TAB BOOKS/No. 1174

$6.95

MODEL RADIO CONTROL — 3rd Edition

A complete, updated guide to the fascinating world of model radio control!

by Edward L. Safford Jr.

TAB BOOKS/No. 1174

$6.95

MODEL RADIO CONTROL — 3rd Edition

A complete, updated guide to the fascinating world of model radio control!

by Edward L. Safford Jr.

by Edward L. Safford Jr.

This *all new* and complete revision will thoroughly acquaint you with everything you need to know about model radio control—how it works, how to design a system, how to install it, and how to operate model airplanes, cars, boats, toys or virtually anything by radio control. Starting out with fundamental RC concepts, the author takes you through all the latent and most modern equipment, including coding and coders, relays, superregenerative receivers, decoders, power control circuits, servo motors, tone-operated and proportional control systems and much more!

Here is complete description of every RC system ever devised—including the latest digital proportional control systems. *Nothing* is left out—you can choose the system you prefer and then read all about it. Even if you're a novice in the world of radio control, you can learn from this book, and be in charge of a radio control system in no time at all! If you're a veteran hobbyist, there's still plenty of *all-new* info on the most modern equipment here. This book will bring you up to date and keep abreast of the constantly changing, constantly developing RC technology. So, if you want to keep up with the changes in radio-controlled modeling, or if you want to get in on the ground floor of the hobby, this lucid guide should be part of your library.

Edward L. Safford, Jr. is a technical writer and amateur radio buff of long standing who has published over 60 articles, 20 technical books and 5 novels. He is the author of several TAB electronics books, and lives in Houston, TX.

0-8306-1174-6

MODEL RADIO CONTROL-3rd Edition

by Edward L. Safford Jr.

TAB BOOKS
BLUE RIDGE SUMMIT, PA. 17214

FIRST EDITION

FIRST PRINTING—NOVEMBER 1979

Printed in the United States of America

Library of Congress Cataloging in Publication Data

Safford, Edward L.
Model radio control.

Includes index.
1. Models and modelmaking—Radio control systems.
I. Title.
TT154.S3 1979 629.04'022'8 79-17079
ISBN 0-8306-9762-4
ISBN 0-8306-1174-6 pbk.

Contents

Preface 7

1 Fundamental Concepts, Devices and Operations 11
The Necessary Motions—The Actuator—Simplest Electric Motor Control—The "Glo-Plug" Engine—Electric Motor Direction of Rotation—A Radio-Controlled Model Car—The Superregenerative Receiver—The Superheterodyne Receiver—Channels, Coding and Decoding—Two-Channel Toy Car—A Simple Steering Arrangement—The Steering Code—The Airplane Self-Neutralizing Motor

2 Coding and Coders 45
Analysis of the Simple Command Code—Automatic Transmission of Codes—Off-On Carrier or Tone Code—Harmonic Considerations—Pulse Codes—A Model Racing Car—How Many Channels?

3 Examining Transmission Systems 59
Radio Transmission—Sound-Wave Transmission—Light-Beam Transmission—Infrared Wave Transmission—Wired Transmission—Magnetic Transmission—Radio Transmission—Methods of Modulation—A More Complex Transmitter—Testing Transmitters and Receivers—Finding Solutions to Equipment "Dogs"—Transmitting Antennas—Some Specific Antenna Systems—Field-Strength Indicators—Radiation Patterns

4 More About Receivers 80
Superregenerative Receivers—The Output Stage—Relay Adjustment—Superheterodyne Receivers—Interference Monitoring—Model Receiver Mounting

5 Decoders 88
Mechanical Decoders—Electromechanical Decoders—Electronic Decoders

6 Power Control Circuits 121
Latching Relays—Reversing Relays—One Operational Circuit Using Relays—An Integrated Circuit Power Control—An Electromechanical Switching Device—Babcock Speed Control and Reversing Relay—Power Control Circuits for AC Motors—Power Control with Digital Servos

7 Servo Motors.....132
Limit Switches—Self-Neutralizing Switches—Commercial Servos—A Cam-Controlled Steering Arrangement—Modifying a Commercial Servo—A Self-Neutralizing Servo Using Transistors—A Very Simple Robot Control System

8 Integrated Circuits and Transistors.....145
Definitions—Integrated Circuit Packages—Transistors—Some Soldering Techniques—Solder Removal Techniques—Heat Sinks for Operational Units—Some Circuits for Experimenters

9 *Evaluating and Selecting Radio Control Systems*.....167
Linear Versus Nonlinear Servos—How Many Channels?—What Equipment to Buy?—Determining Your Requirements—Selective and Proportional Control—Discrete and Simultaneous Control—The Cost Factor—Compatibility of Systems—The More Economical Systems—Modern Digital Equipment Limitations—Summary

10 Radio-Controlled Model Cars.....179
Equipment and Mounting Arrangement—A Home-Built Concept—Size, Gearing, Motors and Other Details—Interference—Test Equipment and Tools—Partial Parts Costs—A Visit to a Model Race Car Event—The Future in Model Cars—Model Race Car Nationals

11 Radio-Controlled Model Airplanes.....196
Scale and Nonscale Models—Construction and Radio Installation—Commonly Used Airplane Sizes—A Beginner's Airplane Construction Details—Another Radio Control Installation—Some Other Installations—The Aileron Connection—A Completed Model—To the Flying Field—The Support Equipment—The Pylon Races

12 Radio-Controlled Model Boats.....222
Types of Boats—Some Sailboat Definitions—Airboats—Model Yacht Construction and R/C Installation

13 Single-Channel and Three-Channel Systems.....235
Pulse-Width Space-Rate Decoder—Second Function Control—Decoder for Fixed Pulse Width—Resonant-Reed Decoder—Numerical-Sequence Coder and Decoder

Index.....253

Preface

This book is a second revision of the book first published in 1951. The first revision was published in 1959, and we thank you for your acceptance of those two works. We hope and trust that you will find this work just as valuable. It is practically a *new* book on radio control.

There is much new material in this edition. It still retains all of the valuable and still useable ideas and information of the two previous works. They are updated and now considered in light of the current state of the art of radio control. We hope and trust that all of you whom we have met through the pages of the previous works, or our other books, and those of you whom we meet for the first time in these pages, will find this new edition as worthy as you have reported the original and first revision to have been. As in the previous editions, we start at the beginning and will advance the ideas fully and carefully so that if you are not familiar with radio control, you can learn what it is all about and how it works. If you are familiar with the hobby, you can still find valuable ideas and concepts within these pages.

Radio control enthusiasm has not diminshed during the years since its inception. If anything, its popularity has increased. We are constantly amazed at how many new applications modern technology is able to develop. In some cases the gains are not just in a hobby sense. For example, there are now on the market, some remote (triggered by radio control) alarm systems to warn neighbors if an intruder is present. The alarm will report if an intruder is present or

if there is a fire burning out of control. It might even be able to tell someone if you are hurt or seriously ill. In a way this is remote monitoring of your welfare and as such can be extremely valuable.

The fact is that radio control of models—and other things— is an accepted hobby and business throughout the world. Radio control simply means that someone or something (a computer) somewhere is going to cause certain events, operations, or conditions to occur at some other place. This happens only when certain commands are sent by radio, sound, light, heat, or other method suitable for the conveyance of commands.

Citizens band radio came, was accepted, and is here. We think nothing of being able to communicate with that car at our "front door" or "back door". In fact, we get upset if we cannot communicate with everyone we want to. We use radio transmission to convey ideas in this case, and not necesarily commands to do things. So there is really nothing unusual, except for the change in equipment. All we need do is convert a *talking* system into a *commanding* system, which is necessary for radio control.

Everyone would like to be a pilot—well, almost everyone. Some can't for various reasons. But almost everyone can become a *model pilot*, flying a true airplane from the safety and security of a ground position. A dream is thus realized, and believe me, the feeling is almost the same as flying the big machine. So this is one reason for radio control of a model airplane. Then there is that great desire to build something, to fabricate and construct, to design and assemble, to plan and activate. Some can build skyscrapers and bridges and whatnot. Some cannot. But again they can realize the essential elements and satisfaction of this desire in the building of models. And since radio-controlled models must, in reality, function and operate just as their larger counterparts do, they must be made properly. Therefore, a second dream is thus realized.

Escape from boredom is another reason why models are built and sailed or raced or flown, or operated. For the most part, people like to have "brain challenges." The building of the models, the installation and operation and test adjustment of the radio control equipment will provide a challenge that is rewarding and satisfying. And everyone can do it. There is no restriction as to sex, age (except young), color, race or creed. And costs can be selected to be within the means of just about everyone. When hobbyists get together with their models, there is no boredom, and the results of these gatherings, or even the isolated building and operation of models, will give that fertile brain new concepts and directions and challenges, so believe me, the boredom can be gone forever.

Radar control is being tested in automobiles as an automatic safety system to prevent a car from getting too close to the car ahead. Also, automatic information transmission and activation of various auto control devices can take place without appreciably slowing down the car or causing the driver or occupants any discomfort.

Radio control will be used more and more in conjunction with home computers as it becomes necessary to gather physical sensor data and activate various electrical-mechanical devices through this increasingly popular instrument. Wireless as well as wired remote control systems—wherein the signal is transmitted over the air or on wires already carrying electrical currents in your home—will be used extensively in the future.

All this is in addition to the ever popular hobby aspect of radio control. How much fun it is to guide your beautiful—and some not so beautiful—airplanes and sail planes through the sky or drive your model car or sail your model boat! What a feeling of freedom and power as you make the model do whatever your mind can conceive in the way of airplane aerobatics, or picture taking, monitoring, or whatever! And how graceful the modern model ship, sailboat, or racing boat is as it cuts through the waters responding to your slightest whim. One just can't find an end to the R/C things which can be incorporated into a model boat. Just think of launching a small plane from a ship deck, and controlling this at the same time that you are controlling the speed direction, whistles and the lowering of lifeboats of the mother ship. Imagine trimming the sails—just so—to gain the greatest speed and the thrill of winning a sailboat race.

Model car racing with either fuel-powered or electric-powered motors is fast becoming a great area of hobby fun and a test of your coordination and skill. Races are being held all over the globe. This gives the electro-mechanically inclined hobbyist a chance to really get involved as well as to give a good show. Of course, he can have fun trying to negotiate the various turns and straight-ways of model car racing roadways.

All this means that radio control systems have come into their own. They have progressed from the single-channel escapement-operated systems into multichannel, proportional systems. The latter are extremely reliable, easy to apply, install and use. A far cry, indeed, from "those days when...."Those of you "old timers" will gain a bit of nostalgia from our mentioning some of the older systems. And, of course, they still work. They can still be used even though they are limited in what they can do. You might want to develop and modify them "just for the fun of it."

The sages tell us that the days of computers and robots are in the offing. Of course, radio control will have its place in this scheme of things. Remote control of scientific robots is best illustrated by the Mars, Saturn and Venus ventures of NASA, and the techniques they use are but extensions of those used in R/V.

We have written and have required many books on radio control. In each we have given the reader something a little different, and perhaps a little more advanced, depending on which book you choose as your next bookshelf addition. This book is the fundamental one that gives basic information on the mechanics of the systems involved. We hope this will be the one to give you a foundation of knowledge for our more advanced and specific books on R/C.

So let us get at it. Grant us permission to keep intact those concepts and systems which are fundamental for those who aren't familiar with Radio Control. We hope the new material here meets with your approval. Thank you again, as always, for your acceptance of our works. We hope that your own imagination and creativity will be sparked by what you read herein.

As always, we have met many wonderful people over the years at so many flying fields, R/C club meetings, hobby shops, and homes who have added to our basic supply of knowledge that we just cannot list them individually here. We do, however, extend our gratitude to each and every one of you in a most personal way.

So be it! Let us begin.

Edward L. Safford, Jr.

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.

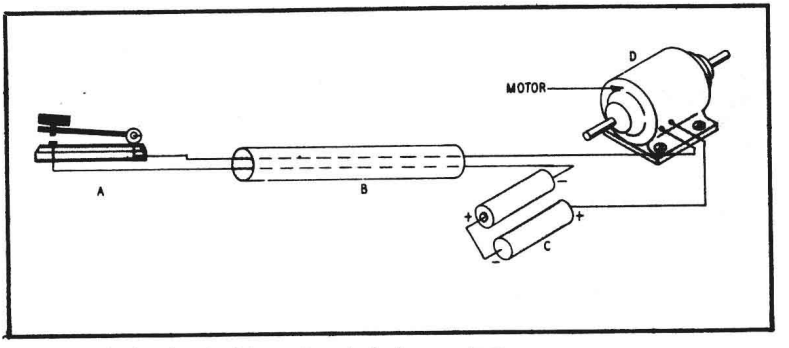

Fig. 1-1. A simple electric motor start-stop system.

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

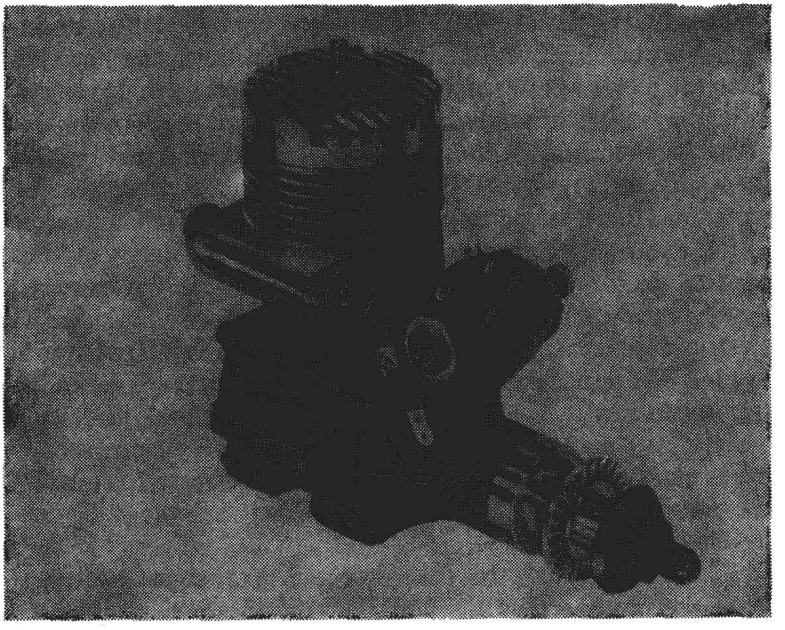

Fig. 1-3. Glo-plug engine with throttle control.

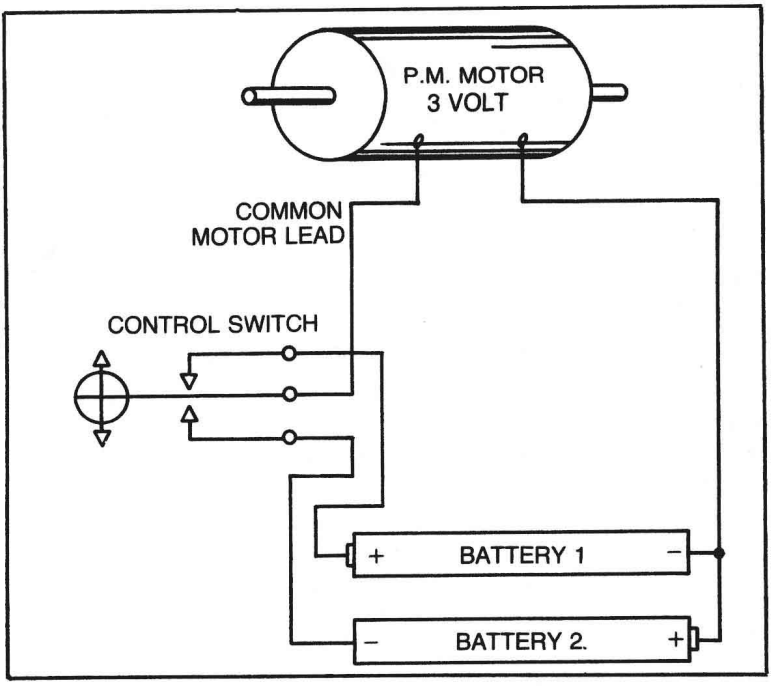

Fig. 1-4. Reversing direction of a pulse-modulated (PM) electric motor.

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