Experimenter's Radio-Control System

A six-channel license-free remote-control system project you tailor to your needs

By Robert C. Frostholm

Most radio-control (R/C) system plans published in books and magazines are fixed in design, usually to control model airplanes, cars, boats, etc. There are no such limitations imposed on the Experimenter's Radio-Control System presented here. This is a basic transmitter/receiver system with "open-end" outputs that *you* adapt to suit your particular needs. In addition to allowing you to control the usual hobby models, the system can be made to control heating/cooling systems and automatic sprinklers, implement sophisticated robotics, and even set up a digital local-area network. In fact, the uses to which the system can be put are limited only by your inventiveness and knowledge of electronics.

Unlike other R/C systems you may have seen in the past, the Experimenter's Radio-Control system has very few components, the credit for which goes to a pair of matched encoder/transmitter and receiver/decoder integrated circuits from National Semiconductor. With these two ICs and a few extra components, you can build the full system in just a few hours.

Our basic system provides six output channels. Its two digital channels provide simple on/off switching, while its four analog channels provide proportional control.

Encoder/Transmitter

A complete six-channel digital-proportional encoder and r-f transmitter on a single DIP chip makes up the heart of the transmitter. This National Semiconductor LM1871 chip (*IC1* in Fig. 1) is intended for use as a low-power, license-free, nonvoice communications device for use on 27 or 49 MHz. In addition to the radio-control hobby, toy and industrial applications, the encoder can provide a serial input of six words for hardwire, infrared and fiber-optic communications links.

Potentiometers *R6* and *R7* in Fig. 1 are used to set the pulse widths of the two analog channels, while switches *S1* and *S2* allow you to set the binary-coded pulse-position modulation for the digital channels (see Fig. 2). Thus, the two digital channel outputs (in the receiver) are determined by the number of pulses transmitted, rather than by the width of the channel.

Two timing circuits make up the transmitter's encoder. The waveforms for these are shown in Fig. 3. Frame time is determined by the values of *R5* and *C9* at pin 7 of *IC1*; pulse time at pin 8 is determined by the values of *C7* and *R4*. The relationships are as follows:

Frame time $T_F = R5C9 + 0.63R4C7$
Modulation time $T_M = 0.63R4C7$
Channel time $T_{CH} = 0.63R3C7$

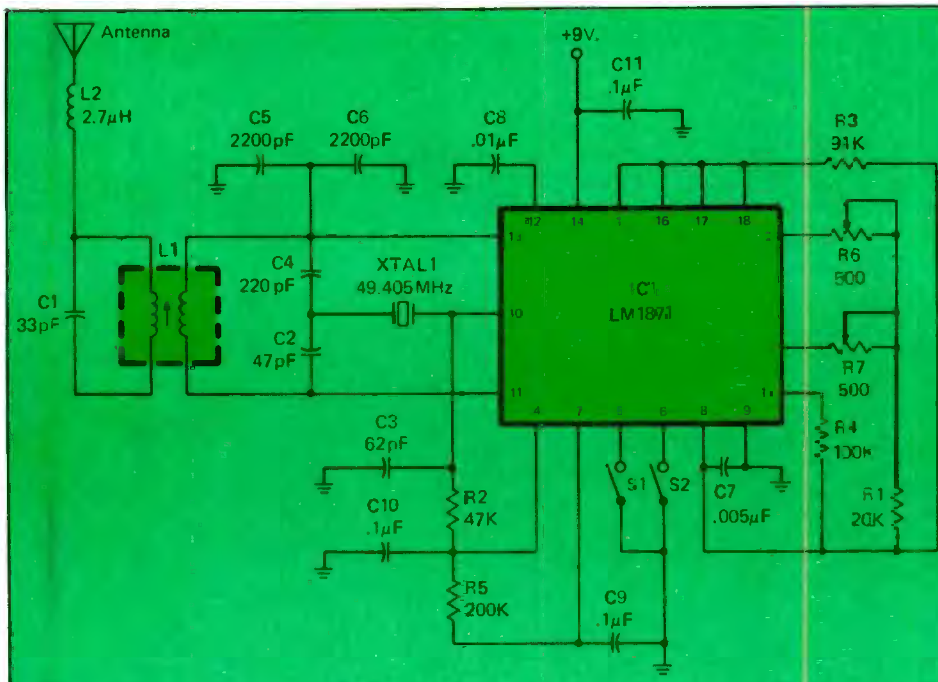
Frame, modulation and channel times should typically be set for 9.5, 0.5 and 0.5 ms, respectively.

Class C was chosen as the operating mode for the crystal-controlled oscillator/transmitter. Resistor *R2* provides base bias current from V (regulated) pin 4 of *IC1*. R-f feedback in the oscillator is via series-mode third-overtone crystal *XTAL1*, which controls the frequency of oscillation. With this arrangement, the best alignment method would be to tune *L1* for minimum supply current while observing the carrier envelope.

Receiver/Decoder

The receiver is based on National's companion LM1872 radio-control receiver/decoder chip, a crystal-controlled superheterodyne design that offers good sensitivity and selectivity (see Fig. 4). In concert with the LM1871 transmitter, the LM1872 provides four independent information channels. The two analog channels are pulse-width modulated (PWM), while the two digital channels offer simple on/off control (see "Modulation Methods" box for more details).

Each digital channel provides sufficient power to directly drive a 100-



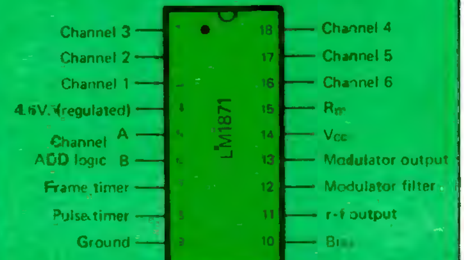


Fig. 1. This is the complete schematic diagram of the R/C transmitter. Pulse widths are set by potentiometers R6 and R7 for the two analog channel and by switches S1 and S2 for the two digital channel outputs.

TRANSMITTER PARTS LIST

Semiconductors
IC1—LM1871 encoder/transmitter (National Semiconductor)

Capacitors (ceramic disc, 5%)
C1—33 pF
C2—47 pF
C3—62 pF
C4—220 pF
C5,C6—2200 pF
C7—0.005 µF
C8—0.01 µF
C9,C10,C11—0.1 µF

Resistors (¼-watt, 5%)
R1—20,000 ohms
R2—47,000 ohms
R3—91,000 ohms
R4—100,000 ohms
R5—200,000 ohms
R6,R7—500-ohm potentiometer

Miscellaneous
L1—Toko No. KEN-K4635JBE r-f transformer
L2—2.7-µH r-f coil
S1,S2—Spst switch
XTAL—49.405-MHz crystal

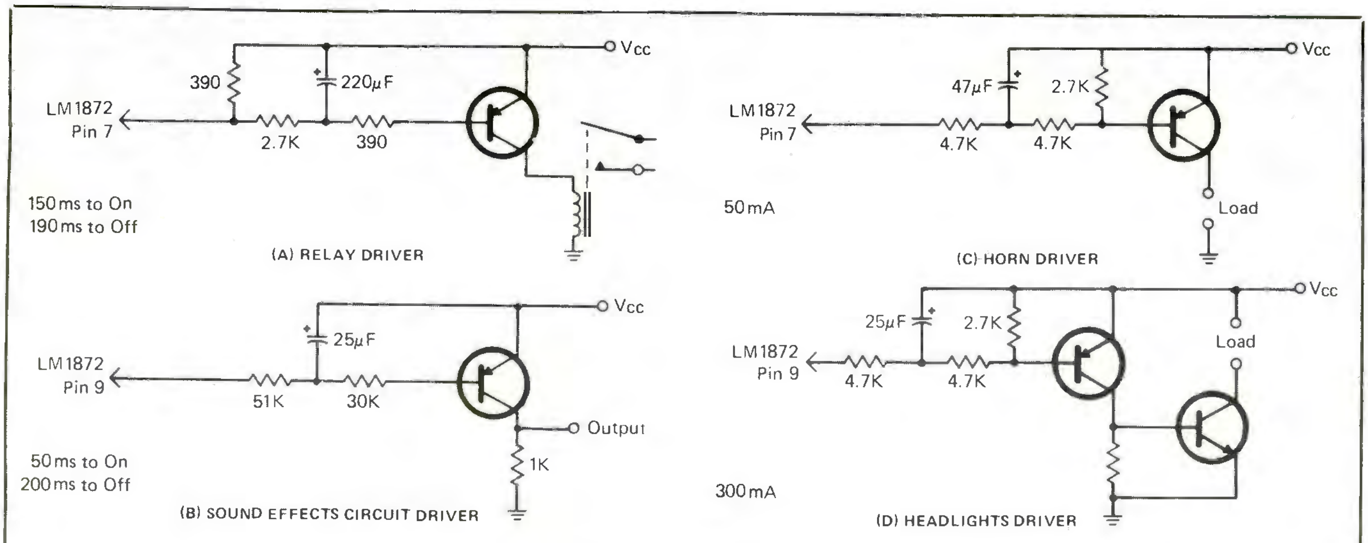
Printed circuit board; socket for IC1 (optional); 9-volt battery and clip; suitable size enclosure; 2-ft. antenna; machine hardware, hookup wire; solder; etc. Note: See Receiver Parts List for kit supplier.

mA load. Instead of providing direct control, each of the LM1872's analog outputs goes to its own separate SN76604 pulse-width demodulator/servo amplifier. The SN76604 has on-chip transistors that are capable of driving a 400-mA load. This servo amplifier is unique in that it provides bidirectional output capability from a single-ended power supply.

In the Fig. 4 circuit, the r-f signal from the transmitter is demodulated and decoded by negative-edge triggering of a cascade of three binary dividers. The dividers count the number of pulses to determine the number of information channels being transmitted.

Fig. 2. Shown here are details of digital channel encoding and decoding via pulse-count modulation. Transmitter conditions in first two columns generate the receiver responses indicated by entries in the last two columns.

LM1871 (TRANSMITTER)			LM1872 (RECEIVER)		
PIN CONDITIONS		TRANSMITTED WAVEFORM	BINARY PULSE COUNT	DIGITAL OUTPUTS	
PIN 5 (CH A)	PIN 6 (CH B)	T_F		CH A	CH B
Open	Open		100	Off	Off
Ground	Open		10	On	Off
Open	Ground		110	Off	On
Ground	Ground		11	On	On



Interfacing to the Real World

For the Experimenter's Radio-Control System receiver's digital outputs to do anything useful, they must be interfaced with the so-called "real world." Shown here are four typical examples of simple interfaces for the digital outputs of the LM1872 (*IC1* in Fig. 4) at pins 7 and 9. These simple circuits—and others you might think of—can be assembled on small pieces of perforated board and housed within the receiver's enclosure or external to it.

Circuit (A) is an example of an interface that can provide on/off control for high-power loads. Power for the load, independent of the receiver's battery supply, is routed through the relay's contacts. Circuit (B) provides a direct on/off *signal,* rather than the mechanical make/break action of circuit (A). Circuits (C) and (D) source current for medium- and realatively high-power loads, respectively. Other interfaces will suggest themselves.

can fabricate your own pc boards, using the actual-size etching-and-drilling guides given in Fig. 6, or purchase an entire kit, which includes ready-to-use pc boards, from the source given in the Receiver Parts List.

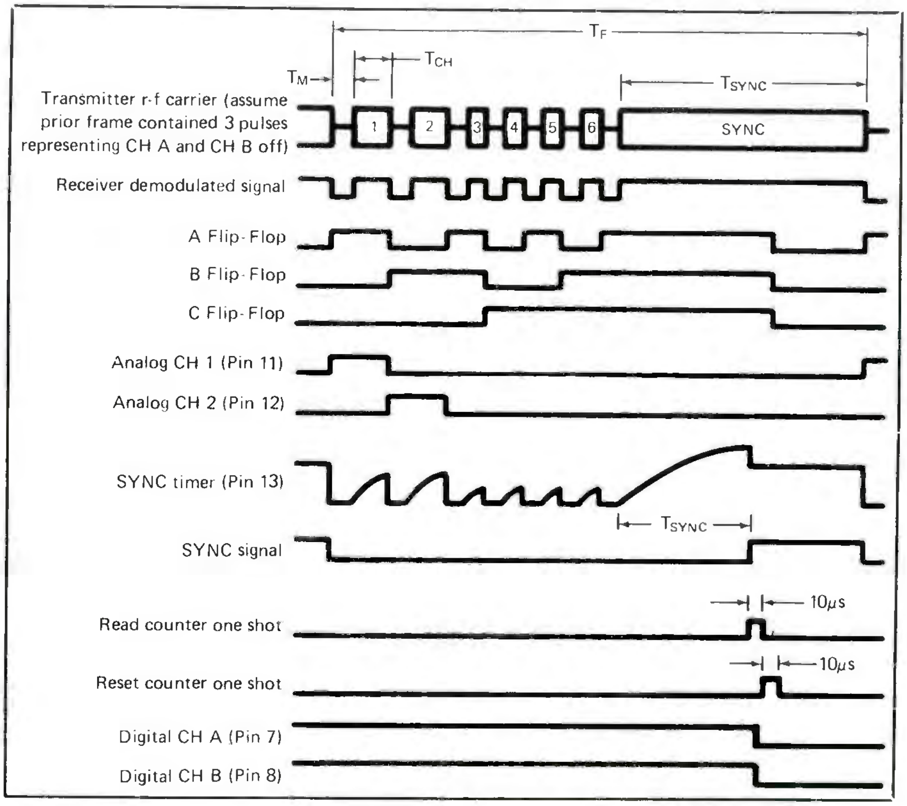
Circuit assembly on the pc boards is a simple, straightforward procedure (see Fig. 7 for details). You simply plug each component into the indicated holes on the board, making sure to properly orient it, and solder its leads or pins to the foil pads on the underside of the board. You can use DIP sockets for the ICs if you wish, but this is not essential.

You can house the transmitter and receiver in any size boxes, preferably metal, that will comfortably accommodate them, their battery supplies, antennas and any controls and interfacing that may be required for your application.

Using the System

A 2-ft. antenna is recommended for

Fig. 5. Timing waveforms available at various points within the receiver.



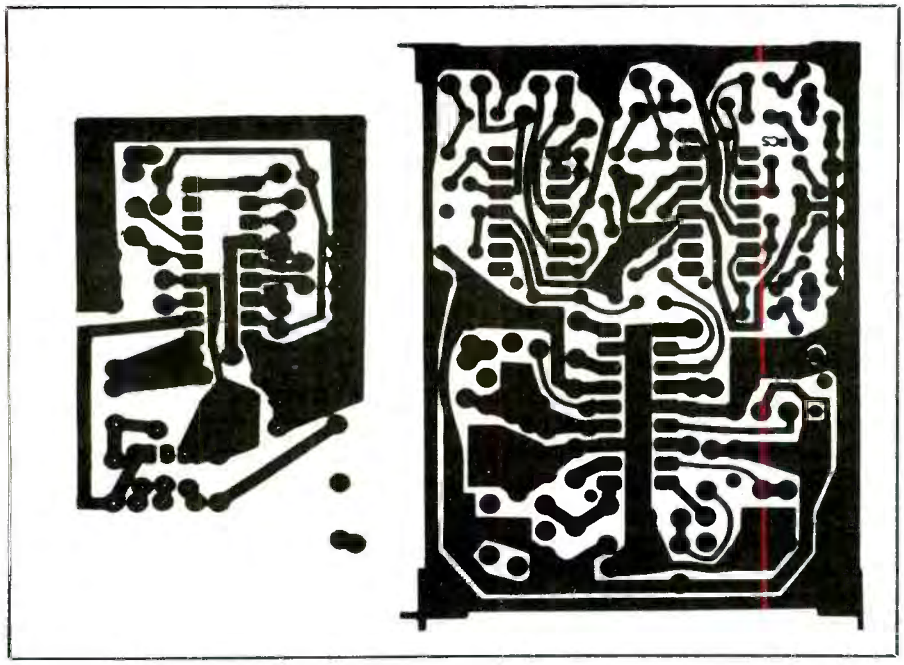


Fig. 6. Actual-size etching-and drilling guides for transmitter (left) and receiver (right) to use when making your own printed-circuit boards.

most applications. This will give roughly a 200-ft. communicating range. If you wish to increase the range of the system, you can increase the length of the receiving antenna. Additional range can also be obtained by increasing receiver sensitivity. Decreasing input transformer *L5*'s turns ratio, for example, will couple more signal into the mixer, but at the expense of a lower tuned-circuit Q, due to mixer loading. Moving the primary tap on mixer transformer *L3* farther from the supply side and/or decreasing the primary-to-secondary turns ratio will also increase gain. Changing *L3* to a 5:1 ratio coil (the specified coil gives a 32:1 ratio) will double 49-MHz sensitivity from 6 to 12 microvolts.

The receiver's digital outputs have significant drive capability. They are capable of sinking 100 mA with a saturation resistance of 7 ohms. Alternatively, they can source 100 mA at up to 1 volt above ground for driving grounded npn transistors and silicon controlled rectifiers (SCRs). For higher currents, the digital outputs can be summed by connecting together pins 7 and 9 of *IC2*.

The 455-kHz intermediate frequency was chosen for convenience. Actually, system i-f can be as low as 50 kHz or as high as 1 MHz, obtainable by changing the values of the appropriate components.

Receiver alignment is quite simple, requiring just a voltmeter capable of tracking down to about 25 mV and a

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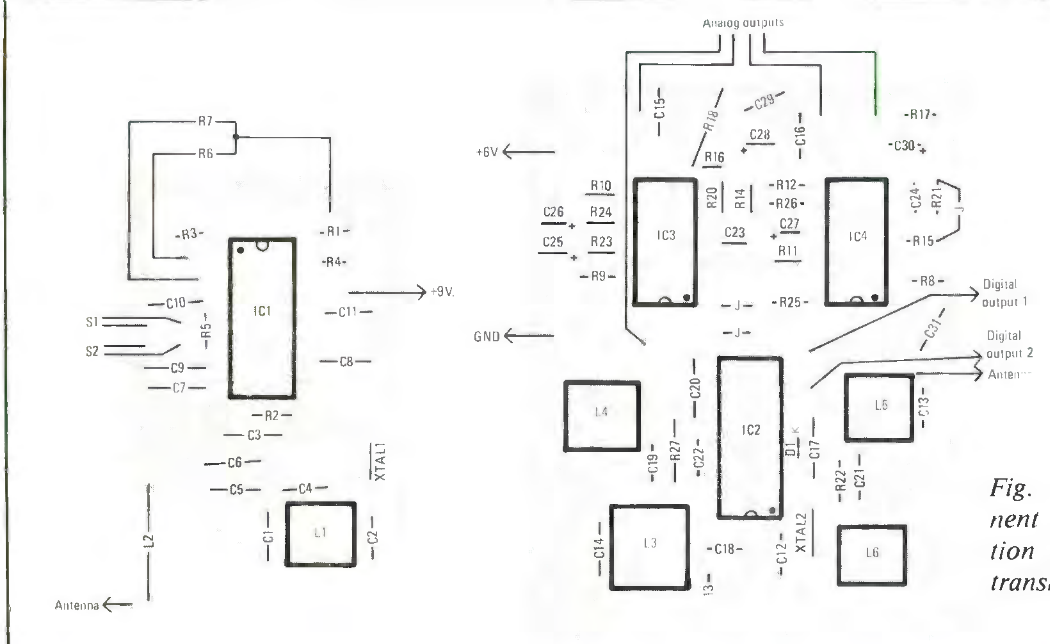


Fig. 7. These are the component installation and orientation guides for the encoder/transmitter (left) and receiver/decoder (right).

general-purpose oscilloscope with a minimum bandwidth of 1 MHz.

The alignment procedure is as follows. Adjust the slug in *L6* while using an oscilloscope to monitor the local oscillator signal at pin 2 of *IC2*. As you adjust *L6*, you will note that signal amplitude increases, reaches a peak and then abruptly falls off. For proper alignment, adjust the coil's slug in the opposite direction from the drop-off point, just below peak.

To adjust *L3*, *L4* and *L5*, use the r-f signal from the transmitter. Before proceding to adjust these coils, however, it is necessary to defeat the agc by temporarily grounding pin 16 of *IC2*. Use the amplitude of the i-f signal at pin 15 to guide in alignment. It is sometimes advantageous to monitor this signal on the unused output of *L4* to prevent the i-f from shifting as you touch pin 15.

Place the transmitter at a sufficient distance from the receiver so that the measured voltage on pin 15 of *IC2* is less than 400 mV (less than 50 mV if you are monitoring *L4's* secondary). Adjust *L5*, *L3* and *L4* for maximum signal strength. Repeat adjusting these coils until you observe no further increase in amplitude.

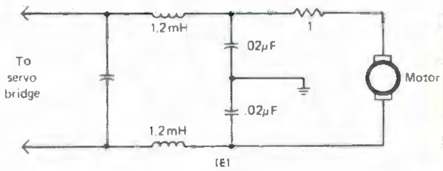
Applications Suggestions

The Experimenter's Radio-Control System described here consists of a basic encoder/transmitter and receiver/decoder sans interfacing to the outside world. Since this is conceptually an *experimenter's* R/C system, we have left applications implementation to your ingenuity.

The system described is excellent for remote radio control of the usual model airplanes, boats, cars, etc. By adding some very minor interface circuitry at the decoder outputs of *IC3* and *IC4*, it is possible to remotely control lights, appliances, heating systems, automatic sprinkler systems and much more. For such applications, no modification of the transmitter is necessary.

Motor Drive Notes

For applications in which motors are used, the receiver and drive motors are powered by the same battery. Because of high current drain, alkaline cells are preferred. An alkaline C cell can deliver 400 mA, a D cell 700 mA, for 10 continuous hours. Comparable carbon-zinc cells will last only one or two hours.



Since dc motors generate wide-spectrum noise, this can have an adverse effect on the receiver's r-f and i-f sections. Also, high peak-current demands by a motor under heavy load can affect battery terminal voltage. This can be critical as cell voltage drops toward its end-of-life 0.9-volt level. Fortunately, sensitive circuit elements in the receiver are referenced to the supply line, and the LM1872 has good common-mode rejection characteristics.

Most notable problems will occur with very inexpensive motors in which a metal stamping is used for commutator brushes. The brushes have very-light, single-point contacts that cause a great deal of arcing and, hence, electrical noise. If a motor is located several inches from the receiver, you may have to use a noise-suppression network like that shown here. In projects where space considerations force close proximity between motor and receiver, use low-noise motors with wire or carbon brushes. Various types of small dc servo motors are available from local hobby dealers and mail-order houses.

For more ambitious—and knowledgeable—experimenters, other applications might include simple robot control; complex robot control (tie the transmitter into a personal computer and program the floorplan of your home, for example); conversion of video games to eliminate the cable attached to the joysticks; a carrier-current digital local-area network (FSK or on/off carrier modulation) communications link using local house ac wiring; remote temperature monitoring with associated heater/air-conditioning control; etc.

Some simple interfaces to help you get started are given in circuits A through D in the "Interfacing to the Outside World" box. If your primary interest is to adapt the system for motor drive (as needed for model airplanes, boats and cars), important information is given in the "Motor Drive Notes" box.

Whichever way you decide to use the Experimenter's Radio-Control System, you will find it both highly flexible and eminently adaptable. **ME**