APRIL

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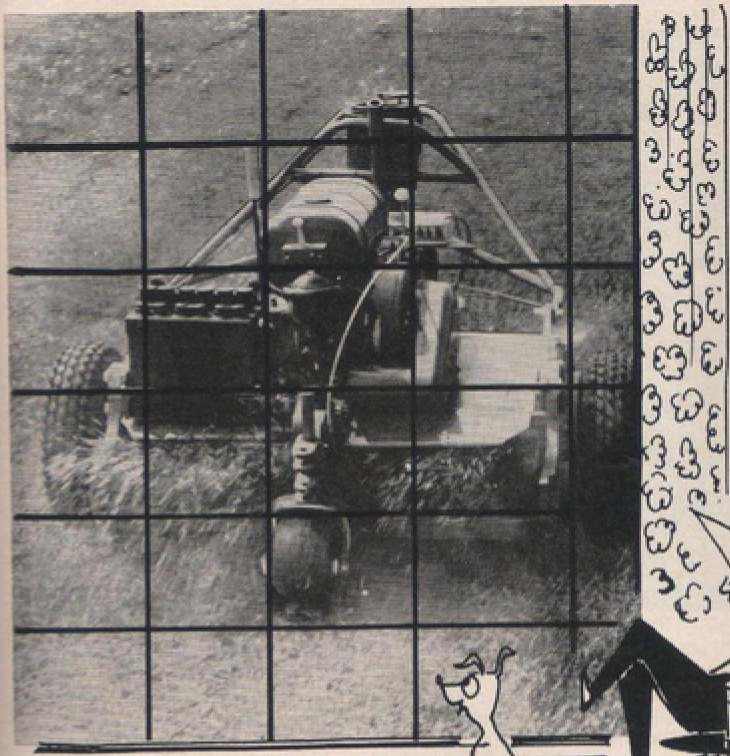
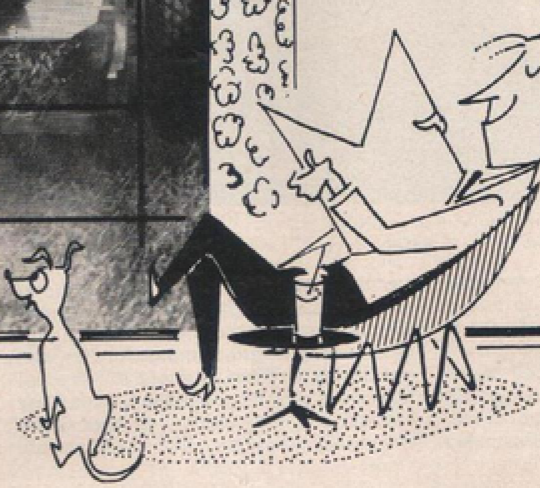




THE LAZY MAN'S DELIGHT...

...An Automated Lawnmower

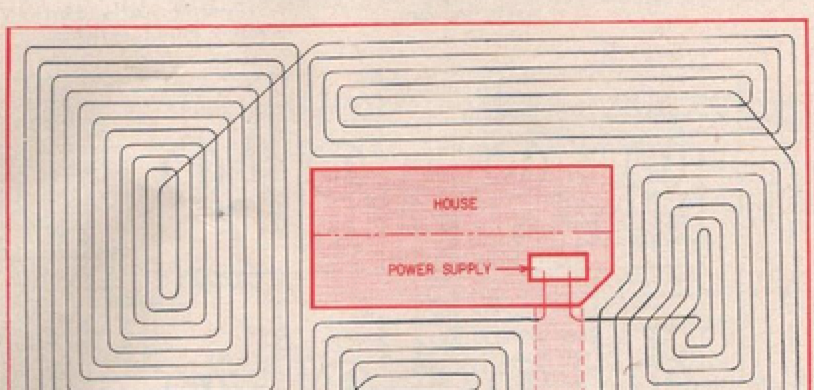
By GORDON CARLSON*

MUCH has been done with remote control, but a remotely controlled device that must maneuver in tight places (such as a grass cutter near the wife's flower beds) and in near panic situations (like a very close miss) requires constant and close observation. This means radio control from the lawn chair is out. Instead, a completely reliable, fully automatic device that doesn't require watching, that does not run over the neighbor's dog or the children's toys is the type of easy living lawnmower that allows plenty of time for relaxation.

Basically, the operation of this automatic lawnmower is this: A length of ordinary plastic-covered hookup wire is buried about 1 inch under the lawn in the pattern the grass is to be cut (Fig. 1). The distance between wires depends on the width of the cutting blade and the amount of overlap desired.

Mounted about 16 inches in front of the steerable wheel of the mower are two pickup coils (Fig. 2), about 6 inches apart and 2 inches above the lawn. When a small alternating current is passed through the buried wire, an electromagnetic field is set up around it.

When the coils are near the wire, the magnetic field induces voltages in them. The amplitude of these voltages increases as the coils move nearer the wire. If the coils are equally distant



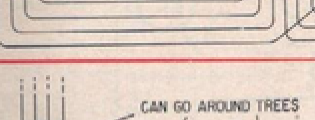


Fig. 1—Pattern for mower guide wire in one particular application.

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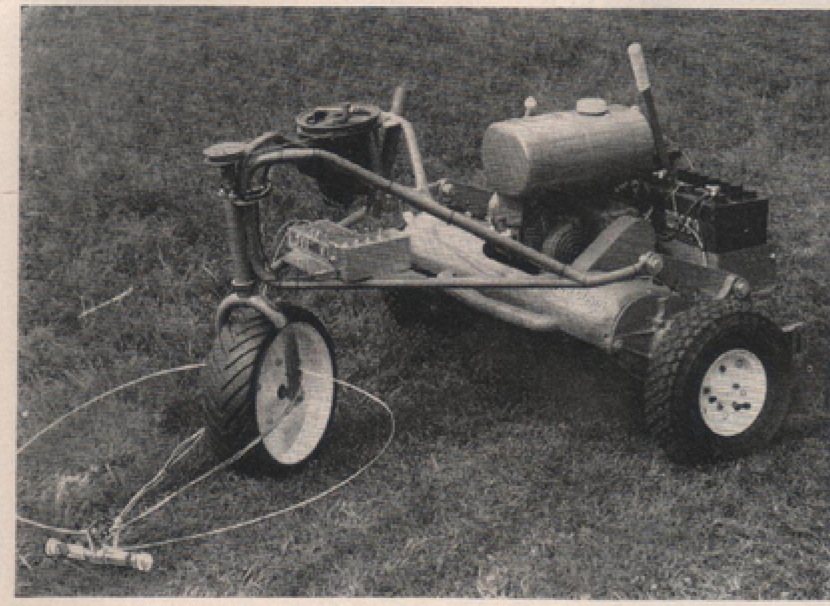


With all electronics mounted, the mower is ready to go. Hoop-like wire around front wheel is safety device.

from the wire, their induced voltages are equal. If they are moved so one is closer to the wire than the other, unequal voltages are induced.

The output of each pickup coil is fed into a four-stage ac amplifier (Fig. 3). The amplifier output signals are rectified and combined in the comparator circuit to produce a dc difference signal which is applied to the two dc relay amplifiers. When equal-amplitude signals are fed to the comparator, its output is zero. When signals of unequal amplitude are applied, the comparator outputs are proportional to the difference in signal amplitude, but of opposite polarities. The relay amplifier whose base is driven negatively conducts more heavily and picks up its relay, while the other amplifier is driven almost to cutoff.

Since the relays the amplifiers operate are small, power relays capable of handling the steering motor currents are connected to them. Actually the relays form a sort of amplifier, permitting an 8-ma signal to control a 2-amp load.

The coils are in front of and mechanically connected to the steerable wheel so they move when it turns (Fig. 2). Thus if the wheel direction is not exactly correct, the coils drift off the ideal location over the buried wire and produce an error signal. This signal causes the amplifier, the relays and the motor to reposition the coils correctly over the buried wire.

An arrangement as simple as this is far from an ideal servo system since it would be constantly hunting. To reduce hunting, a two-speed steering system is used. When a small error is detected, the motor turns at about two-thirds speed to reposition the coils. Larger errors (such as in a tight curve) cause the motor to run at full speed to make the largest part of the correction. When the coils approach their mid-position, the motor slows and comes to a stop with little overshoot.

Thus, with both steering control and steering speed control, the lawnmower has all that is needed except safety devices.

An automatic stop relay stops the unit if the coils leave the magnetic field entirely. This relay also protects the mower in case of component failure. Instead of making you run like crazy to save the flower bed or the grass cutter from destroying itself, it just stops and waits to be put back on track. For the protection and preservation of movable obstacles like dogs and toys, a set of feelers extends out in front

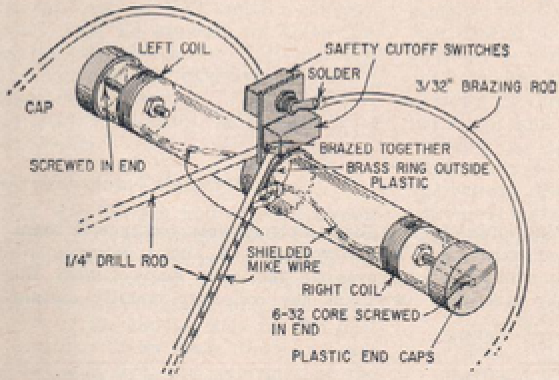
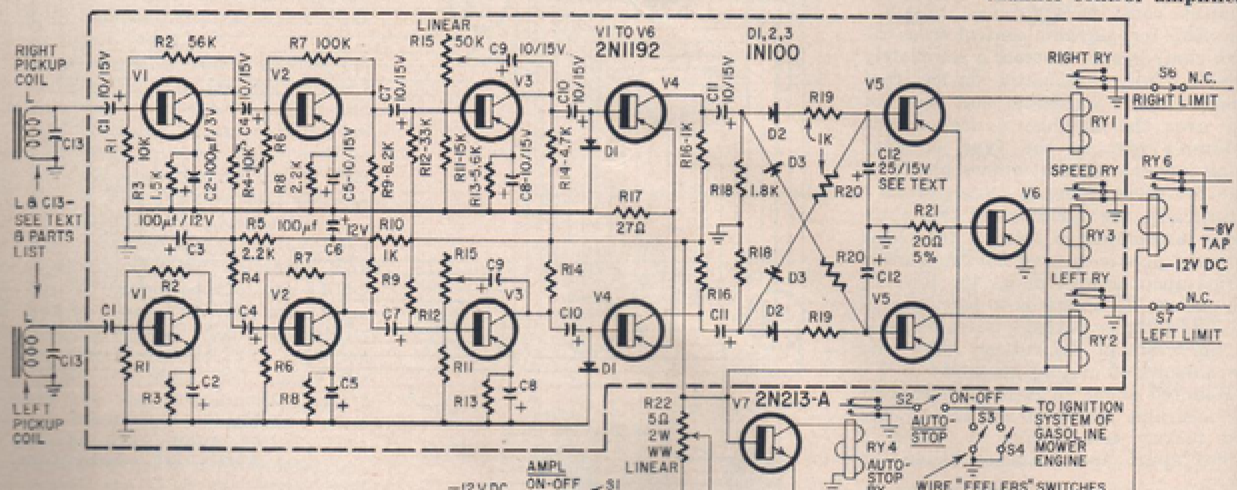
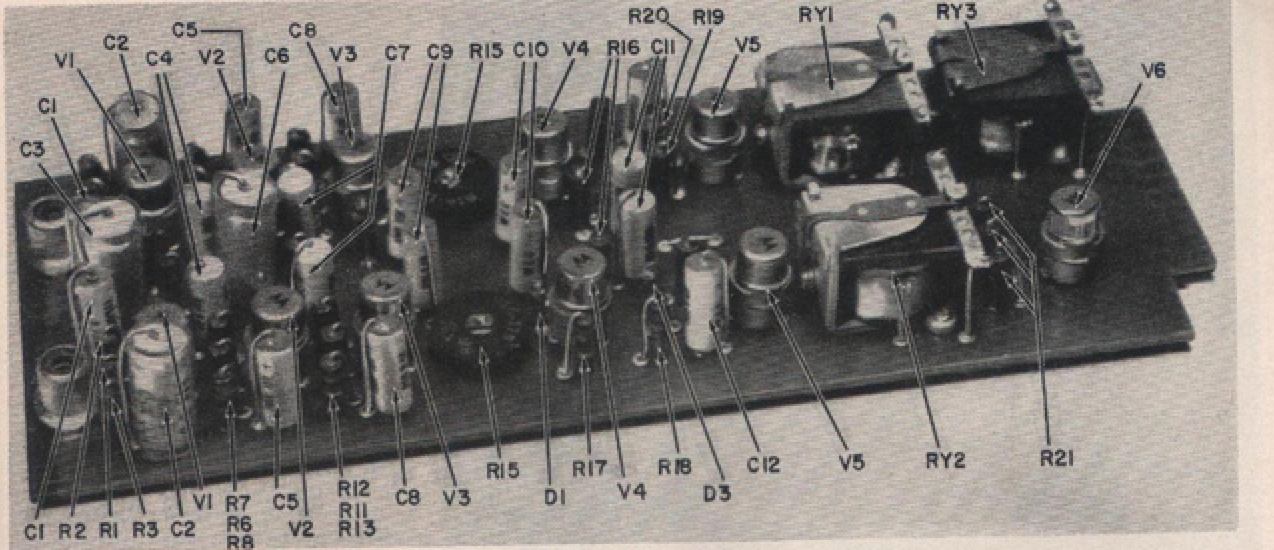


Fig. 2—Details of steering coils and safety cutoff switches.

Fig. 3—Circuit of the 2-channel control amplifier.





Top view of the printed-circuit board. Note upright mounting of components.

of the mower and causes it to stop if physical contact is made with them.

Transistor amplifier

The transistor amplifier uses the grounded-emitter configuration. A combination of bias methods provides a high degree of temperature stability. Both negative voltage and current feedback are used in both V1 and V2 stages (Fig. 3). R2 and R7 provide voltage feedback and, with R1 and R6, stabilize the dc bias current. Even though bypassed, R3 and R8 provide a small amount of current feedback.

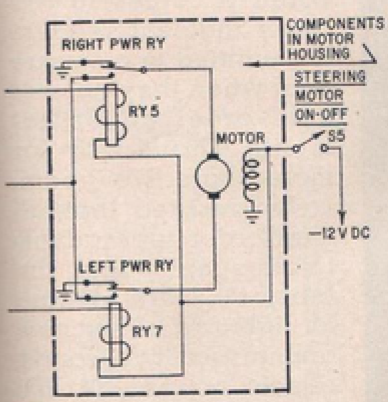
V3 differs from the two preceding stages—the negative voltage feedback is variable. This provides a means of controlling the gain of each channel. The 2N1192 transistors provide more than enough gain so the large amount of negative feedback allows transistor replacement with little or no selection. Increasing the feedback loop to extend beyond one stage is impractical because problems of low-frequency stability arise.

The comparator circuit introduces some loss and, since it should produce as large a difference voltage as possible, V4 is operated at a fairly high output level. To avoid excessive dissipation in V4, the bias current is developed by rectifying the incoming signal with diode D1. This form of variable bias eliminates the need of the stabilizing feedback used in the preceding three stages. Since both amplifier channels are identical, and with the signals from the pickup coils in phase, signals throughout the ac amplifiers are in phase channel for channel.

V4's common-emitter resistor, R17, aids in producing greater voltage differences between channels. When the pickup coils produce an error signal, the increase of signal in one channel and the corresponding decrease in the other vary logarithmically, causing the voltage across R17 to increase. Thus there is more bias and the channel having the smaller input signal further decreases its output. In the comparator —D2, D3, R18, R19, R20 and C12— the signals are rectified along with the inversion of the polarity of the smaller voltage.

The channel that feeds the larger signal into the comparator drives its V5 stage base positive; the smaller signal, negative. In the V5 stage, resistor R21 is common to both emitters. When a larger than normal error voltage is produced, the conducting V5 stage carries more than average collector current. This produces enough bias current to cause V6 to conduct. The resulting increase in V6's collector current energizes the steering-speed relay.

The normal operating current of the entire amplifier is about 15 to 40 ma, depending on the position of the coils with respect to the buried wire. With no signal, the current drops to about 8 ma. Therefore, in stop amplifier V7, R22 is adjusted so that, normally, the voltage across this resistor keeps V7 conducting and its relay energized. If the voltage across R22 decreases, RY4 is de-energized and shorts out the mower's ignition, stopping its forward



NOTE

DUPLICATED CODES IN LEFT & RIGHT PICKUP COIL CKTS HAVE EQUIVALENT VALUES

R1, R4, R6—10,000 ohms
R2—56,000 ohms
R3—1,500 ohms
*R5—2,200 ohms
R7—100,000 ohms
R8—2,200 ohms
R9—8,200 ohms
*R10—1,000 ohms
R11—15,000 ohms
R12—33,000 ohms
R13—5,600 ohms
R14—4,700 ohms
R15—pot, 50,000 ohms, miniature, linear taper (Centralab B16-119 or equivalent)
R16, R19, R20—1,000 ohms
*R17—27 ohms
R18—1,800 ohms
*R21—20 ohms, 5%
*R22—pot, 5 ohms, 2 watts, wirewound linear taper
All resistors ½-watt 10% unless noted
C1, C4, C5, C7, C8, C9, C10—10 μf, 15 volts, miniature electrolytic
C2—100 μf, 3 volts, miniature electrolytic
*C3—100 μf, 12 volts, miniature electrolytic
*C6—100 μf, 12 volts, miniature electrolytic
C11—10 μf, 15 volts, miniature electrolytic (for 60 cycles)
C12—25 μf, 15 volts, miniature electrolytic (for 600 cycles)
C13—see text
D1, D2, D3—1N100
L—see text
Pickup Coils—from Advance Tiny-Mite M/2C/5000D relays. Remove core and replace with 1-inch long 6-32 threaded rod. Place nut on each end. Excess rod screws into plastic end cap.
MOTOR—surplus, White - Rogers 12 volts, dc, 3 rpm, 150-inch/lb. torque, trim tab motor (Possible sources: Electro Sales, 50-58 Eastern Ave. Boston 9, Mass.; Fair Radio Sales Co., 132 S. Main St., Lima, Ohio; Servo Tech, 1086 Goffle Rd., Hawthorne, N.J.; Lectronic Research Lab, 715 Arch St., Philadelphia 6, Pa.)
*RY 1, RY 2, RY 3, RY 4—spdt, 6 volts dc (Potter & Brumfield RS5D or equivalent)
*RY5, RY7—in motor specified
*RY6—dpdt, 12 volts dc (Potter & Brumfield KA11D or equivalent)
*S1, S2, S5—spst, toggle
*S3, S4—spst, toggle, snap-action type
*S6, S7—spst, roller, snap-action type (Acro BRD2-2M-15 or equivalent)
V1, V2, V3, V4, V5, V6—2N1192
*V7—2N213-A
Transistor sockets (11)
Chassis and case, to suit
Miscellaneous hardware
*1 each of these parts. All others 2 of each.

Safety devices stop mower if it runs into an obstruction.

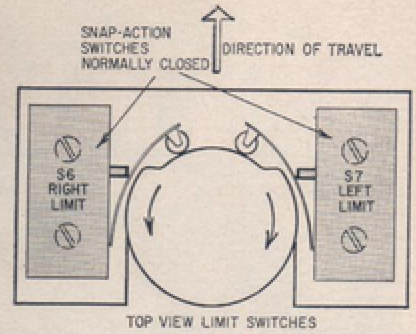


Fig. 5—Closeup of limit switches, section of steering system.

motion. This automatic stop operates any time the mower leaves its buried wire by more than 3 inches, and can be adjusted (with R22) to stop the mower anywhere between 2 and 8 inches.

Construction

To build the amplifier, an etched wiring board was used—an amplifier subjected to the vibration found on a grass cutter has to be very rugged to be reliable. Of course, a perforated insulating board might be simpler for many people. Even a regular chassis with terminal strips would work.

The layout of the parts is not at all critical. Our first breadboard model proved this. Because the input impedances of transistors are low, the only extra care needed is to separate the V1 stages from the V4 stages by 2 inches or more. No special parts were used in the amplifier. The pickup coils are miniature 5,000-ohm relay coils removed from their mountings.

Capacitors C12 were selected to resonate the pickup coils at the frequency of the ac in the buried wire. Since this unit was to be used for demonstrations here at DeVry Tech and elsewhere, the buried grid of wire was energized with a current of different frequency from that in the ac power line. We didn't want interference from strong magnetic fields that we couldn't control. Our coils resonate at 930 cycles with a .02-μf capacitor. In our demonstration setup, a 10-watt audio amplifier driven by an audio oscillator is used to supply 4,000 feet of No. 20 wire with about 0.4 amp of current.

A unit intended only for cutting grass could use a stepdown transformer to energize the wire at 60 cycles. The same current would be used in the wire. For 60-cycle operation, besides a larger value capacitor for C12, coupling capacitors C1, C4, C7, C9, C10, and C11 should be 20 μf. The amplifier has never failed in any way even though the relays open and close many thousands of times for each cutting of the lawn.

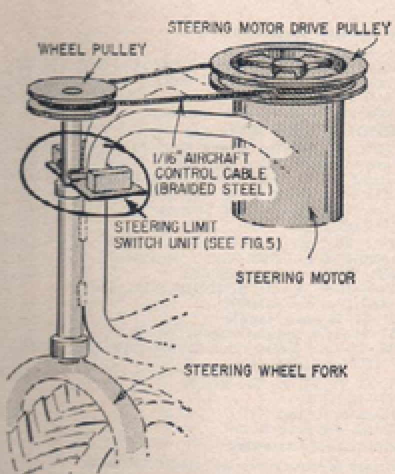


Fig. 4—Details of the steering motor and pulley arrangement.

Mechanical details

The lawnmower has an electric starting system which is powered by a self-contained 12-volt battery. With this power source, we used a surplus White-Rogers 12-volt dc, 3 rpm, 150-inch/lb.-torque trim tab motor to handle steering. Two pulleys with a woven steel cable drive the steerable wheel (Fig. 4 for details). A steering speed of 45° of arc per second (7.5 rpm) gives the least hunting while traveling at forward speeds of 5 feet per second or 3+ miles per hour. For higher forward speeds, a steering system that is completely proportional to the input signals would probably have to be used. Limit switches (Fig. 5) keep the steerable wheel from turning too far. The present mower (a Jacobsen Lawn King) has shown that it traces the wire without deviating more than ¼ inch from previous runs. Our mower has differential gears between its two drive wheels. Whether a unit without this feature would work as well has not been determined.

An automatic steering arrangement for other types of power mowers would, of course, be somewhat different. Therefore, details of the steering control will have to be worked out by the builder for the particular mower he is using. In any event, once the job is done, you can sit back to the easiest lawnmowing you ever did. END