Chapter 1

Fundamental Concepts, Devices and Operations

In this chapter we will explore the fundamental ideas associated with radio control. We will examine some modern systems—simple types—and we will learn what devices and units are required for radio control operation. It will be fun, so let's get started!

The most fundamental unit in radio control is, perhaps, the output device. This is the element which converts the radio signals into some kind of mechanical motion, and that, after all, is probably the ultimate end product we desire from our radio control system.

Some mechanical motion is necessary to move the rudders on boats or planes, or the steering wheels of cars, or the arms, legs and head of a robot. To make each of these kinds of models do something physical, be it sail, fly, race or track over a rugged terrain, we first need this mechanical motion.

THE NECESSARY MOTIONS

What kind of mechanical motion do we need? Well, we generally need to have some kind of two-way movement; that is, left-right, up-down, turn and bank, etc. Also, if you think of steering whatever the output element (rudder, steering wheels, etc.) may be, you will also think of a *neutral* position which always makes the model go straight ahead, or the robot relax. (After all, we humans have such relaxed positions, don't we?).

We can also think of three positions for the driving elements of a model. That is, it should have a forward and perhaps reverse, and if not a reverse (a model airplane doesn't have one) then it should have a normal speed forward and a high and low speed at least associated with this "normal speed." Again we are thinking in terms of three positions of some governing element like the throttle of a model engine, or a forward, stop and reverse position of a model drive motor.

Models nowadays employ one type of drive motor, the glo-plug fuel engine that's used in racing cars and boats and almost always on model airplanes. We say "almost" because some airplane types now have electric motors. These motors are small and powerful and can give good performance, even in model airplanes. They are reasonably lightweight, and the battery supply is not too heavy for a small model aircraft to carry. But we need steering motors or an *ACTUATOR* to steer the models, or move things and certainly a drive motor to propel it, except in the case of sailplanes and sail boats.

THE ACTUATOR

Let's think of what an actuator is. It is a kind of motor which will turn one direction or another when electricity is applied to the winding of a coil associated with it. But it does not rotate! It has a magnet which is free to turn on an output shaft, and when the electricity is applied in one direction (plus to minus on the coil windings) the magnet will rotate in one direction and stop. When the battery connections to the magnet are reversed, the magnet will cause the output shaft to rotate to the other extreme in the opposite direction. When the magnet moves, the created force can cause a rudder to move, or other relatively lightweight, low-force (torque) output element to move. But it is not as powerful, nor as versatile as a small electric motor with a good gear system. Usually the small electric motors run so fast that we cannot use the output directly from their motor shaft until we slow it down through gears. Realize that when we gear down a motor, we also get more turning power or torque from it, and we want that also. The only time we want the fastest possible rotation with as few gears as possible is when the electric motor is used as an airplane engine and turns a propeller. Then we want speed as well as torque. Sometimes we want speed in rotation if we use the motor to drive the wheels of a race car, or turn the propeller of a model boat. But for steering or movement of an arm or other device, we want a reasonable speed—not too fast—and quite a bit of power in the output shaft turning ability (torque).

SIMPLEST ELECTRIC MOTOR CONTROL

With this bit of background on why we are interested in electronic control of a motor, let's now examine the fundamentals of electric motor control, using wires first, and then using a radio system as the connecting element between the controller and the model. Figure 1-1 shows the most basic arrangement possible. Remember that you might be able to substitute an actuator for the motor as it looks about the same physically, has two output leads and an output shaft and reverses direction of movement when the battery connections are reversed. However, the actuator does not rotate; it just turns approximately 60 degrees each way from its neutral.

The basic idea behind radio control is to send a command or series of commands from a control point to the model being controlled and to have the model follow the commands exactly as directed. The person sending the commands will be referred to as the controller.

Suppose a controller wants to *start and stop an electric motor located* some distance away. Fig. 1-1 shows that four items are necessary: a switch the controller may turn off and on (A); connecting wires that link switch, motor and battery (B); a battery which causes the motor to run when the switch is closed (C); the motor itself (D). The control operation is simple: when the switch is closed, the motor turns in one direction. When the switch is opened, the motor stops, although it may coast a bit without a brake of some kind.

This is a very limited operation but it could be used to start and stop a boat drive engine, the motion of a car, or an electric airplane engine. Speaking of electric motors, let's look at one which is used in a control system, just to have some idea of the size and type of electric motors that are a fundamental part of almost all modern radio control systems. Notice that we always hedge our statement with that "almost"? We are quite certain that some system probably doesn't use an electric motor.

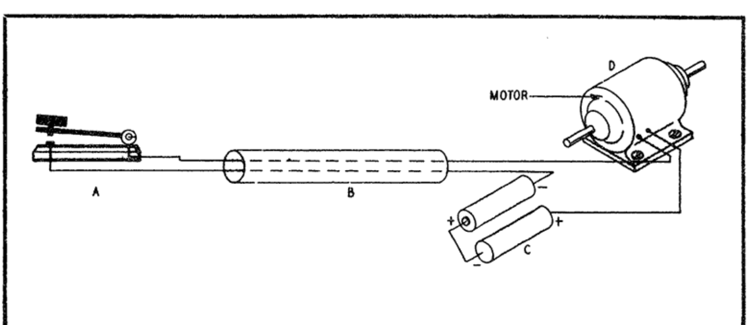


Fig. 1-1. A simple electric motor start-stop system.

Fig. 1-2. Typical electric motor used in modern radio control systems.

Again we must hedge a little. It might be that in some larger radio control systems, and other types of control systems, it is necessary to use much larger electric motors to get that enormous amount of physical power needed. In that case, the motors would be very much larger. The battery or primary supply of electricity must have larger capacity in this case, too.

THE "GLO-PLUG" ENGINE

The glo-plug engine is used in model aircraft, boats and cars as a propelling engine. See Fig. 1-3. To move the throttle arm, which is right next to the input air venturi, in order to close the fuel intake line slightly and also close the exhaust port slightly as the speed is controlled, we need a physical motion. This is accomplished by having a small electric motor geared to an output shaft. The electric motor is made to run forward or backward by radio signals. So even though we use this kind of engine as a propelling system in the model, we need electric motors to make them operate as we desire. We cannot reverse direction of rotation of this kind of engine, and usually they are not geared to the propeller they drive. They do have a kind of gearing or pulley drive to the wheels of model racing cars as we shall see later.

ELECTRIC MOTOR DIRECTION OF ROTATION

What must be done to make the *electric* motor reverse its direction of rotation? The idea also will apply to the reversing of an actuator. In Fig. 1-4, the electric motor is known as a permanent magnet (PM) type. There are other types, but with this kind you simply have to reverse the battery connections to make it run in the opposite direction.

Notice the control switch. In its center position it does not make contact to either of its lever points. The motor, then, does not run, because the circuit is not complete. But when pushed up, the common motor lead is connected to the top contact which applies a plus voltage to this connection. Since the other motor winding is connected permanently to the minus end of battery number 1, the motor runs in one direction. Moving the switch to the down position

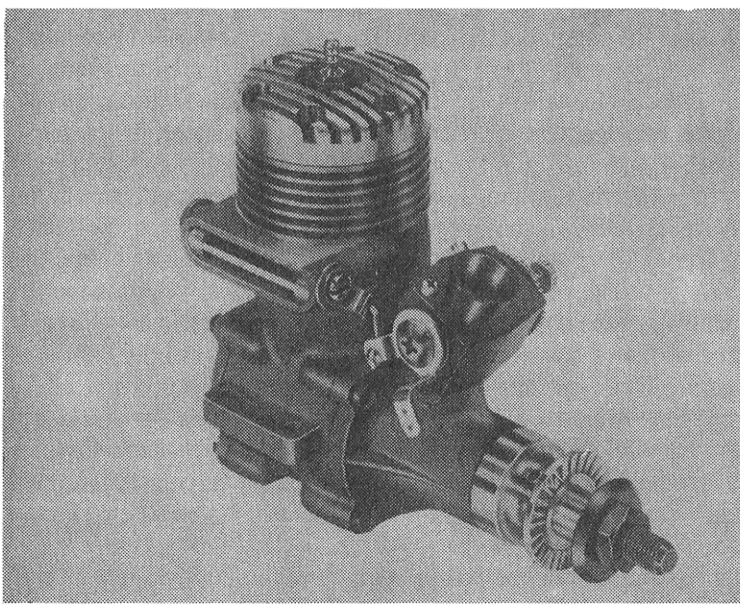


Fig. 1-3. Glo-plug engine with throttle control.

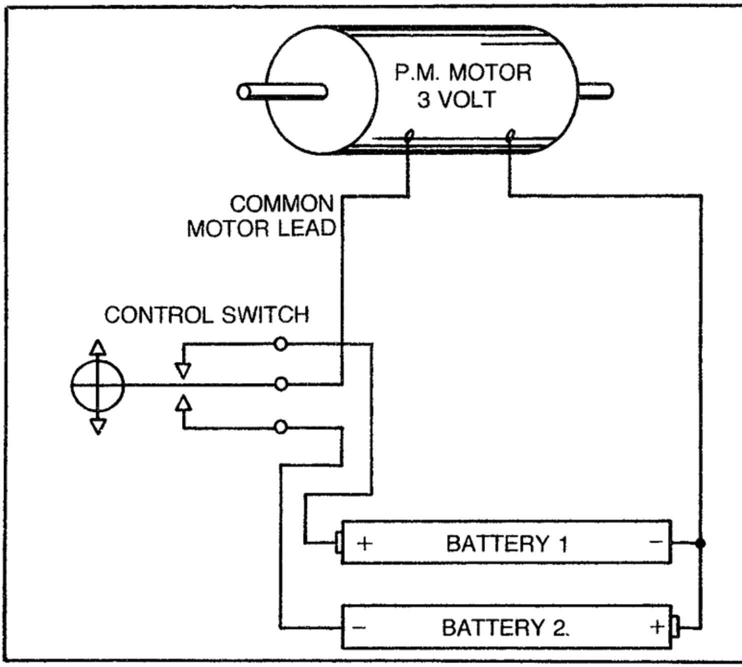


Fig. 1-4. Reversing direction of a pulse-modulated (PM) electric motor.

changes the polarity of the electricity to the motor leads by connecting battery number 2 into the circuit and eliminating battery number 1, so the motor will run in the opposite direction. With this simple switch arrangement we have now accomplished the forward, reverse and neutral (stop) positions which we said are needed for radio (or other) control systems. We did this with a wire connection to the motor, and this is a good way to start out. The wires from the switch to the motor can be pretty long—up to, say, 25 feet— and this permits you to walk around and follow the model as you move the switch to make it go. In Fig. 1-5, a small airplane on a tower has its electric motor connected through a nonreversing switch, such as in Fig. 1-1. The plane takes off and flies around the plylon. It uses a slip ring connection to the rotating arm that supports the model and which is fastened to the top of the pylon tower. As the model rotates it flies outward and thus rises from the floor or carpet. You can test complete control systems with a wire connection between the control box and the model.

You must be sure that the motor runs in the right direction to make the propeller *pull* the airplane. If it does not, reverse the connections to the battery. There is no motor driving the support arm; all the power to pull the airplane and make it fly comes from its own propeller.

A RADIO-CONTROLLED MODEL CAR

Before we examine what can be done with a simple electric motor and a connecting control system, let's look at a modern radio-controlled toy, such as the little car in Fig.1-6.

This model uses a *short-range radio system*. Notice the antenna from the little hand-held transmitter. The car operates as follows: when you turn the drive motor on by moving a switch on the car body, the car will run forward without any signals being sent to it. When you press the little switch on the radio transmitter, the car will back up. It never reverses in a straight line, however. The arrangement of the front wheel, shown in Figs. 1-7 and 1-8, causes the car to back up in a circle.

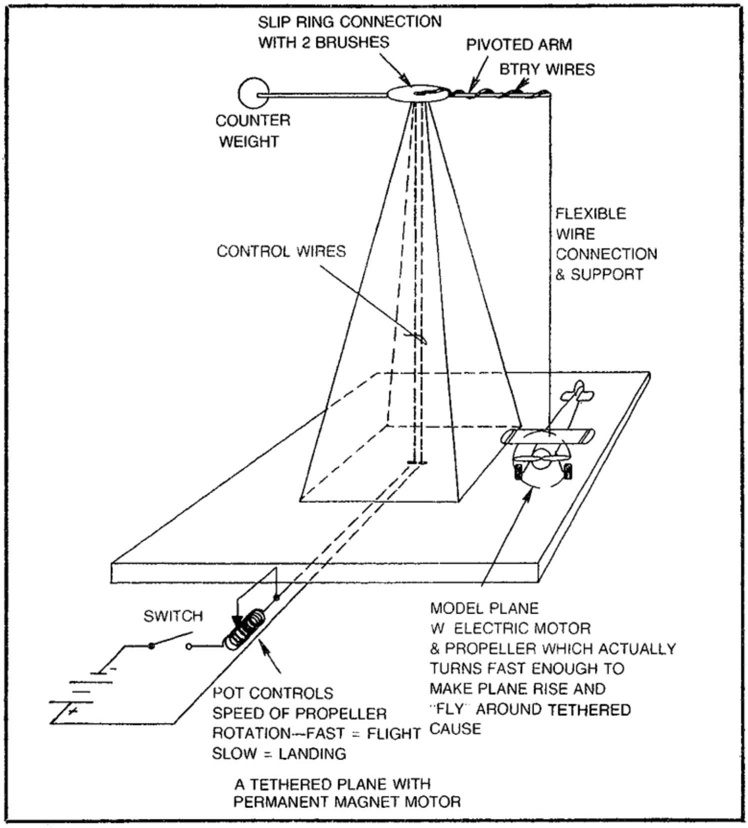


Fig. 1-5. A tethered plane with a permanent magnet motor.

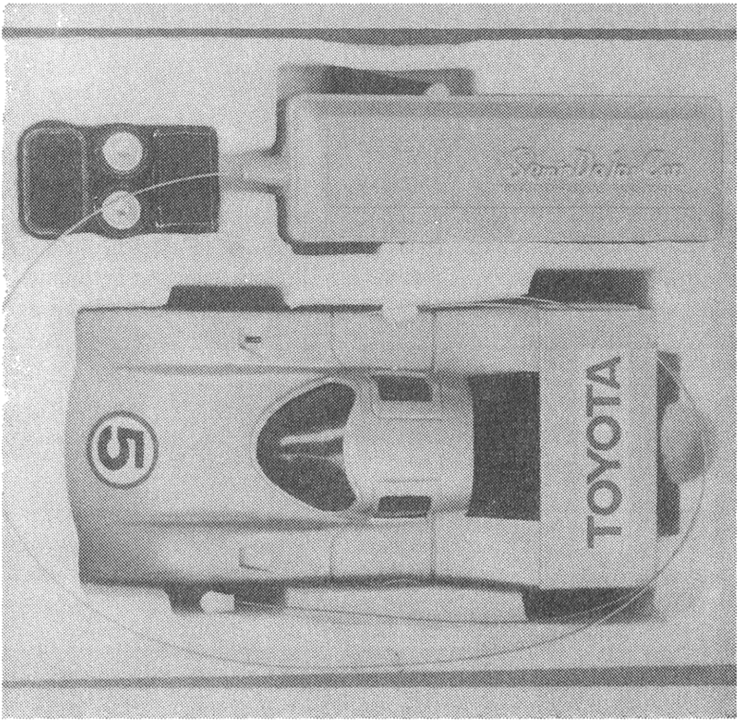


Fig. 1-6. Boxed Toyota radio-controlled car.

The center wheel is the one on the floor. The two others are for appearance only. This means that the car changes its direction if you *release* the radio transmitter button, so you can get a *kind of steering* with this arrangement. When the car goes forward, the steering wheel moves backward in its slot so that the car goes straight. The position of the wheel as shown in Fig. 1-7 is when the car is in reverse. The steering wheel moves freely to this position just by friction drag on the floor.

The Elements Of The Radio Link

In this simple model, whose parts are shown in Fig. 1-8, and relative size in Fig. 1-9, there is just a simple electric motor, batteries, a receiver inside the car body, the transmitter and its switch. The wires of our previous system have been replaced by the radio link, making this model a radio-controlled one.

To understand what happens in the radio part of the system, see Fig. 1-10. You can see that the switch of Fig. 1-4 has been

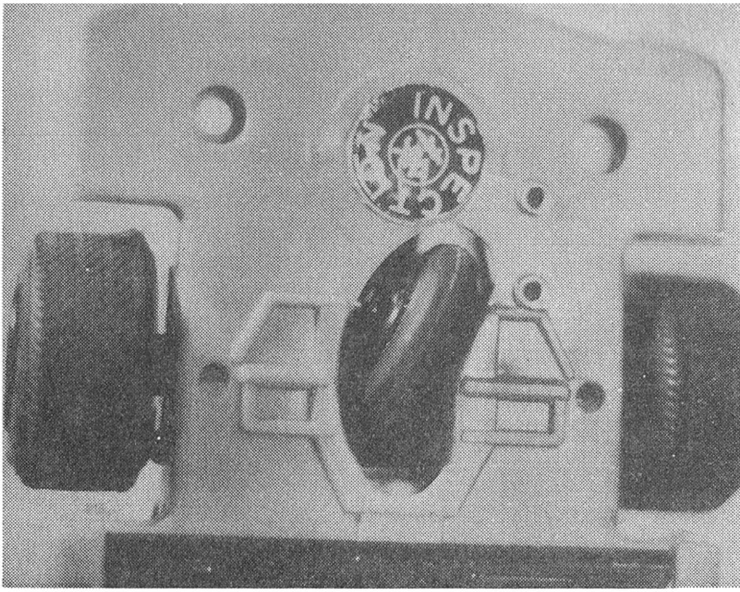


Fig. 1-7. The mechanical steering arrangement of the toy car.

replaced by an identical kind of unit called a *relay*. It also has two contacts: (1) and (2). The armature of this electrically-operated switch moves down with a signal to make contact with (2), and when there is no signal, the armature rests against contact (1). Since we described how the motor would run in Fig. 1-4, we won't repeat that here, but the two are identical in operation. The *only* difference is that we now close the relay-switch remotely by a radio signal from the little transmitter when we push its on button.

The Relay

We can use a lot of relays in radio control systems. Some types most used are shown in Fig. 1-11. Relays are operated by transistors and may have one or two armatures in most common applications. When one armature is used that makes two contacts as we have shown, this is called a single-pole double-throw relay. When two armatures make contact with two contacts each, the relay is called a double-pole-double-throw type. We will use both kinds as we proceed.

One Type Of Transmitter

We have already seen the little transmitter in its case, and if we judge from the space for the battery, we can assume that the

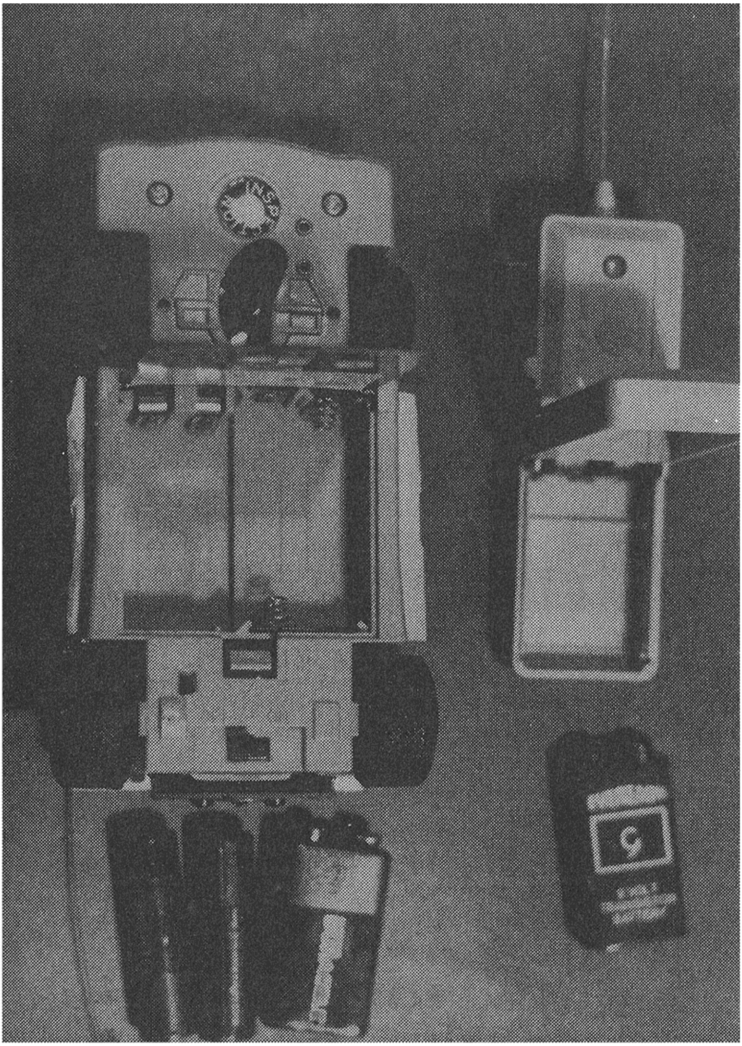


Fig. 1-8. The parts of the radio-controlled car, including car, transmitter and batteries.

electronic circuit inside the rest of the case must be very small and compact indeed. This is true, as shown in Fig. 1-12.

You can judge from the hand in the figure how small this little unit really is. A few transistors, a crystal, a coil, a resistor and capacitor or two and that is all there is to it. Notice the off-on signalling switch on the lower side of the case—the protruding black bar. Perhaps you can see its workings better in Fig. 1-13.

Fig. 1-9. Battery installation is simple for many toy R/C systems.

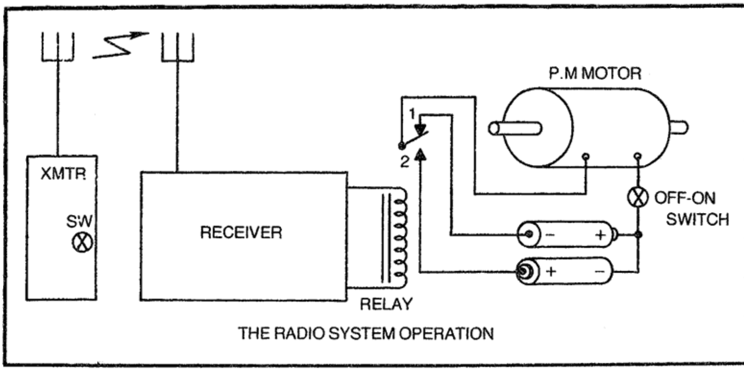


Fig. 1-10. The radio system operation.

Nothing about the transmitter needs adjustment and nothing is critical, except the antenna length. The antenna must never be changed after it is adjusted for proper range and operation. Batteries, of course, must be kept in good condition, but since the only time you have drain from the battery is when you transmit, these last a long time if they start good. Later we will see how rechargeable ni-cad batteries are used in place of the dry batteries shown here.

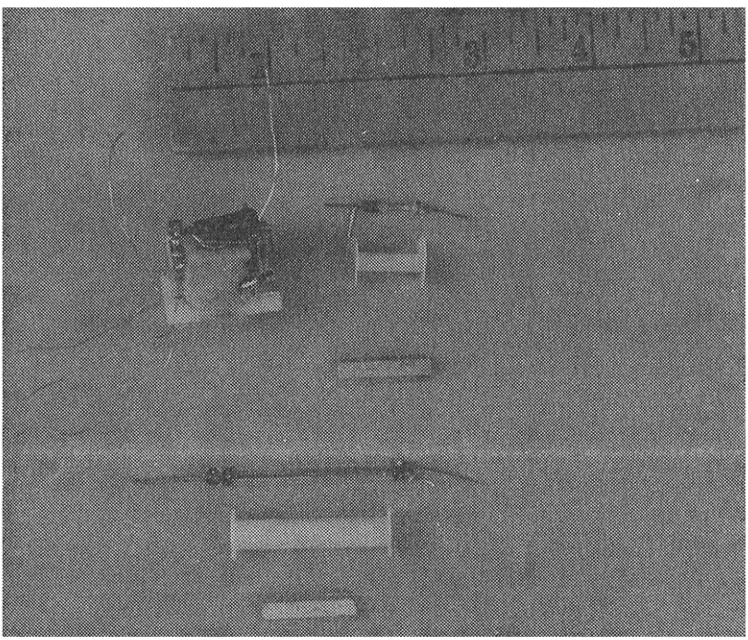


Fig. 1-11. Some types of relays. At the top left is a standard sensitive relay. At the top right is a small reed relay. At the bottom is a larger reed relay. Reed relays can also be closed with a magnet, shown below each.

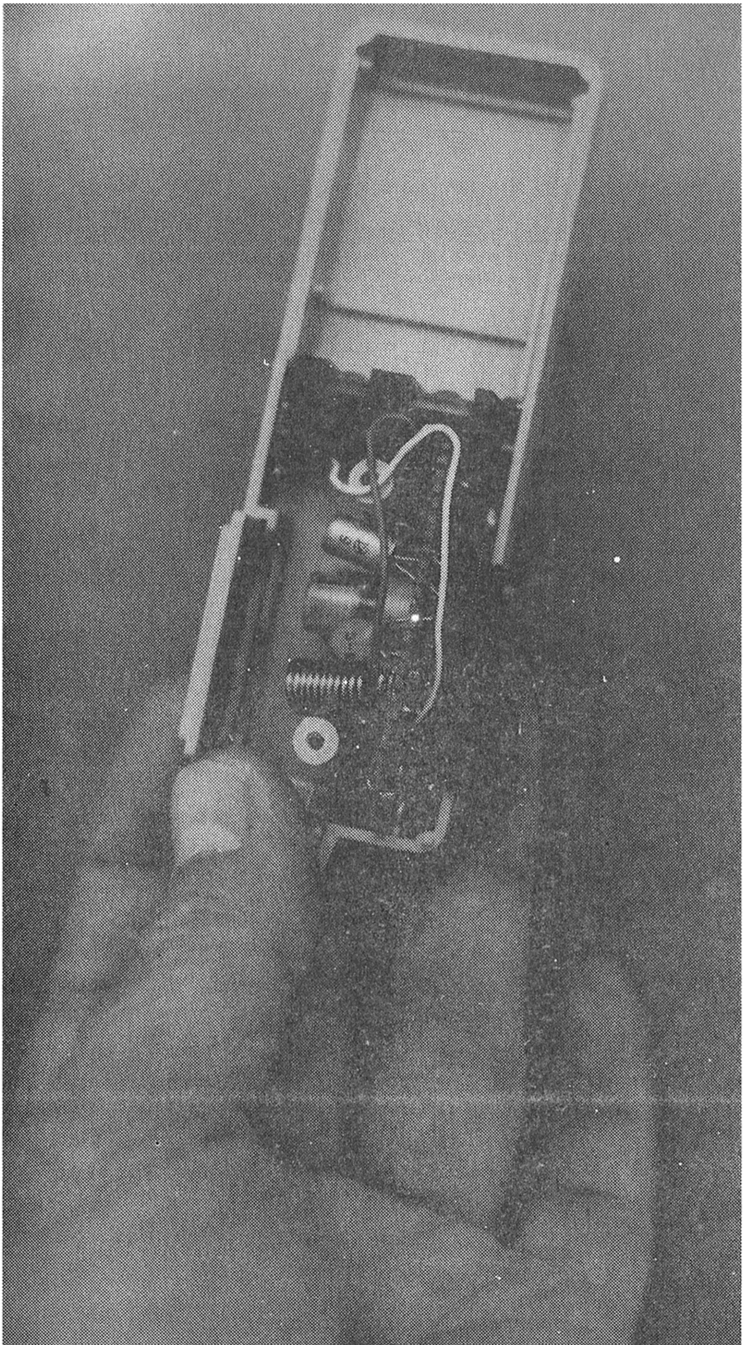


Fig. 1-12. The transmitter of toy R/C car.

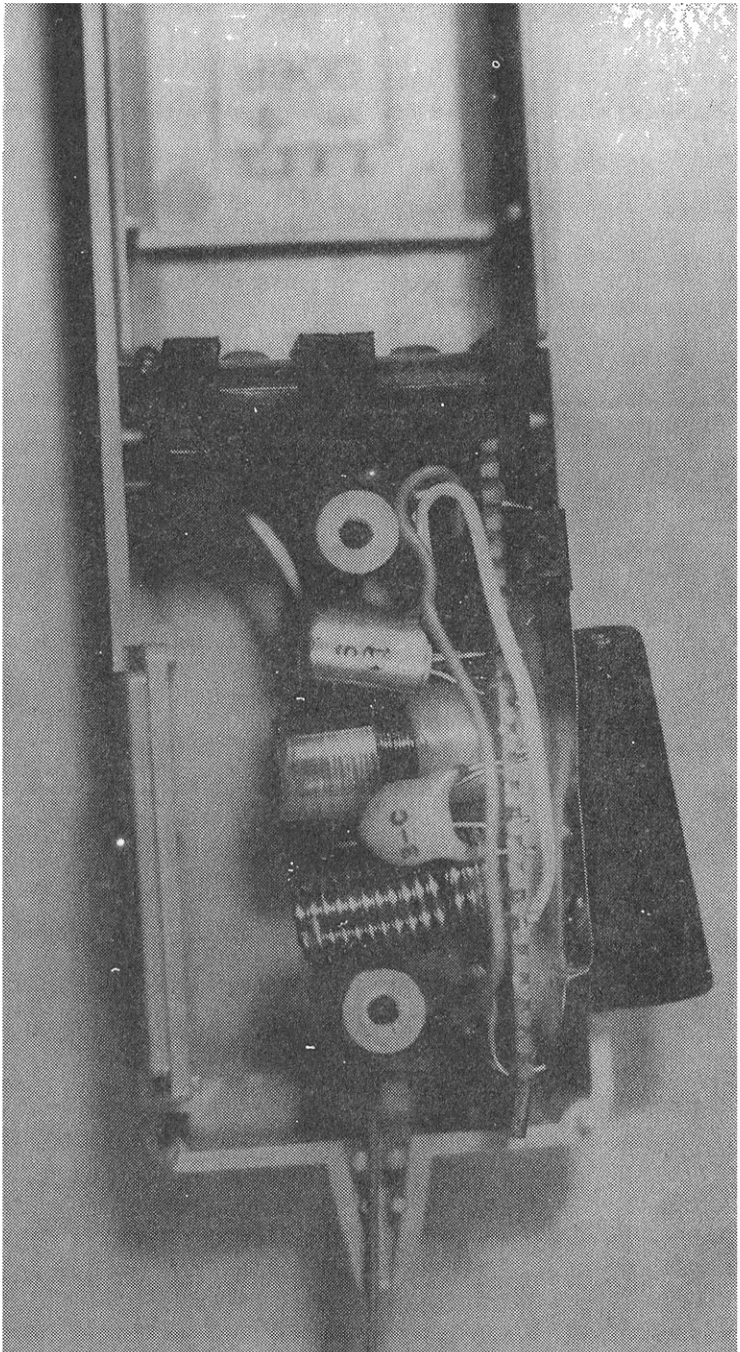


Fig. 1-13. A closeup of the transmitter working.

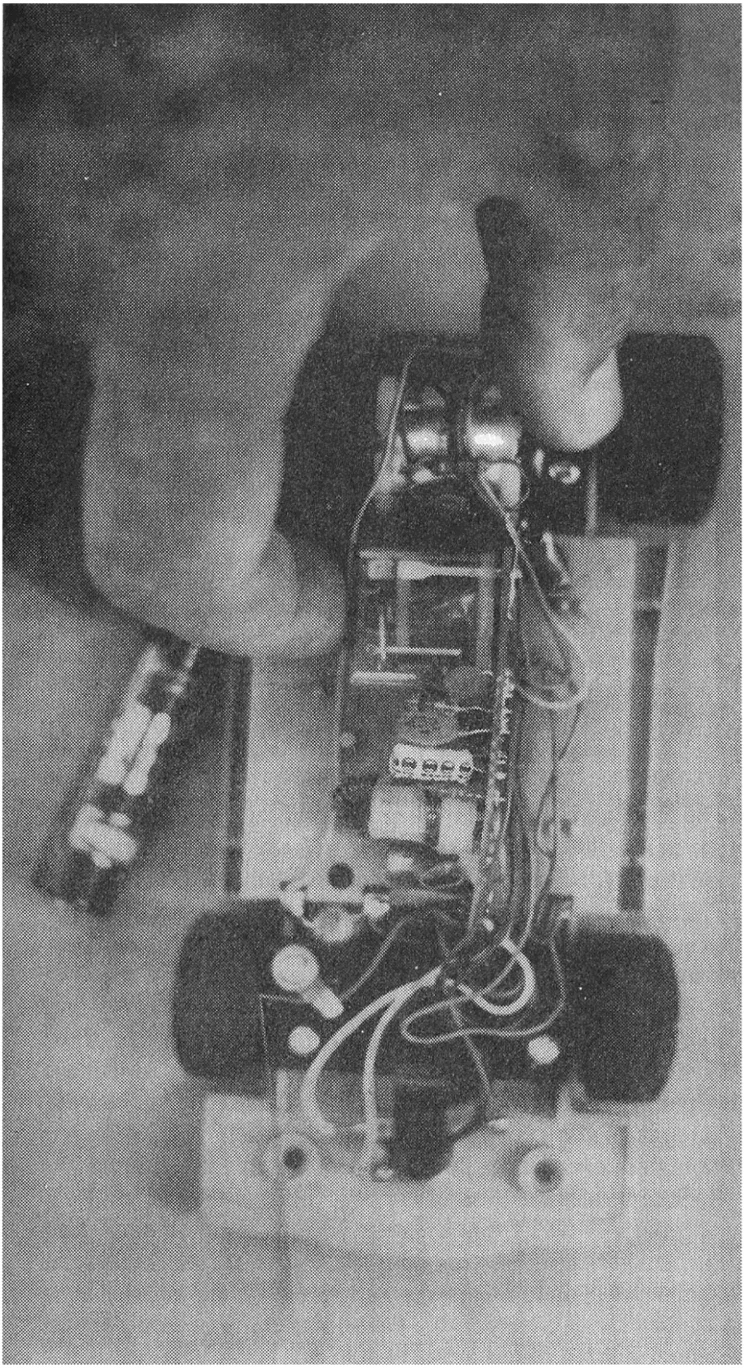


Fig. 1-14. Inside the model radio-controlled car.

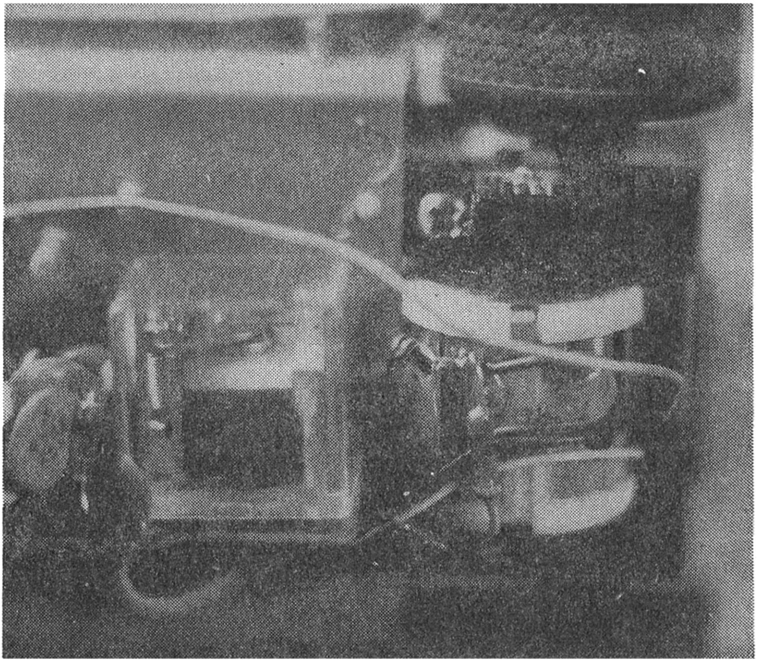


Fig. 1-15. Closeup of the relay and drive motor. Note the capacitor across the motor terminals and the relay armature.

The Receiver

The receiver is always in the model, and this receiver, like the diagram of Fig. 1-10, uses a relay. We make a point of saying this because in many radio-controlled systems nowadays, we don't have to use relays. Instead, we use transistors to do their job. The reason for this is smaller size, simplicity, and no mechanical moving parts to worry about or adjust. But using relays is a good way to start, so examine the inside of the model in Fig. 1-14.

The receiver is that electronics section just to the left of the relay. Isn't it small and compact? The wiring to the off-on switch and battery compartment runs forward underneath the receiver chassis. The antenna of the receiver is also critical and on radio control systems, you never lengthen or shorten this antenna, either.

A close-up of the drive motor and the relay is in Fig. 1-15. Between the PM motor and the rear wheel it turns, a small gear arrangement gets more power and slows down the car. These small motors can turn at up to 6-7000 revolutions per minute and that is far too fast for driving a model car. Some circuits for energizing and reversing the drive motor are shown in Fig. 1-16.

Some Technical Details

Just in case you are knowledgeable in electronics and feel a sudden desire to build a simple radio link to go with some little system you have in mind, we give you the circuit schematic of a short-range transmitter in Fig. 1-17.

This is a so called Part 15 transmitter which simply means that the FCC does not require a license for its operation. It will operate in the 27-MHz band and causes a tone signal to be sent out when you press switch S1. There is a power switch S2 to turn the unit off and on.

To tune the unit, connect a 25 mA meter in series with B1. Remove the crystal and flip S2 to on. You should get a reading of about 2 MA. Turn the core in T1 all the way in. Then insert the

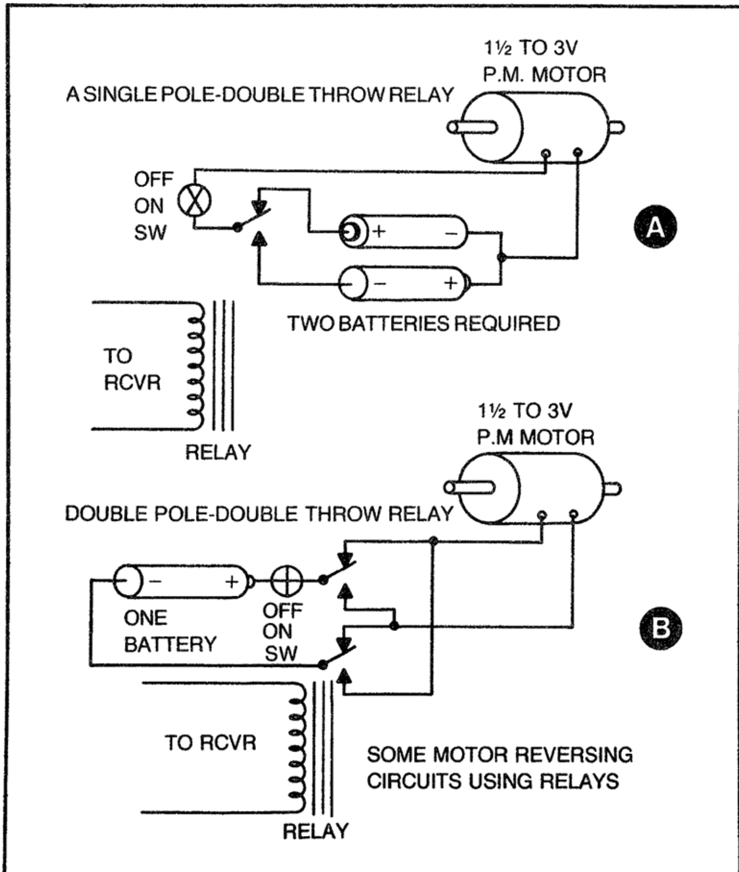


Fig. 1-16. Some motor-reversing circuits using relays.

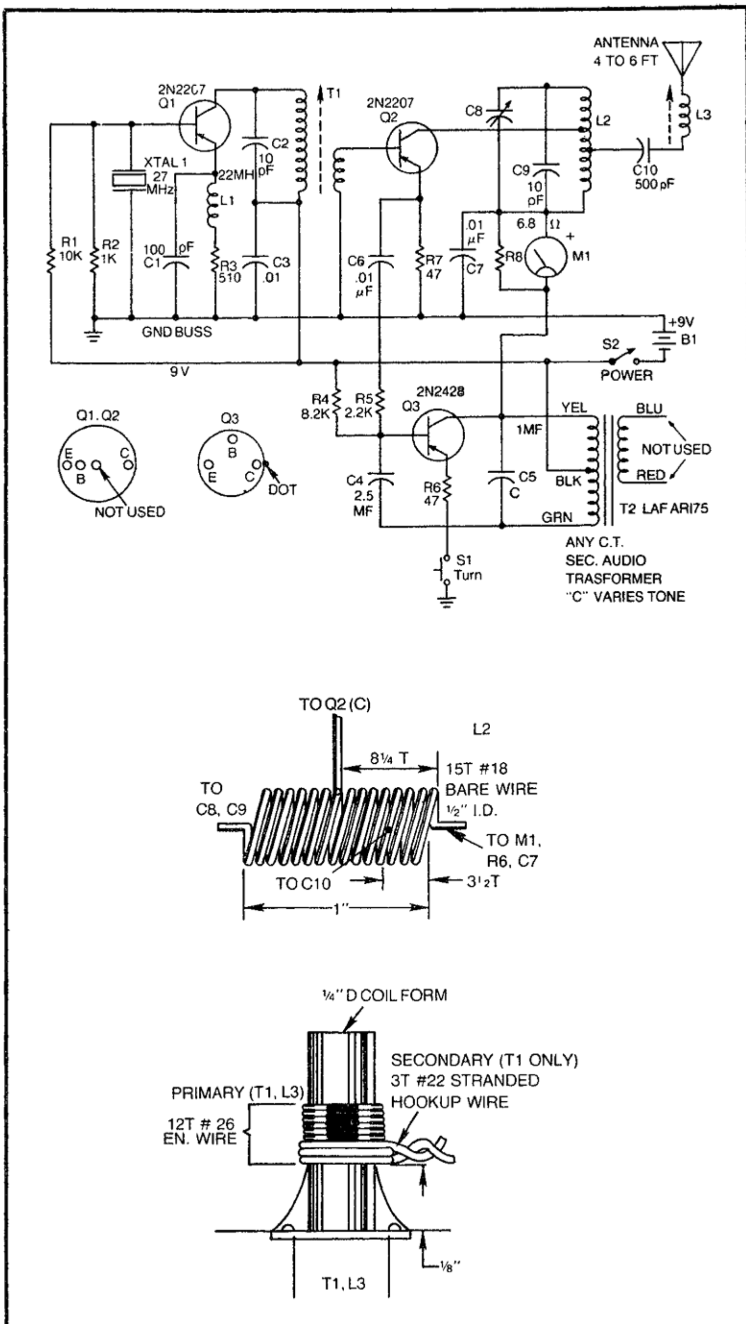


Fig. 1-17. A short-range "Part 15" transmitter.

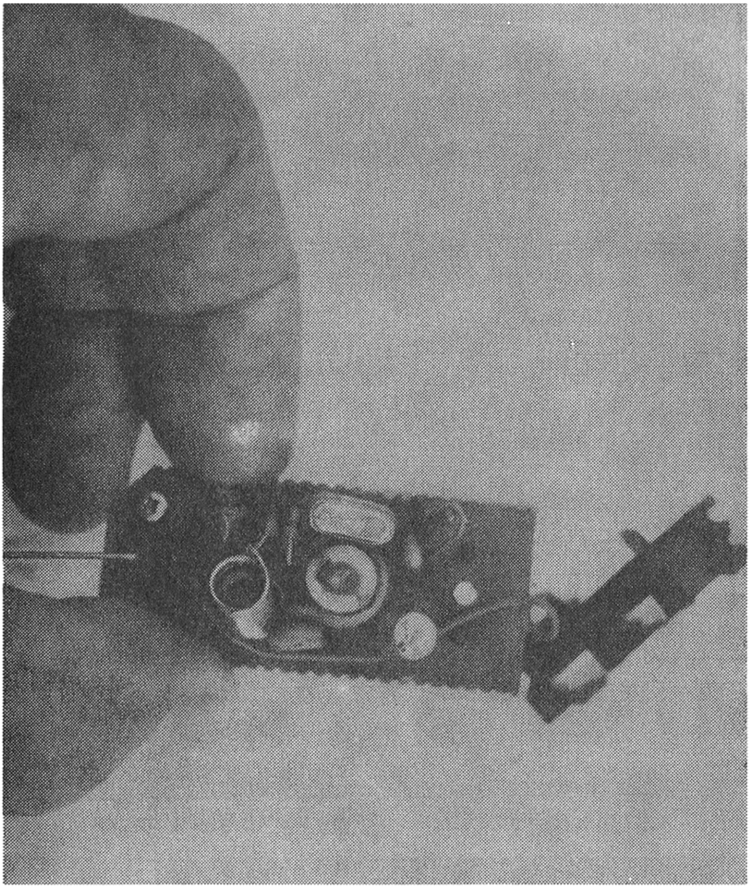


Fig. 1-18. Coil core adjustment slot.

crystal and rotate the core slowly outward. You should see a sudden jump in the meter hand. Move the core one full turn further out.

Extend your antenna fully. Hold the transmitter case and put the core of L3 about 2/3 out of its winding. Turn C8 with an insulated screwdriver and watch the meters. They will *drop*, indicating that you have tuned the transmitter. L3 may need adjustment to keep the total current less than 11 MA. When operating properly, Q1 will draw about 2 to 3 MA, and the total transmitter current with both transistors operating will be about 12 MA. Tune C8 and L3 for a minimum dip at about 8 MA when the antenna is very short. With modulation, the current drain is about 20 MA. In Fig. 1-18 you can see the screw adjustment inside the left coil, a slot which permits the powdered iron core to be moved up and down (out and in) the coil.

Operating The Car By Sound Signals

If you don't want to use the radio link in this kind of a control system, you might want to experiment using a *sound signal* to make it operate. Realize that a continuous tone is necessary at this stage of development to make the car back up, but you might whistle to make it do this and you'd have fun watching it go forward *until* you whistle. What is needed is a sound-operated relay, shown schematically in Fig. 1-19.

You can get a kit with a transmitter to assemble and a receiver already built that works fine for this kind of radio control system, and other, even longer range models. One is available from Ace R/C, Higginsville, Mo. 64037. Ask about their WEE 1 transmitters and receivers. The transmitter is shown in Fig. 1-21. It is about 4 inches by 3 inches by 2 inches and operates with ni-cad rechargeable batteries. Its circuit is shown in Fig. 1-21. The receiver is not shown here but is available as a companion unit. The transmitter and receiver can be used to control a model airplane at quite a long range and may be obtained with capabilities on any of the FCC-allocated radio control frequencies listed in Fig. 1-22. It is important to know that in the 26-27 MHz range, some frequencies, especially 27.255, are shared with other kinds of services, so you might get interference from these machines and transmitters. Also, you might get intereference from stations in the 72-75 MHz region. Model car racing equipment does operate on the other 27-MHz spot frequencies, and due to the splendid selectivity of the equipment does not suffer from the adjacent CB transmissions unless a nearby CBer

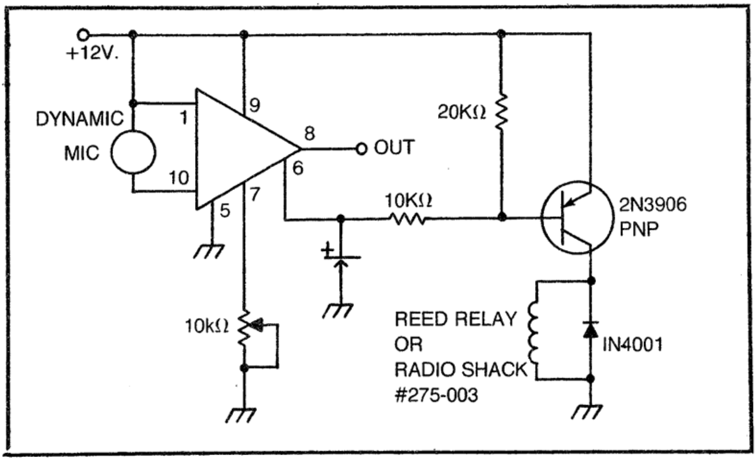


Fig. 1-19. A sound-operated relay (courtesy National Semiconductor Applications Handbook).

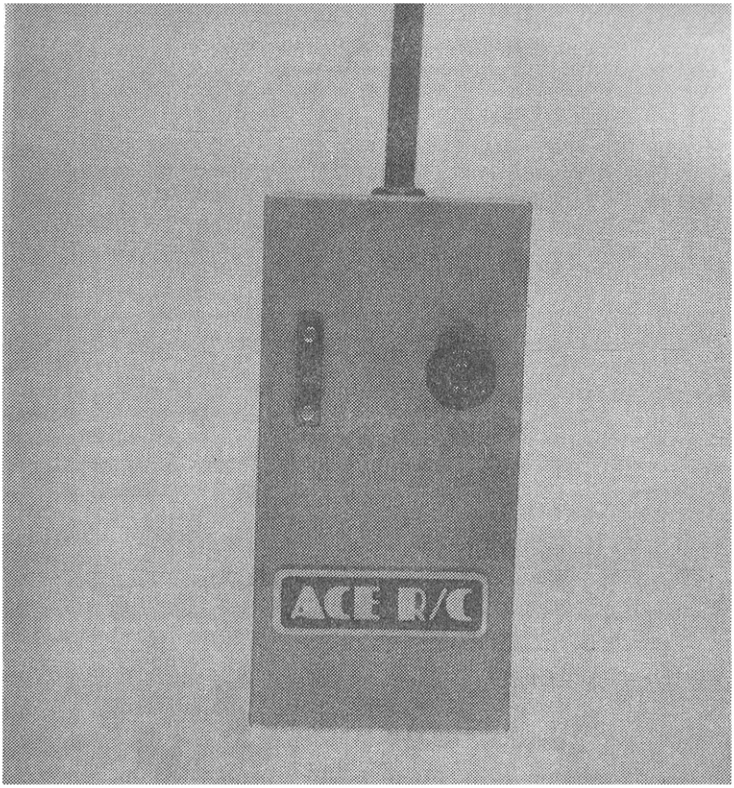


Fig. 1-20. Wee-I transmitter kit assembled.

uses illegally high transmitting power. Check with local model clubs about interference problems and which channels are best to use *before* you buy equipment.

It is also important to know that legal operation in the frequencies in the 50-MHz range requires at least an amateur radio Technician class license. Notice the two spot frequencies which the Academy of Model Aeronautics (AMA) has designated through the FCC for superregenerative receivers. We will see why this is important as we consider the second part of the radio link, the receiving system.

THE SUPERREGENERATIVE RECEIVER

A radio control receiver has but one function: that is to control the electric current to some electro-mechanical devices which, in turn, cause something to move. The receiver can do this in two basic ways. First, it can generate within itself a signal to close a relay after

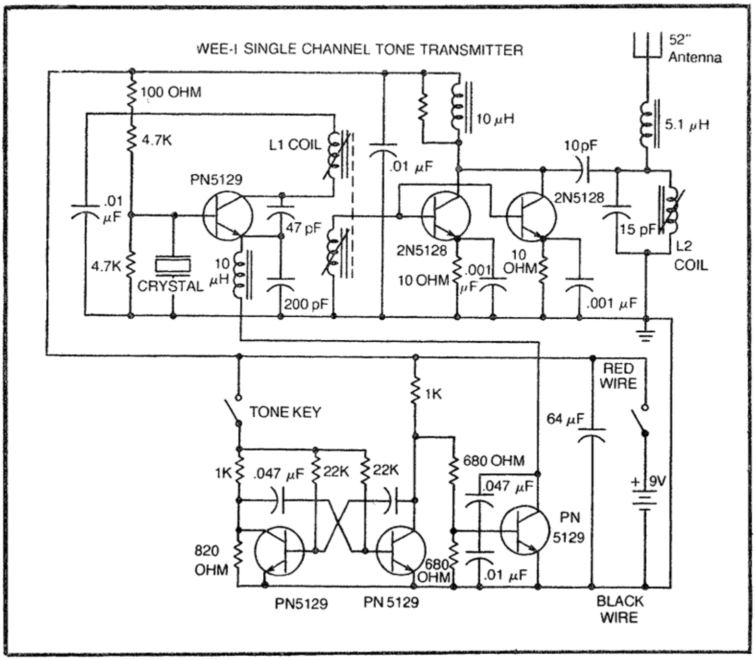


Fig. 1-21. Circuit diagram of the WEE-I transmitter, a single-channel tone-modulated unit.

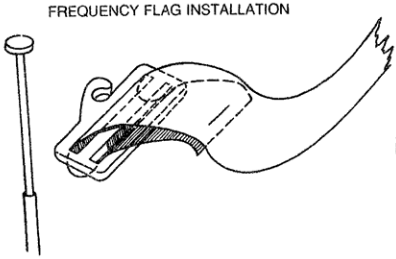
rectification, by causing a transistor to conduct a rather large amount of current. Or it can receive, amplify, rectify and shape a transmitted signal to do the same task. In the first case, the transmitted signal stops the internal transmitted signal and thus causes the relay to *open*. In the second case, the transmitted signal causes the relay to *close*. By the way, use the proper relay contacts for radio control.

The kind of receiver which generates a signal within itself is called a superregenerative receiver. It is normal with this kind of receiver that the detector make a hissing noise which can be amplified and rectified and caused to control the current through a transistor to a relay or a motor. When this kind of receiver receives a carrier-only signal—a carrier to which it is tuned,—it tends to stop hissing and becomes very quiet. Thus, in the simplest operational sense, it will then let the relay or other controlled device move to that position where it would normally be without current applied to it.

The superregenerative receiver can also receive a modulated signal—a tone—in the *carrier silent* condition and use this signal to make a relay operate or a motor run. This type receiver has a wide band of signal acceptance, which is a disadvantage, because it will

NOTE: IT IS YOUR RESPONSIBILITY TO INSURE THAT THE FREQUENCY FLAG COLOR CORRESPONDS TO THE TRANSMITTER FREQUENCY AS SHOWN IN THE TABLE BELOW:

FREQUENCY FLAG INSTALLATION



FREQUENCY	RIBBON COLOR
26.995	BROWN
27.045	RED
27.095	ORANGE
27.145	YELLOW
27.195	GREEN
27.255	BLUE
SUPER-REGENERATIVE RECEIVERS	
51.200	BLACK & LIGHT BLUE
52.040	BLACK & VIOLET
53.100	BLACK & BROWN
53.200	BLACK & RED
53.300	BLACK & ORANGE
53.400	BLACK & YELLOW
53.500	BLACK & GREEN
* 72.080	WHITE & BROWN
72.160	WHITE & BLUE
* 72.240	WHITE & RED
72.320	WHITE & VIOLET
* 72.400	WHITE & ORANGE
72.960	WHITE & YELLOW
* 75.640	WHITE & GREEN

* MODEL AIRCRAFT USE ONLY

Fig. 1-22. Local frequencies for radio control operations.

pick up signals off the frequency to which it is tuned. However, it has an extremely high amplification factor in just one stage, the detector, and thus needs to have only a simple audio amplifier following this detector stage. Also, because of the type circuit employed, this receiver has an automatic gain control ability which keeps the receiver from swamping on loud signals and increases its sensitivity for weak or distant signals.

The superregenerative radiates a signal too, and that is its really bad trait. It is a controlled oscillator—an intermittent oscillator—and so it can create interference with other receivers even if they are not exactly on its frequency. That really bad characteristic is the one which has limited the use of the superregenerative. A number of circuits for the superregenerator appear in our TAB book No. 1135, *Radio Control Manual–Systems, Circuits, Construction–3rd. Edition*. One circuit which shows the general layout is given in Fig. 1-23. You will have to try various high-frequency transistors in the detector stage to find one that is suitable and operates satisfactorily. We list two possible types which you might start with, one for 27-MHz and one for a higher frequency. You must adjust the voltage carefully to get the hiss sound in earphones at the audio output that tells you the detector is working. The hiss should be soft. If it is extremely loud, then the voltage is usually just a little too low. C1 may not be needed as feedback. Experiment to find out. Also, in Fig. 1-24 we show you one type of receiver which does *not* use an integrated circuit amplifier. The use of this kind of device would make the receiver even smaller and more compact.

THE SUPERHETERODYNE RECEIVER

The radio control superheterodyne receiver may also generate a signal inside itself with the presence of a carrier, in order to operate a relay or motor. If the receiver has a beat-frequency oscillator (BFO) built into it, then when a *carrier* is received, a tone will be generated that can be rectified and used to make a transistor draw enough current to operate a relay, motor, or actuator. But the BFO must be extremely stable.

Normally, however, the superheterodyne receiver requires a *modulated* signal as its input, which it then converts into the transmitted tone, or received pulses or whatever is used to make the radio control system operate. We don't think of carrier pulses as a

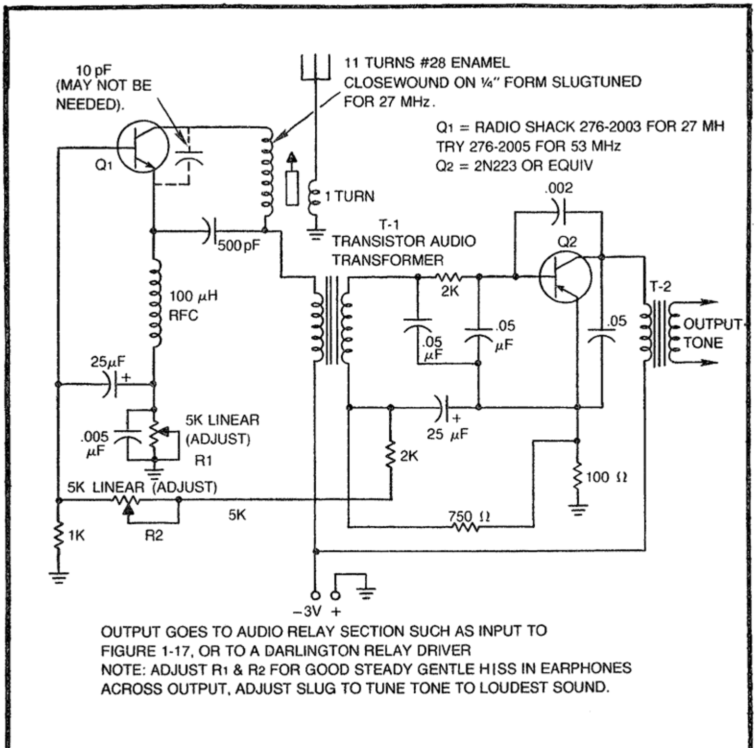


Fig. 1-23. A typical superregenerative circuit.

form of modulation but they are. Modulation is simply the variation of the carrier in some definite and consistent manner, and pulses which turn the transmitter on and off, even if at a very fast rate, do exactly that. One example of a cased superheterodyne receiver is shown in Fig. 1-25. The rf and oscillator portions of the receiver are plug-in units so that frequencies can be easily changed.

The advantages of the superheterodyne receiver are many. It is very selective, using crystals as frequency control devices, so it does not pick up signals from adjacent spot frequencies. It has gain control so it doesn't swamp easily and has great sensitivity at long range. It is small and compact and does not radiate a signal as the superheterodyne receiver does.

The superheterodyne receiver requires a modulated signal to produce an output which is useful for operation of a relay or motor(s). This signal can be pulses, turning the transmitter off and on. It can be an audio tone or a combination of them. But the receiver will not operate on a carrier alone unless you have a beat-frequency oscillator built into it. With a BFO, an internal audio tone is generated

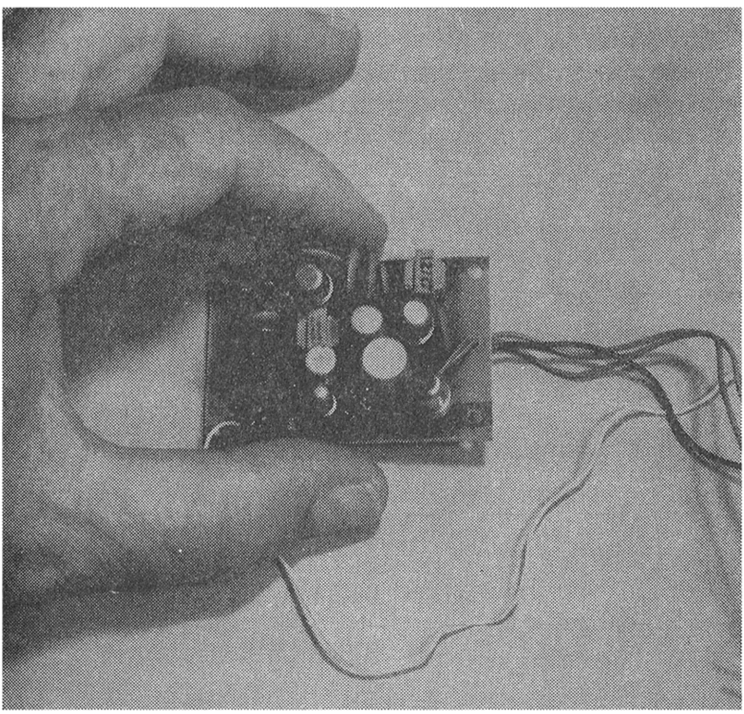


Fig. 1-24. A superregenerative receiver with a slug-tuned coil. It uses a transistor output instead of a relay to drive an actuator or motor.

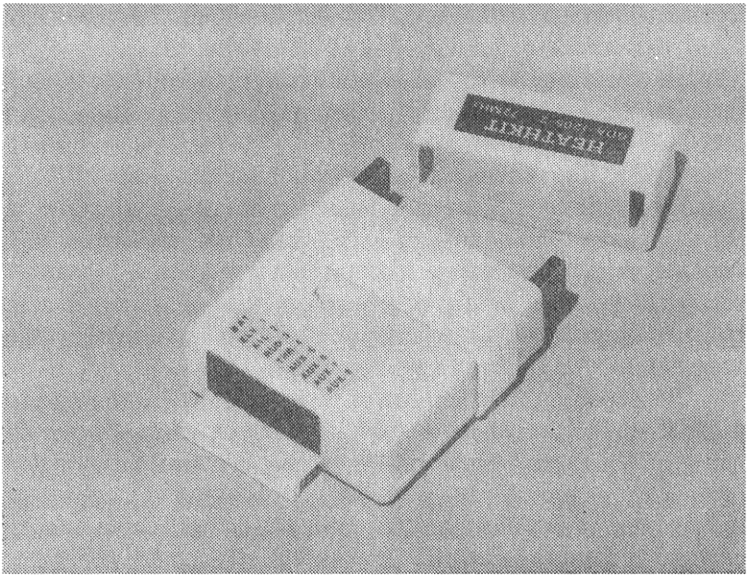


Fig. 1-25. Heath receiver with module unplugged.

when you receive a carrier, and this, in turn, can be rectified and used to cause a relay or motor to operate. We will examine some systems of sending intelligence to make different things operate and get many operations from small motors in a later chapter.

Many manufacturers, including Ace R/C, supply receivers and receiver kits. Ace R/C has a companion superhet receiver for its WEE I transmitter, but it is *not* furnished in kit form. Most other manufacturers do have kits, but the receivers are designed to operate with their companion transmitters and are not interchangeable in most cases with the equipment of other manufacturers. So be careful about purchasing a receiver from other than your transmitter manufacturer.

CHANNELS, CODING AND DECODING

When we speak of *channels* in radio control we simply mean how many functions are controllable. For example, with a model airplane, if you use just one command for, say, left, right and neutral rudder, you will be using one channel. If you also control the elevator, the motor and ailerons, then one channel is required for each, so you will be using four channels of command.

It is possible to make a model do many things with just one channel, but usually when this is done, the operations are in sequence. You normally cannot do two or more things at the same time with only one channel. With a multichannel system, you can be sending commands over many channels at practically the same time, so you can have simultaneous control over many things. For you computer enthusiasts, it's like a series operation for single-channel, and a parallel operation for multichannel.

Coding is the method of sending discrete commands in either system. Some difference in signals must exist which the *decoder* in the receiver can recognize. It can then make different things happen with the different signals. International Morse code is one type of coding used to send information. You, the *decoder*, convert the dits and dahs to letters and numerals. We will examine coding in more detail in the next chapter.

In Fig. 1-26 you can see one example of a multichannel system at the top, and two possible arrangements of a series of single-channel systems at the bottom. Notice, however, that if you use the two units at the bottom together—that is, transmit from one transmitter to one receiver for one channel, and to the second receiver on a different frequency from a second transmitter—the two together make up a two-channel system. Modern systems are generally of the top multichannel type. The boxes marked A are the control levers, or wheels or switches which you move to send commands.

There is a particular significance to the bottom arrangement in Fig. 1-26. If you substitute multichannel systems for each of the two

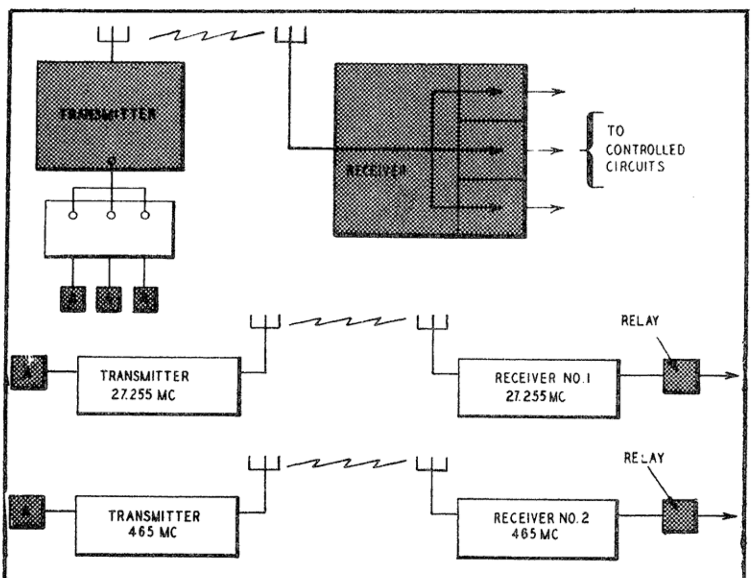


Fig. 1-26. Single-channel and multichannel system concepts.

Fig. 1-27. A two-channel radio-controlled toy "18-wheeler."

shown, and reverse the location by putting the bottom system inside the model so that it *transmits back* some information on model control positions, altitude, speeds, or other kinds of data, then you have a *telemetry system*. This could permit you to fly airplane models or sail boats out of sight. It could also permit you to develop and invent a ground control system that would be a duplicate of the control system inside an airplane where the instruments and such are all operated by the ground receiver and decoding system of the telemetry system. Of course, the channel going to or transmitting to the model would be your control channel. As models develop and systems advance, we may see this kind of arrangement come into being. The military uses it to fly high-speed drones at possibly very high altitudes. See TAB book No. 122, *Advanced Radio Control*.

TWO-CHANNEL TOY CAR

We have looked at a single-channel toy car in some detail. These kinds of radio control systems are very popular and have been expanded upon in the manner shown in Fig. 1-27.

Two buttons are on the transmitter to send out two different signals: one signal for steering left and one for right. The signals are sent out by pushing buttons on the transmitter.

Another way to control a model with two signals is to use the *carrier* to cause the drive motor to operate in a forward direction. Therefore, when you turn on the transmitter, the model starts to move, providing you have turned on its own switch. Then if you send one tone, the model will turn left; push a second button and consequently, a second tone, to cause the model to turn right. No tone at all will be an *automatic* straight ahead, or neutral. You might think about having *three* relays in such a model, all activated by these radio signals.

We can fabricate a simple motorized decoder for more *than one function control* based on a device developed some years ago, which is still very usable in boats, cars, or slow-flying airplanes. It is a

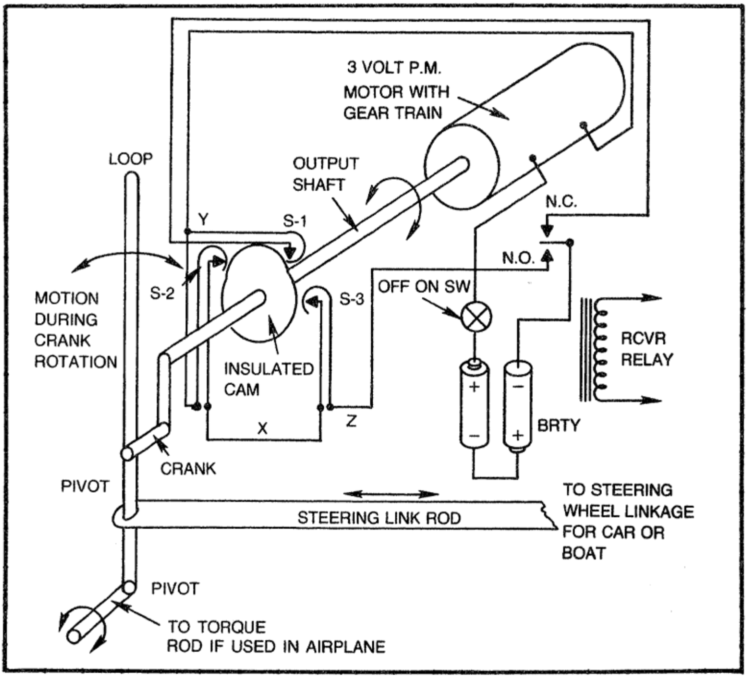


Fig. 1-28. A mechanical decoder for a single-channel system. Switches S-1, S-2, S-3 are normally closed.

sequence device, so it won't give control of two or more operations *simultaneously*. Nevertheless, in the types of models we would use it, we will have only one thing operate at one time such as the motor, or the road wheel or rudder. With this unit, control of the two functions of steering does not occur during control of a drive motor.

You might ask, How do you get *two* functions for steering? The answer is that we are thinking of one signal for left and one signal for right motion of a rudder or steering wheel. The return to straight steering must be automatically accomplished, but we will use just a single channel system to do this. This type of system is one you might get with a toy. We will need just one single-pole double-throw type relay in the receiver output.

A SIMPLE STEERING ARRANGEMENT

We will first describe this unit as used in a model airplane. Be aware, however, that if you use a toy model car radio system, it is designed to operate up to only about 200 feet. So you really cannot use that system for a model airplane. You need a better radio system for that kind of model with a range of at least ¼ mile. More about the airplane system transmitters and receivers later.

Let's first examine the basic principle of the decoder, which is the heart of this kind of system. Study Fig. 1-28. Notice that there is a small permanent magnet motor, say 3-volt type, with a gear train attached or built-in so that the output shaft with the insulated cam will move reasonably slowly. Three switches which are *normally closed* are mounted around the cam so that as it rotates it will open each one in turn. Then examine the linkage output, which is yoke-driven by the crank so that it moves back and forth. For airplane use, the yoke will turn a torque rod which in turn can position a rudder. For model cars or boats, an attachment linkage will move back-and-forth to position road wheels or rudder. An off-on switch is located at the battery site, although in operation this kind of system will position itself to cut off all electricity so it uses current only when in motion. This latter feature is excellent for gliders and sailboats.

When the receiver relay is de-energized as shown, the armature makes contact with the normally closed contact. Follow the circuit and you will find that power is applied to the motor through switch Sl. This means that the motor will rotate the output cam and yoke until the riser on the cam opens the switch S1 and stops the motor. We set the position of the switch so that when this happens the yoke will be straight up, or in a *neutral* position. Adjust the system to give straight motion for a car, boat, or plane.

Imagine that you depress a button which sends out a tone or other kind of signal to cause the receiver relay to close and stay closed as long as you keep sending the signal. Through the normally open (N.O.) contact of the relay, we now find the battery applied to the motor through contacts S2 and S3 in series. This means that the motor will stop if *either* of these switches is opened, as long as the signal is being sent to the receiver.

The first switch to be opened is S2. If this switch is so positioned that the cam will rotate 90 degrees from neutral, you then have a maximum left movement of the yoke. This could be left steering of the car, boat, or plane. If, then, you stop sending the signal, the motor will again rotate as we first described until the cam opens switch S1. You are back to neutral and straight motion.

Now, consider that you depress the signal sending switch of your transmitter and hold it while you count, say, "one two." If this time interval is long enough to make the motor rotate to position of switch S2, it would then *stop* if you didn't then release the button that keeps the cam moving toward switch S3. You then count "one two" again and depress the transmitter signal sending switch. Now, when switch S3 is opened, the relay armature is on the normally open contact, so the motor will stop in this third position. This should be 180 degrees away from the position it stops at when opening S2. This is the right turn position of the road wheels, rudder or whatever. When as much of a turn as you desire has been accomplished by the model, you release the transmitter button and the motor will drive the steering elements to neutral again, ready for another set of signals.

THE STEERING CODE

As with all kinds of control systems, we must have a *control code* to make the system work as it does. In this case it is as follows:

- Neutral—No Signal.
- Left—Signal on and hold.
- Right—Signal on, then off, then on and hold, with a rhythm to match the motor rotation.

It's simple, but very effective. And remember that the advantage of this system is that you can take one of the small systems available in toys, which have a relay in their output, and add this kind of decoder and expand your control over the model. Of course, you might use sound signals to operate the relay using the sound

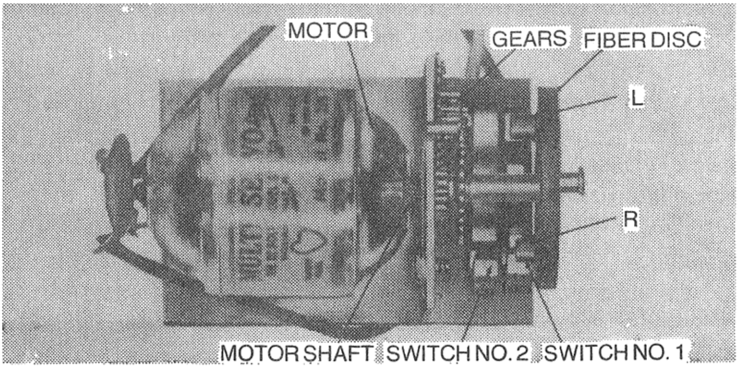


Fig. 1-29. A cam-and-pin arrangement on the motor.

amplifier shown earlier, or you might build your own system transmitter from the diagram we have shown and a receiver using the sound amplifier as the audio section for a receiver, and a superregenerative kind of detector feeding into this amplifier instead of the crystal microphone. Superregenerators, remember, are used *only* on the prescribed spot frequencies in the 53MHz band. Do not use a superregenerator for airplanes on any other frequency.

There are many ways to make the cam-switcher for the motor. Figure 1-29 shows another concept of mechanical construction on a unit which was produced commercially some years back.

THE AIRPLANE SELF-NEUTRALIZING MOTOR

We chose to examine the simple self-neutralizing servo in an airplane concept next because it is self-powered and its motor speed or running time does not need control. With a model such as we are about to examine, the propeller motor running time is limited to only a few minutes by having a small fuel tank. Nevertheless, this is long enough for the plane to get pretty high. Then the airplane motor runs out of fuel and stops. If the airplane is properly adjusted, it will glide for a long time as it comes down. You then will be steering a glider down to a landing. Of course, you steer the model while its engine is running and try to keep it upwind from our position. You also turn it around and maneuver it to keep it close enough to always receive its radio signals and to keep in sight. In case it gets up a little higher than wanted, give it a sharp turn by holding a turn command signal on. This can make the model lose altitude with a large rudder deflection. The arrangement shown in Fig. 1-30 has the various switches positioned on the base mounting plate, instead of around the cam as shown in Fig. 1-29. Before examining the operation, note the fiber disc and the insulated shafts N (neutral), R (right), and L (left). In the neutral position shown, shaft N is depressing contact switch 2, opening its connection to D. This shaft does not open switch 1 since this switch is not as high as switch 2 and N is nearer to the center of the fiber disc than L or R. Notice also how the mechanical output of the motor, the rotation of the fiber disc, is coupled to the control surface through yoke Z. As the disc turns, the yoke loop will be moved left and right from the neutral or center position and this in turn will cause the rudder to move left or right.

Assume that the code signal "on and hold" is transmitted. The armature of the relay is pulled down to make contact with G. This lets power flow from the motor battery through the relay to B switch 1. At this moment, B is in contact with A, so the power goes to one lead of the motor. Since the other motor lead is directly connected to the opposite side of the battery, the motor begins to run, turning the fiber disc in a clockwise direction. It will continue to run until shaft R opens switch 1, breaking the circuit. At this point, loop Z has been moved to the right and, through the linkage, the rudder is moved to the full right position. As long as the signal is held on, the steering element will be thus deflected, but since the circuit to the motor is open, the motor consumes no power from its battery. This is an important consideration in operation over long periods of time.

Now assume that the signal for neutral is sent. According to the code set up, this simply means that no signal at all is transmitted. The relay armature is pulled up by the spring opening the circuit to G, but closing the circuit to E. The battery is now connected to the motor through switch 2 and so the motor runs again. It will continue to turn the fiber disc until shaft N again opens the circuit by opening

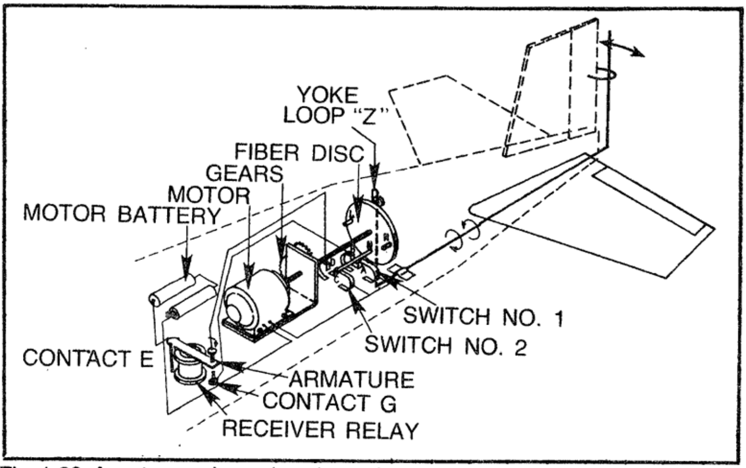


Fig. 1-30. A motor used as a decoder and power unit to provide a single-channel radio system in an airplane.

switch 2. In this position, the loop Z and the rudder are again at neutral.

The third command of "on-off-on" and "hold" causes the following action: The first "on" signal causes the motor to turn as before—to the right. It moves rapidly enough so that when the off part of the signal comes, it is just in time to keep the circuit closed and cause the fiber disc to keep turning. Now the second "on" arrives at the receiver. The relay is energized again, and the circuit is completed through switch 1. Shaft L is turning toward the switch and now opens the circuit by breaking the contact through switch 1. Loop Z is not held in the left position and through the linkage produces left rudder. It will hold it there as long as the signal is kept on. When another neutral or no signal command is sent, the motor again turns around to the neutral position.