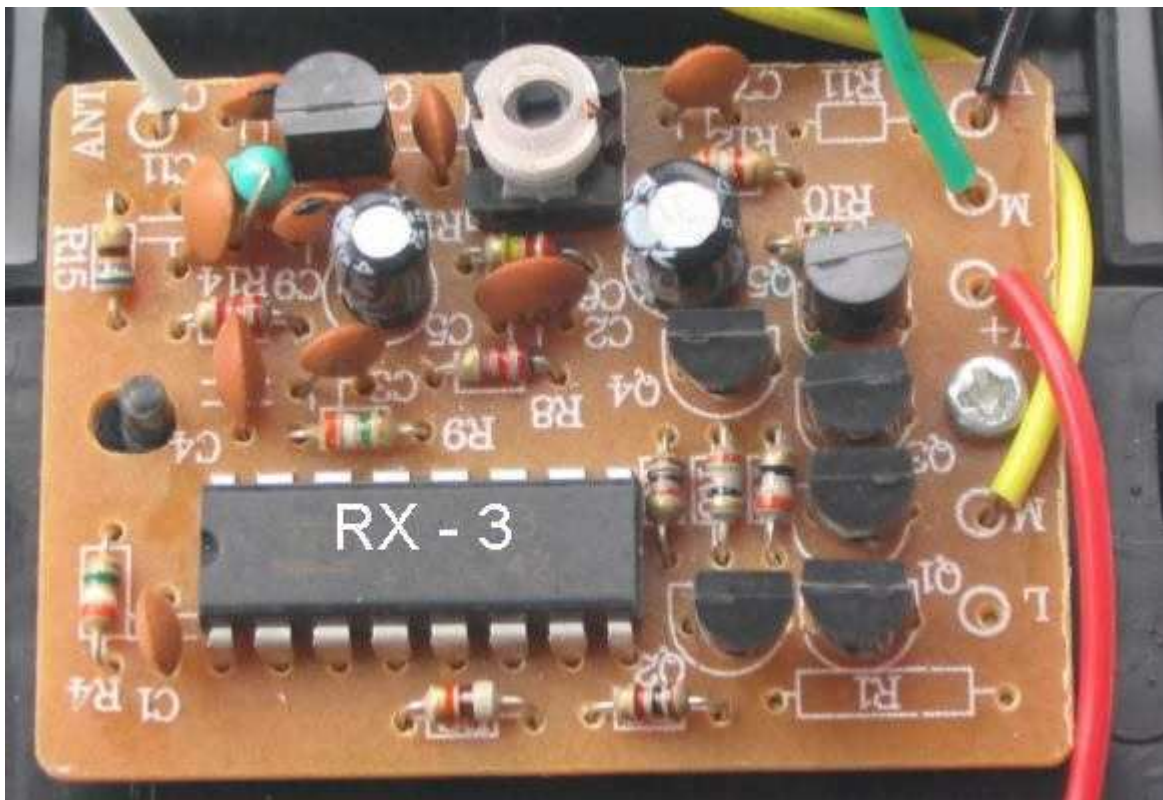
Circuit for the RX-3 IC

The circuit for the receiver has not been taken off the printed circuit board, however a general circuit is provided in the datasheet for the IC and this has been reproduced above.
Both output of the chip cannot be HIGH at the same time as this will destroy the transistors in the "H-bridge."
For the forward direction, the forward output is HIGH and this turns on Q9, Q11 and Q13.
For the reverse direction, the backward output is HIGH and this turns on Q8, Q10 and Q12.
This toy remote control car cost less than $8.00, but a defect in the design was noted.
The motor would reverse approx every 2 minutes for a short period of time, even though no transmitter button was pressed and the motor would operate in bursts when the car was distant from the transmitter. The interference was not from any electronic device in the home as the receiver was taken to an open space and it still faulted. The first transistor was removed and the fault did not occur. This means the RF transistor is generating a fault that is detected by the chip to turn on an output.
This could be due to the chip detecting a frequency of 1kHz or 250Hz to turn on an output. Random noise could be in this range and that's why the RX-3 receiver chip is unreliable.
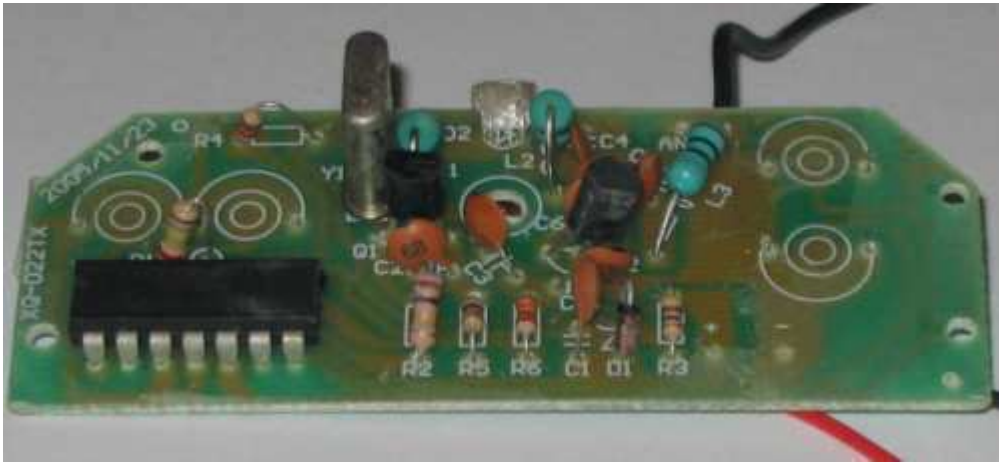Maybe that's why the car was $8.00!
Another point of comparison: the RX-3 receiver circuit consumed 4.4mA at 4.5v, while the RX-2B receiver consumed 0.7mA at 3v.
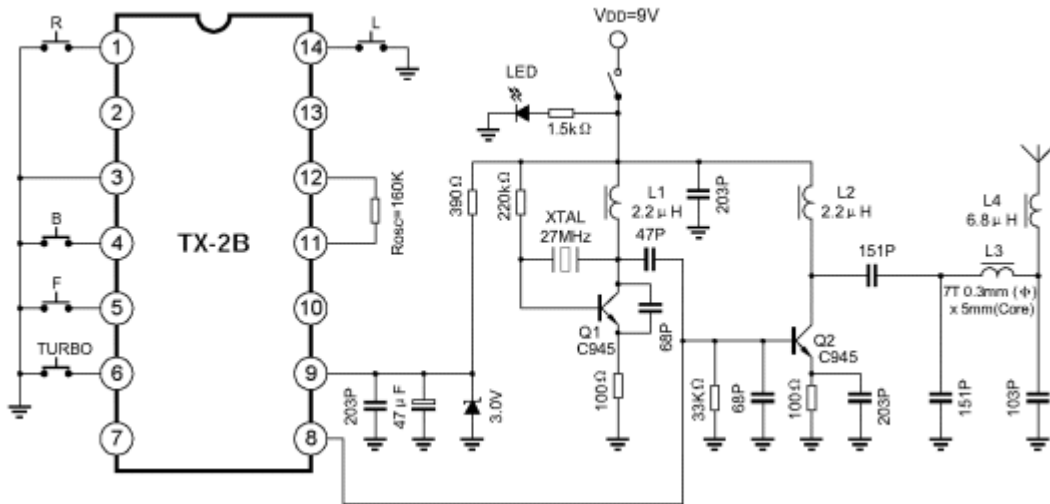

4 CHANNEL TRANSMITTER
This circuit uses the TX-2B RX-2B chipset discussed on the previous page. The chip has 5 channels and the circuit uses 4.
Click HERE for TX-2B RX-2B chipset datasheet .pdf

4-Channel Transmitter PC Board

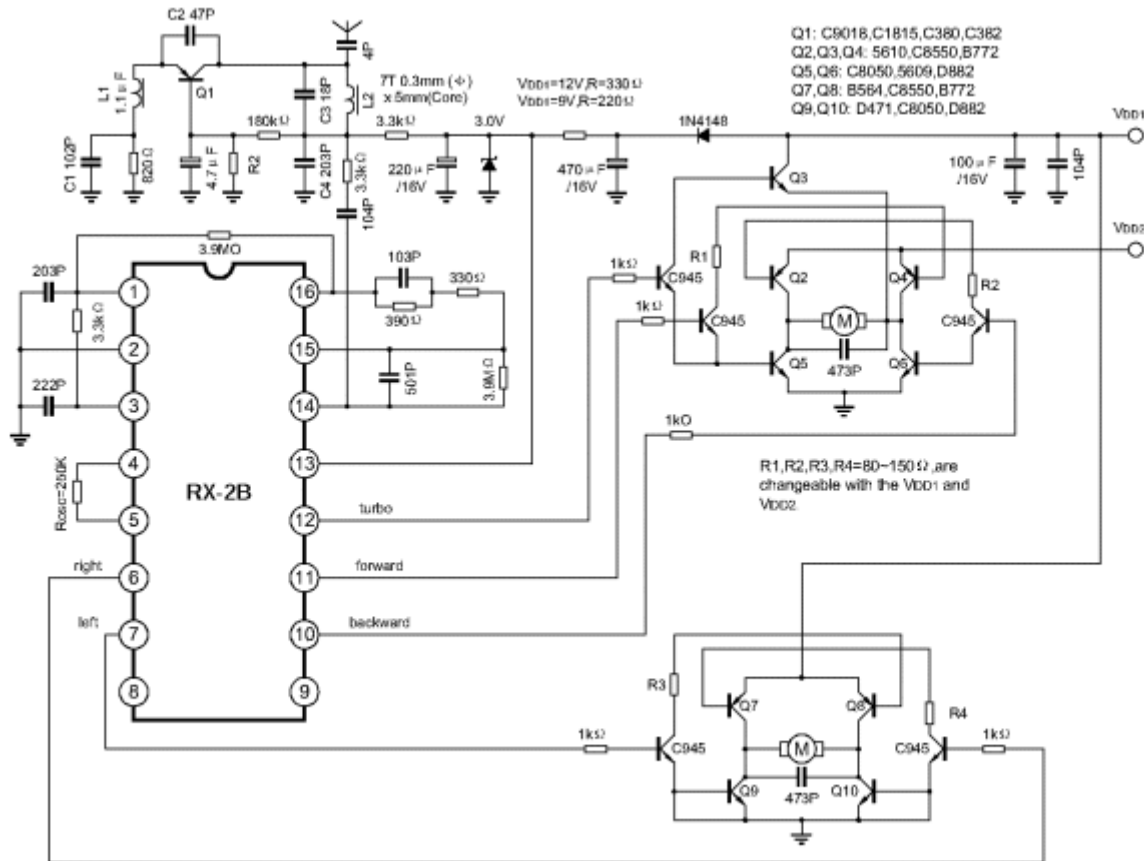## RECOMMENDED APPLICATION CIRCUIT

TX-2B circuit on datasheet

The receiver using the RX-2 chip:

4-Channel Receiver PC Board

RX-2B circuit on datasheet

We have covered 27MHz (and 49MHz) links on P1 and P2 of this article and shown how to produce a simple circuit (or buy a toy for less than $10.00) and get 4 or 5 channels.
We also showed how to produce on/off from a single channel and how to detect 27MHz with a Field Strength Meter.

27MHz can transmit at least 100 metres and provide a reliable link as proven by the countless garage-door openers on the market.
But 27MHz transmitters are fairly bulky and need a short antenna to produce a good range.
They are not suitable for short range applications where an antenna is not wanted. These include anything you want to put in your pocket, such as emergency call-buttons, garage door openers, remote car locking, alarm activation/deactivation etc.

For these applications the 303MHz frequency is ideal.
The antenna (the radiator) can be etched onto the PC board and provide an amazing range.
We have tested a 303MHz $10.00 doorbell in open space and achieved a range of 70 metres. It may have operated for a greater distance but we could not hear the doorbell activate!
The range is reduced inside a building but you generally want to see what is happening and 30 to 50 metres is ideal.
For a greater range we have shown how to increase the distance, later in this article.

The two things you will want to do when working on 303MHz transmitters are:

1. Be able to detect 303MHz to see if a transmitter is operating,
2. Determine the output power to compare one transmitter with another.

## 303MHz TRANSMITTER with 32kHz Crystal

The first circuit we will investigate has a 32kHz crystal to generate a tone so the receiver does not false-trigger.

We have already experienced a fault with a RX-3 circuit. It false triggered every 2 minutes and pulsed the motor for 1 second. As we mentioned before, this could be due to the chip detecting a frequency of 1kHz or 250Hz from the background noise received by the RF transistor, to turn on an output. That's why the RX-3 receiver chip is unreliable. 32kHz is a better frequency to detect as it does not get created from background noise.

The operation of a 303MHz circuit has been covered in our project WIRELESS DOORBELL.

We are not going over how the circuit works but explain the importance of some of the components and how they effect the range.

The Wireless Doorbell transmitter and receiver circuit have been included below:
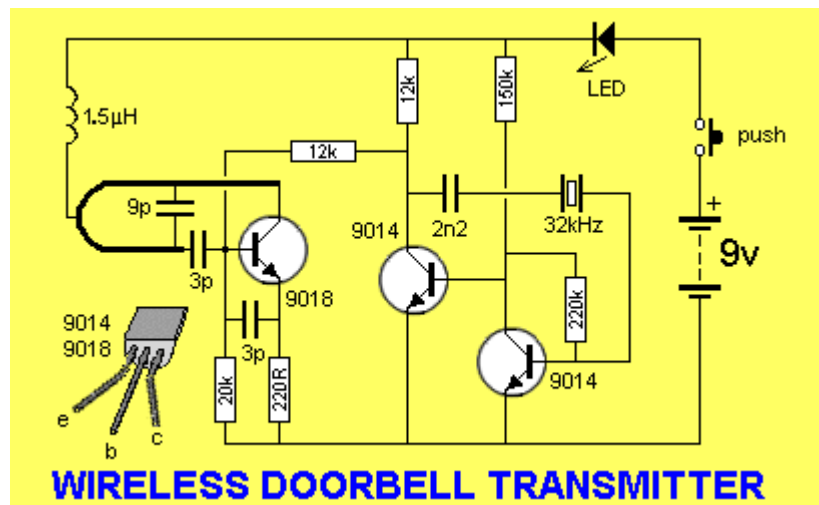
The Wireless Doorbell PC board

The most critical component is the transistor.

A quality transistor is important in the RF section and Japanese transistors are by far the best for this purpose.

The transistor used in the 303MHz oscillator has a maximum frequency of operation of 1,000MHz and this is where its gain is equal to "1," so we want a transistor to have a good gain at 300MHz.
A   BC 547 transistor will not operate at this frequency so we have used a 2N 3563 which is low cost and will operate up to 1,000MHz. The specification sheets for these transistors:
2N3563.pdf   9018.pdf

303MHz TRANSMITTER using 4069 IC

The following circuit uses a CD 4069 IC to produce the 32kHz tone and 4 gates in parallel to turn the oscillator transistor on and off at the tone-rate.
A single gate will not have enough output to pull the emitter to ground, however 4 gates will bring the emitter close to 0v rail. It must not be at exactly 0v as the 6p will not have an effect in maintaining oscillation.
The chip has 6 gates and when an input is just above mid rail, the output goes LOW. When the input is just below mid rail the output goes HIGH. The gap between detecting a low and a high is not very large and the gate will detect signals called "analogue signals."
But to get the oscillator circuit to start-up, a resistor is placed between output and input.
This will produce an oscillation at the highest frequency for the gate about 500kHz to 2MHz..
When another gate is added and a crystal connected between the output and the input, a "fight" takes place between the signal produced by the 1M and the frequency delivered by the crystal. Since the crystal has a lower impedance than the 1M, it delivers a larger signal to input pin 11 and the two gates operate at the frequency of the crystal.
The exact nature of how the signal from the crystal overtakes the signal fed back from the 1M resistor is not important however if you can consider the first gate starts to increase in frequency from zero, when the signal gets to 32kHz, it starts to activate the crystal and this signal appears on the other side and into the input pin of the first gate.

WIRELESS DOORBELL TRANSMITTER Using 4069 IC
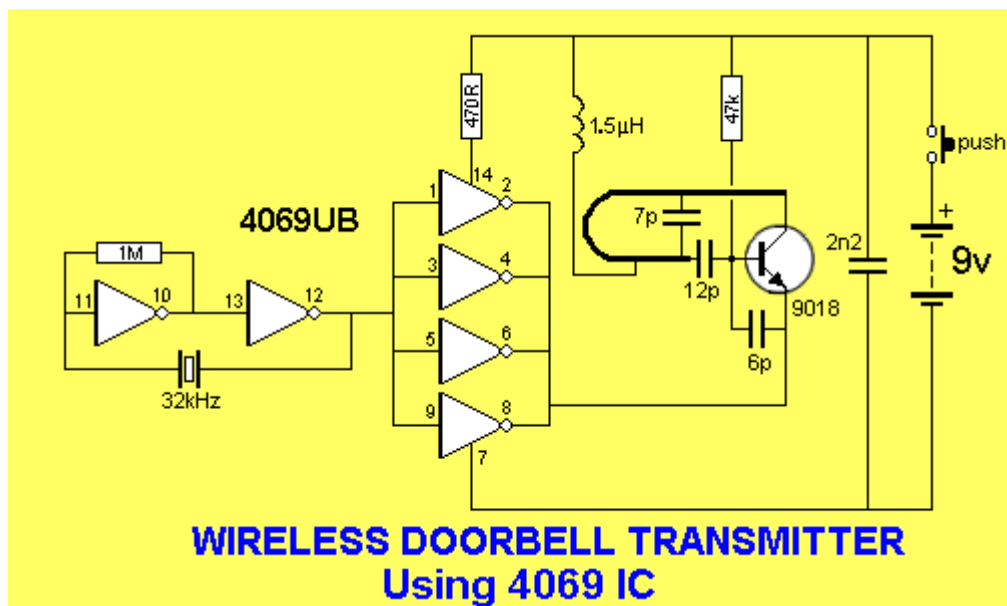
Both transmitters produce the same result, a 303MHz carrier with a 32kHz modulation (tone - although we cannot hear this frequency). Both have the same range.

The oscillator coil is also the radiator of the signal and the 1.5uH inductor on the "centre tap" of the coil can be as high as 10uH or as low as 1.5uH, with little difference in output.
The frequency may have to be adjusted slightly if the inductor is changed.
We changed it for a 40 turn air-would coil using .25mm wire on a 2mm former. This increased the range by 1 metre.
A 60 turn coil increased the range a further 3 metres and when it was spread out it added to the effect of the antenna. The two photos below show the placement of these air-inductors.

40 turn coil replacing the 1.5uH inductor

60 turn coil spread out to increase the range of the transmitter
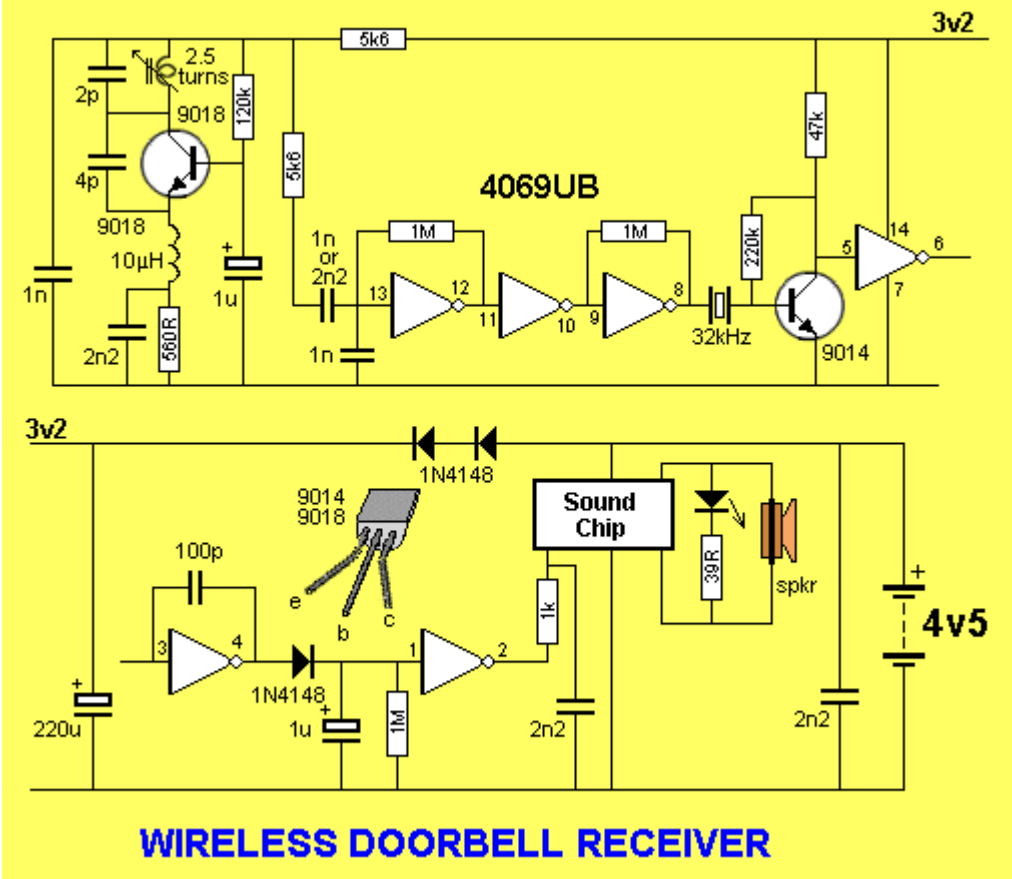
303MHz RECEIVER

This circuit is almost identical to the Wireless Doorbell article, only the pin numbering has been changed to suit the layout on the PC board. I suppose, when you are onto a good circuit, stick to it! This doorbell cost less than $8.00 and you cannot buy the components individually for less than that. This type of circuit makes an ideal basis for experimentation. You can experiment with the RF side of the circuit as well as the high impedance sections. Each gate is capable of providing a very high gain and by putting a 1M from output to input the gate is kept in a state of excitement, oscillating at approx 500kHz, if no other components surround the gate to control the frequency. This is designed to keep the gate active so that the smallest signal will be processed.

In the case of the gate between pins 13 and 12, the 1n capacitor between the input and ground will reduce the frequency enormously, as well as the effect of the 2n2 and 5k6 resistor.

The second and third gates simply increase the amplitude of the signal and do not provide any form of removal of unwanted signals.

The end result is a full amplitude signal at the left-side of the crystal with all sorts of hash and background noise, but unless the signal has a 32kHz component, it will not start to oscillate and the right side will have no signal. The crystal is the component that does most of the "detection work" and

prevents false triggering as it magically picks out the 32kHz signal from the "hash" and delivers a very clean signal to the transistor for further amplification.
This signal is amplified further to full rail and charges an electrolytic to activate a sound chip.

WIRELESS DOORBELL RECEIVER
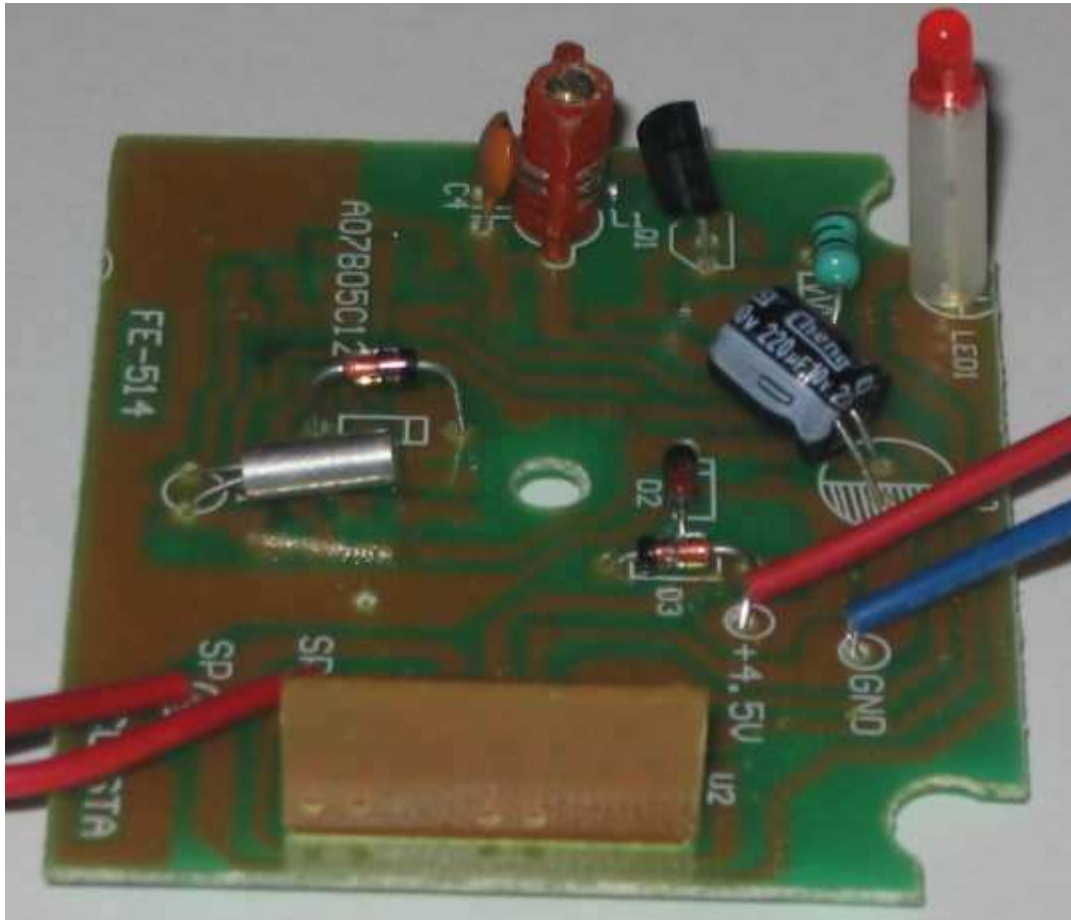
Receiver circuit topside with sound module
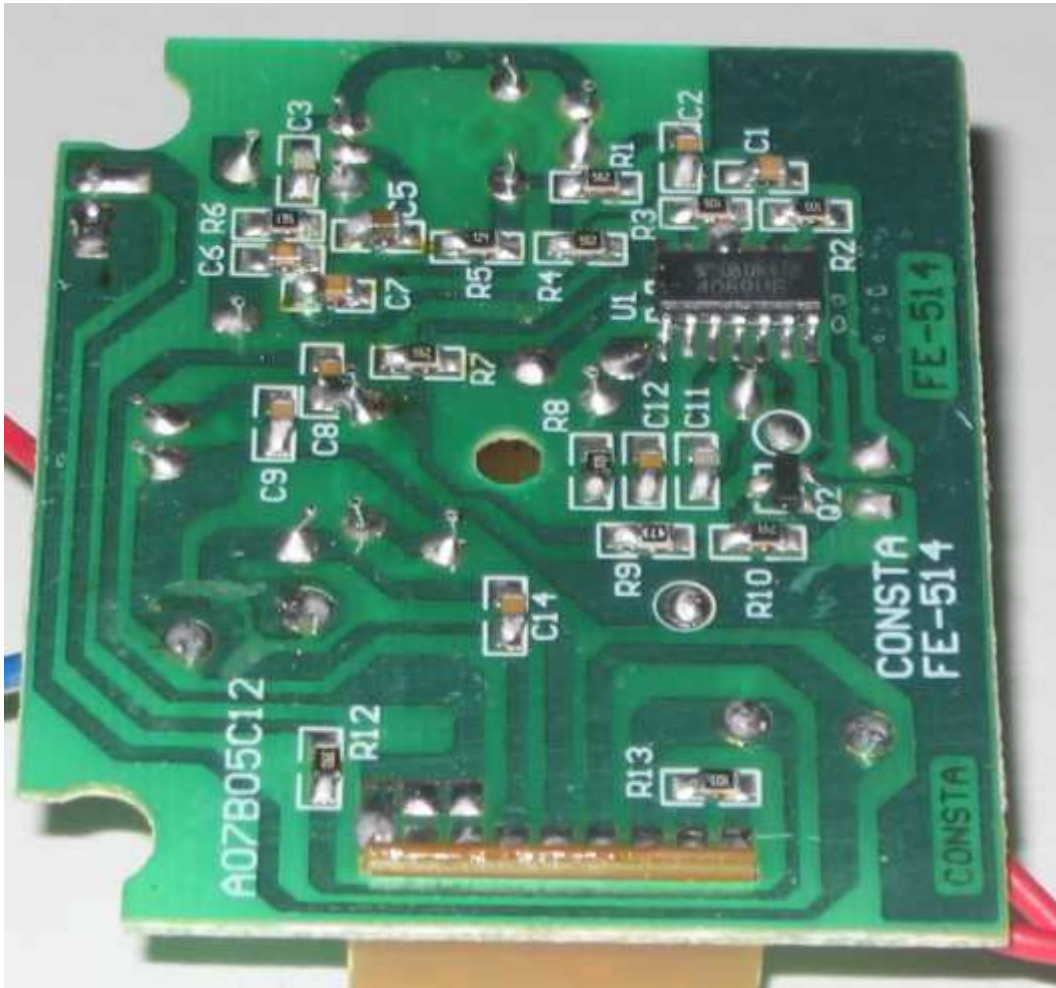
Receiver circuit underside

DETECTING OUTPUT POWER

The output of a 303MHz transmitter can be detected using [Field Strength Meter MkII](#) from Talking Electronics.

It needs to be modified to detect this frequency.

The 47p in series with the 4 - 40p air trimmer is replaced with 10p.

The PC coil on the board is cut as shown (to remove it from circuit).

A loop of tinned copper wire is fitted from the negative rail to the 10p land on the board.

This loop now becomes the "pick-up" for the signal and the 47p is turned until the LEDs illuminate to a maximum.
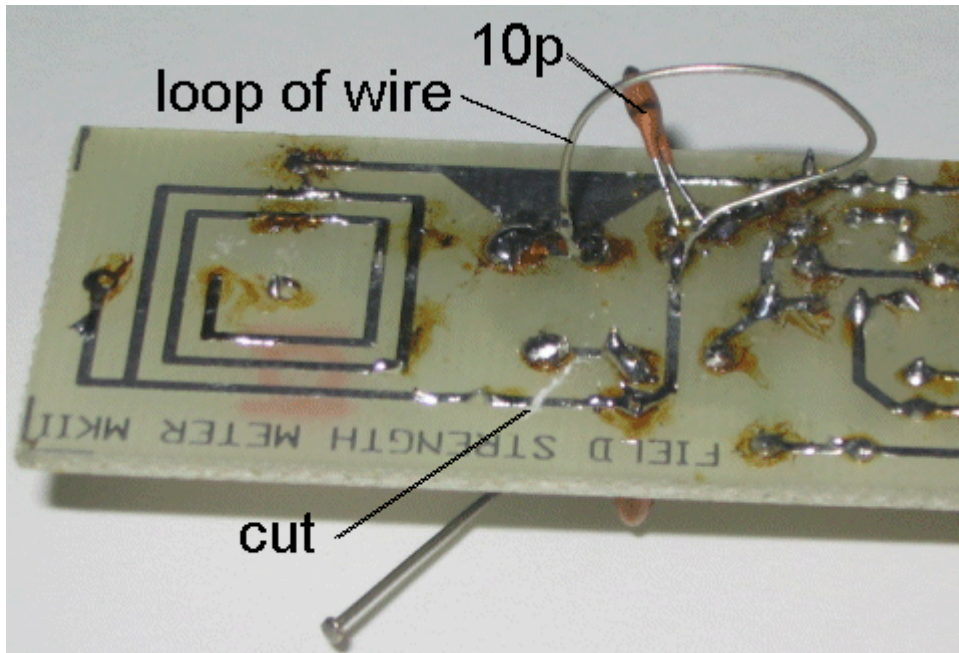
Modifying Field Strength Meter MkII

Since none of the transmitters have the frequency set via a crystal, you will need to use a transmitter with a known frequency to calibrate the Field Strength Meter. Once this is done you can use it to check the frequency and output of other transmitters.
Place the loop near the transmitter and adjust the air trimmer for a maximum.
The position of the pointer will indicate if the transmitter is near the required frequency.

FIELD TESTING
Since the range of these transmitters is fairly short, the only real way to set the exact frequency is to do a "field test."
Take the transmitter say 20 metres and press the transmit button. Keep moving away and remember the maximum range.
Adjust the coil on the receiver and re-test. If the range increases, you are peaking the coil in the right direction. If the range decreases, turn the slug in the opposite direction.
It will take only a few degrees of adjustment to peak the receiving frequency.
In this way you can compare one transmitter with another.