

HOW TO

Interface R/C Servos

R/C servos are good for more than controlling model planes and cars. Here's a description of how they work, and some ideas on how you can use them.



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RADIO-CONTROL (R/C) SERVOS ARE GOOD for much more than just operating model aircraft or boats. They can be used to keep a signal generator on frequency, steer a small robot, govern your lawnmower, interface a computer to run a strip-chart recorder—in fact, those miniature servos provide just about the ideal electrical-to-mechanical interface. They are simple to use and cost-effective, and the circuits needed to drive them are simple, and easy to build—you can even put them together on prototyping boards.

How servos work

Servos are slow-running electric motors that can be stopped and started almost instantaneously. As long as they receive a control signal they run; when it stops, so do they. That makes them well suited for use in proportional-control systems, such as are used in model airplanes, boats, and cars. The control signals can be sent by radio, or fed directly to the servo-control circuits.

R/C servos generally operate from TTL logic-level voltages—about five volts—which makes them very convenient to interface with computer or other TTL circuits. The devices—which may generate several pounds of thrust—draw a maximum of 400 mA to 1000 mA, depending on the particular type used. Servo-control signals are pulses whose widths vary from one to two milliseconds in length; the servos convert that pulse-width-modulated signal into a precise mechan-

ical movement.

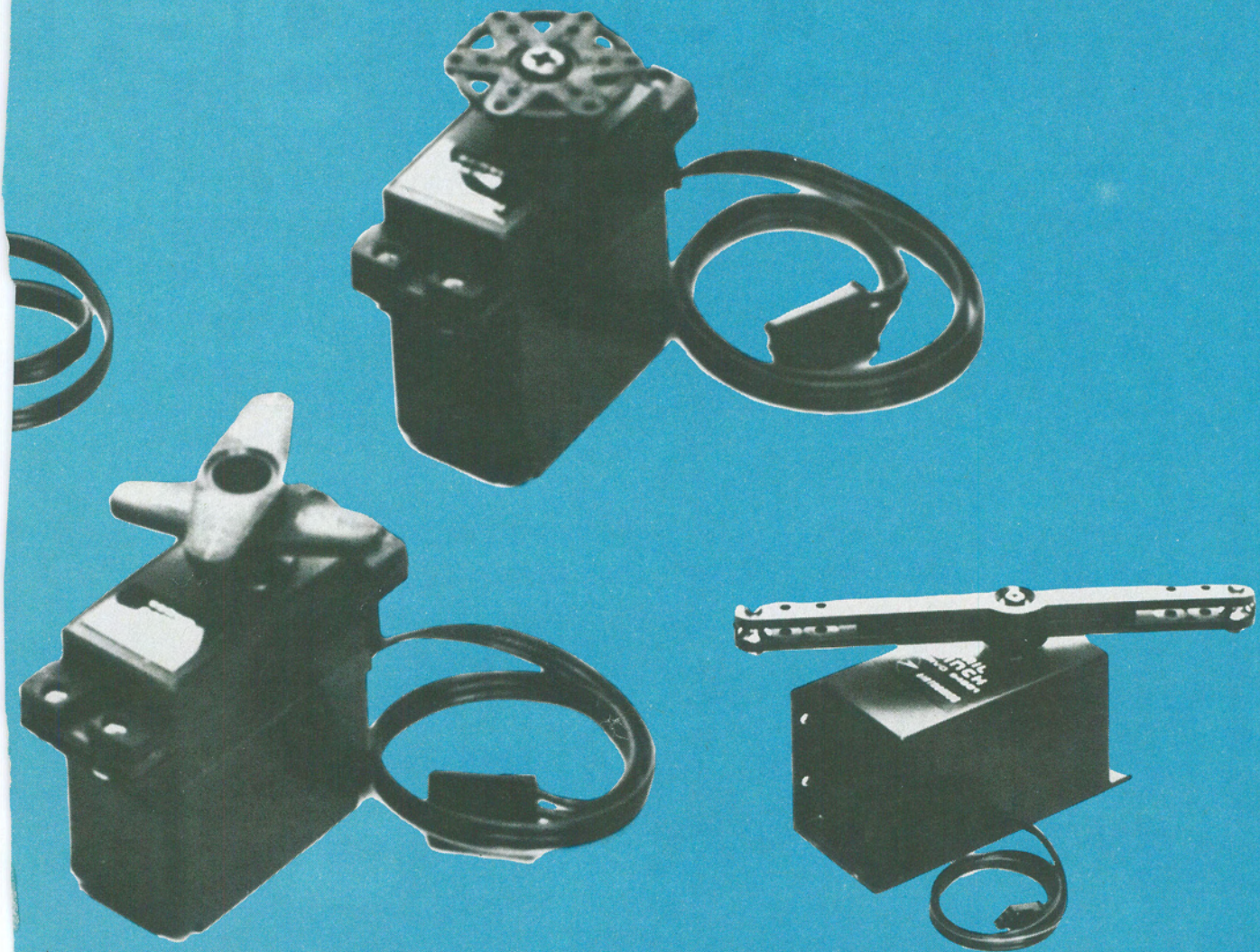
Inside the servo housing is an IC that provides all the functions needed to convert the width of a pulse into the signals needed to drive the servo motor so that the output shaft is correctly positioned. Figure 1 shows a block diagram of a typical servo-driver IC and its connections to the servo motor. The output shaft of the servo motor is attached to a potentiometer. As the output shaft is driven by the motor, the voltage across the potentiometer varies. The amplitude of that voltage is directly related to the position of the output shaft, and the voltage is fed back to the servo-driver IC where it controls the time duration of an internal one-shot pulse generator.

When a logic-level input pulse reaches the servo-driver IC, two things happen. First, the internal one-shot pulse generator previously mentioned is triggered. The time duration of the one-shot's output pulse is controlled by the feedback voltage from the potentiometer on the output

shaft of the motor. The duration of the output pulse is compared to that of the input pulse by two NAND gates. The result of the comparison will trigger one of the two pulse stretchers; that in turn will either set or reset the directional flip-flop.

(The pulse stretchers are required because in many servo applications—model aircraft, for example—as many as eight channels can be in use at the same time with information being transmitted sequentially to as many as eight servos. Under those circumstances, as many as 25 milliseconds may pass before a particular servo receives another input pulse. The pulse stretchers keep the servo motor running for most of the time between input pulses, keeping “chatter” to a minimum and allowing greater speed and efficiency.)

The output of the flip-flop will cause the servo motor to be driven by one or the other of the motor-drive circuits; the circuit selected will determine the direction in which the motor will turn. The motor



will turn the output shaft until it reaches a position that causes the input pulse and the pulse from the one-shot to be of equal durations.

A one-millisecond input pulse will drive the output shaft of the servo motor to one extreme, and a two-millisecond pulse will drive it to the other.

A servo-control circuit

In most applications, you will need to convert the amplitude of a DC voltage into a pulse-width-modulated signal that can be used to drive the servo motor. For example, you may have a remote TV camera that you want to be able to aim from your monitoring location. Your control console could have a joystick for that purpose which, when moved, would move the shaft of a potentiometer.

The output of the potentiometer would be a DC voltage related to the position of the joystick and would have to be translated into a pulse-width-modulated signal that could be used to control the servo.

That signal can be generated by a single quad op-amp (one IC containing four separate op-amps) like National Semiconductor's LM324.

An easy-to-build PWM (*Pulse Width Modulation*) circuit using that IC is shown in Fig. 2. Two sections of the IC (IC1-a and IC1-b) function as a ramp generator whose output is a sawtooth waveform. Op-amp IC1-c is a conditioner that limits the DC level and peak-to-peak swing of the input signal. The last section of the IC (IC1-d) compares the output of the signal conditioner with the ramp (triangle) waveform. The signal conditioner is adjusted to provide a comparator output that is compatible with the servo's requirements.

The heart of the ramp generator is IC1-b. It operates as an integrating amplifier with capacitor C1 acting as the integrating- or feedback-element of the circuit. If the output of IC1-a is negative, a current will flow through R4 and try to pull the inverting input of IC1-b down. In

response, the current output of IC1-b will increase so the current flow through C1 continues to equal the current flow through the input resistor R4.

That charges C1 and, if nothing else were to happen, IC1-b's output would reach its positive limit and stay at that level. However, IC1-a is configured as a Schmitt trigger that monitors the output of IC1-b, and when IC1-b's output voltage reaches a certain point, IC1-a changes state (it goes high). Current then flows through D1 and R3, and the input of IC1-b goes high and its output drops rapidly. When it drops to a certain point, IC1-a changes state again, and the whole cycle repeats. The repetitive cycle generates a sawtooth waveform with a positive going ramp.

Adjustment

After you've built the circuit, if you have an oscilloscope available, connect its probe to the output of the comparator (IC1-d). Set the OFFSET potentiometer,

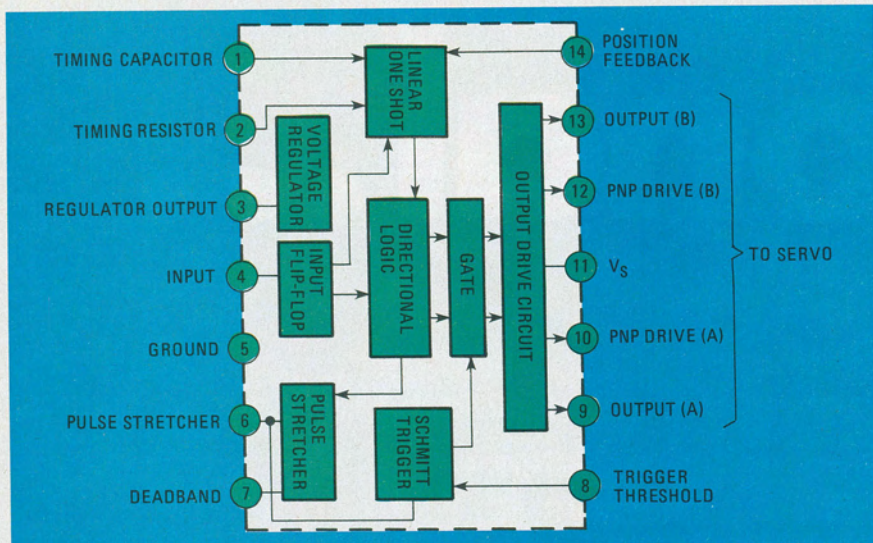


FIG. 1—SERVO-DRIVER IC DECODES input pulses and outputs signals that cause the servo motor to turn in one direction or the other.

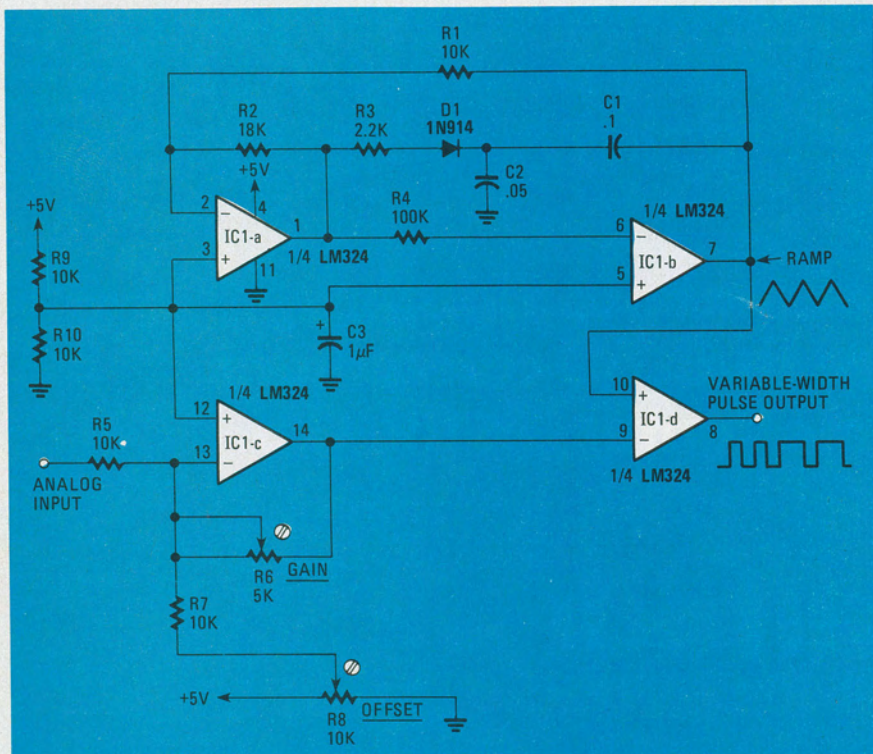


FIG. 2—ANALOG-TO-PULSE-WIDTH CONVERTER senses DC-voltage level and outputs a corresponding variable-width pulse-string to servo-driver IC.

R8, for a pulse width of about 3 ms. At the signal input (R5) apply the lowest voltage you are likely to use and observe the duration of the pulse on the scope (still connected to the output of IC1-d). Then apply the highest-level signal you expect to use and observe the pulse-width. Set R6 (GAIN) so that changing from one input-voltage extreme to the other results in a one-ms change in pulse duration. Once that is achieved, apply the lower-level signal to the input and adjust R8 for a two-ms pulse width. A high-level signal should then cause a one-ms pulse to be generated.

Connect your servo to the pulse-width output. The black or green lead of the

servo is ground; red is the positive supply-voltage, and the remaining lead is for the pulse signal.

Apply the control signals from your generator and be sure the servo doesn't jam. A jamming condition is best determined by measuring the current drawn by the servo. If the current draw exceeds the midrange idle-current at either extreme of the servo's travel, adjust R8 slightly. (Midrange idle-current can be measured when the servo is at any position other than an extreme.) If the servo jams at both travel extremes, adjust R6 to eliminate the problem. If your servo requires negative-going pulses, they can be obtained by adjusting R8.

PARTS LIST

All resistors 1/4-watt, 5%, unless otherwise specified

R1, R5, R7, R9, R10—10,000 ohms

R2—18,000 ohms

R3—2200 ohms

R4—100,000 ohms

R6—5000 ohms, trimmer potentiometer

R8—10,000 ohms, trimmer potentiometer

Capacitors

C1—0.1 μ F

C2—0.05 μ F

C3—1 μ F, tantalum

IC1—LM324

D1—1N914

Miscellaneous: perforated construction board, wire, 5-volt power supply, IC socket, cable and connector for computer's parallel port, servos and linkages, etc.

Servos can be purchased at most "hobby shops" that sell R/C equipment. Check your local Yellow Pages under "Hobby & Model Construction Supplies." They are also available mail order; check the ads in modelling magazines.

Computer control

To control a servo with a home computer, all you need is one line of a parallel port and a program with a timing loop that will provide pulse signals of one to two ms in length that repeat every 20 milliseconds. The pulses will have to be repeated enough times to ensure that the servo has reached the desired position—usually half a second is enough to go from one extreme to the other. Servos are apt to cause power supply noise, so it might be a good idea to add a 0.01- μ F capacitor across the servo's power-supply terminals.

Applications

The output wheel on the servo's shaft can be attached directly to a pen or pointer for use in a strip-chart recorder. It can be directly hooked to a robot arm using model-aircraft linkages. For steerable devices, borrow the front-end parts from model-aircraft nosegear. To govern the speed of a lawnmower, hook an arm from the servo shaft directly to the lawnmower engine's throttle plate; that should give you nearly instant control.

R/C servos have dozens of uses, whether or not you use a computer to control them. Give them a try in your next project.

R-E



"I'd tape toy commercials and play them for Mom and Dad just before my birthday."