DESIGN CONTEST WINNER

Control Your Telescope by Voice

With just six voice commands (eight with a little more work) your telescope will be doing tasks that once left you fumbling in the dark under the night sky. This project might be a good excuse to give amateur astronomy a try.

FEATURE ARTICLE

Michael Swartzendruber

Amateur astronomers are a nocturnal bunch. The very nature of their hobby demands it. Good, deep-sky viewing requires darkness, but that can also be a bit of a hindrance, especially when you want to adjust the position of your telescope. Over time, astronomers develop a sense for the location of the declination and right ascension fine adjustments on their instruments to compensate for working in the darkness. This sense comes from many hours spent groping in the darkness for these controls; a solution that is workable, but sometimes distracting.

Telescope-manufacturing companies have developed and marketed a number of devices that position the telescope, including motors driven by simple switch boxes or computers with built-in "star maps." These methods are nice tools for semiautomated telescope positioning, but they also require hand operation in a low-light-level viewing environment. However, there is another option that does not require the use of the hands.

Imagine what it would be like to have the telescope change its position with a spoken command. For instance, saying "Go" would cause the declination control to raise the angle of the telescope while saying "Reverse" would lower the angle. Sound like science fiction? Well, it's not. The technology for this feat is well within the budget of the amateur astronomer. In fact, the electronics for this system cost about $75. I'd like to give you the opportunity to build a system I've named the Scope Commander. It uses the VCP200, an economical, speaker-independent, word-recognition chip from Voice Control Products Inc. This remarkable little chip represents the start of a new era of voice-commanded appliances and control systems.

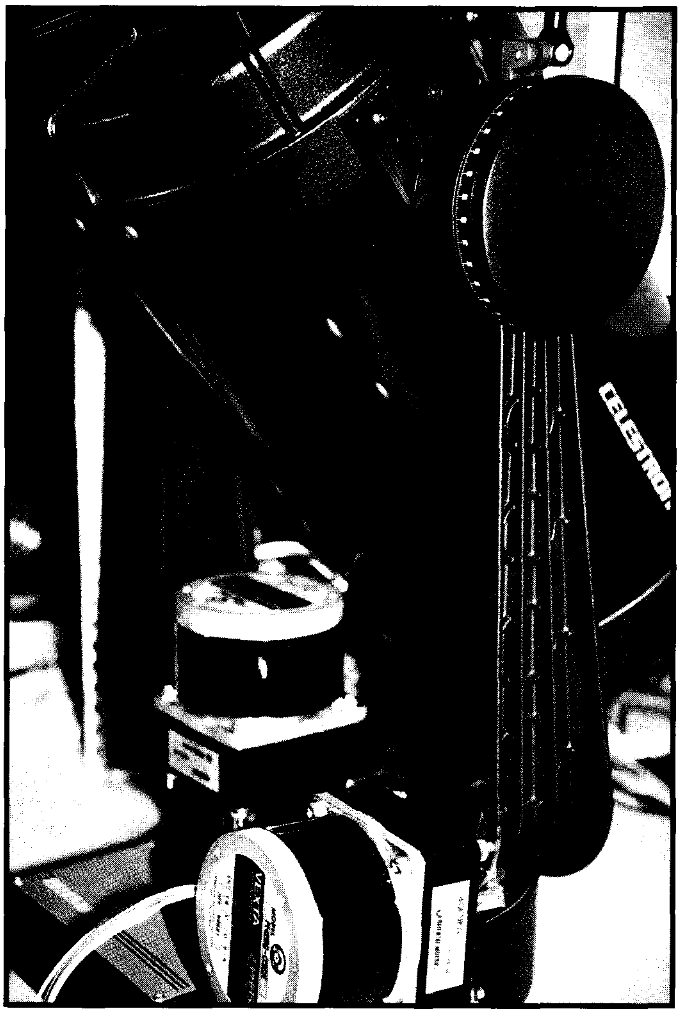


Photo I--The Scope Commander can be used with many telescope mounting *schemes. The prototype is used to control a Celestron C8 telescope.*

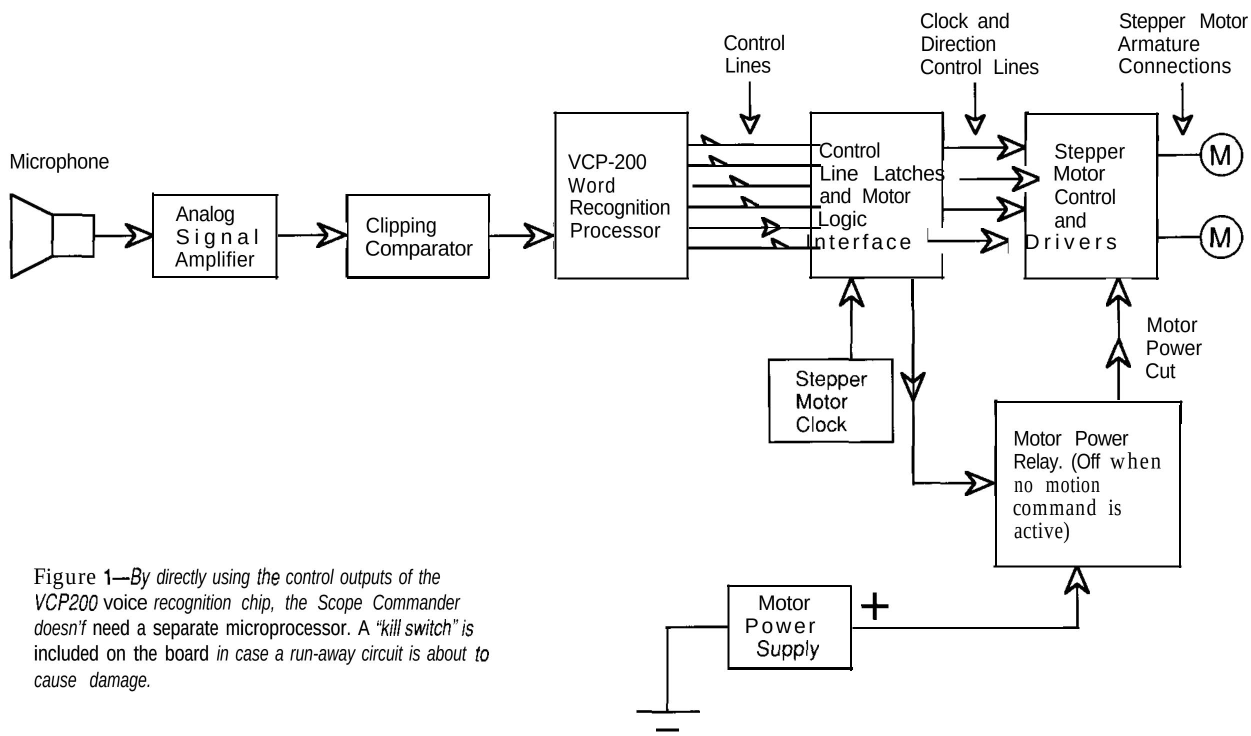


Figure 1—*By directly using the control outputs of the VCP200* voice *recognition chip, the Scope Commander doesn't* need a separate microprocessor. A *"kill switch" is* included on the board *in case a run-away circuit is about to cause damage.*

Experimentation with voice recognition is an ongoing pursuit for many computer specialists. Several word-recognition systems have been developed for experimenters, professionals, scientists, and hobbyists over the years. Some of these systems consist of peripheral cards and software that you must add to a PC. The first system I can remember was used with S-100 bus systems. Macintosh and AT-architecture platforms use more current designs, but who wants to lug around one of these machines with a telescope? I wouldn't and that's why Scope Commander requires a much smaller, stand-alone system.

In a brief overview, word-recognition systems work by accepting the sounds of the human voice as input. For examination purposes, the words are converted to either a succession of electrical waves, a pattern of waves that represent the phonemes contained in the spoken word, or both. A *phoneme* is defined as a sound created within the vocal and nasal cavities of a speaker that is modified by the size and shape of the mouth's opening and by the simultaneous positions of the tongue and teeth. A distinct succession of phonemes is recognized as a spoken word.

The phoneme patterns of a particular word are represented to a computer system as a distinct frequency mix that changes over time Then the system converts the phonemes to frequency patterns and compares them with a previously stored representation of frequency patterns held in a memory array. It declares a match when the patterns contained in the input data stream match the stored patterns precisely enough.

The VCP200 chip is a Motorola 6804 microprocessor preprogrammed to create the core of a word-recognition voice signal-processing system. This core simplifies experiments in word recognition because the ROM on the chip contains the word-recognition algorithm, so the experimenter does not have to develop it. Also, the $15 price makes the device affordable. The processor's preprogramming limits the system's eventual range of capabilities in a gross sense, possibly keeping the VCP200 out of some complex systems, but it is ideally suited for the purposes of small, dedicated, voice-controlled systems like the Scope Commander.

The computer hardware requirements of the VCP200 are minimal. It needs little more than a crystal and a S-volt supply to operate, making this system lightweight, portable, and usable in many dedicated systems. Other circuit blocks in the Scope Commander perform voice input signal conditioning, output data latching, and steering logic and load current control and switching.

As shown in Figure 1, the system consists of a voice signal input and analog signal-conditioning circuit; the VCP200 processor circuit core; and the latching motor control interface, which includes a stepper motor clock source and high-current motor drivers.

CIRCUIT DESCRIPTION

The voice signal input and conditioning module is composed of an electret microphone, a microphone preamplifier, a final amplifier stage, and a clipping comparator. The microphone preamp amplifies the very low voltage output of the polarized electret microphone. This signal is passed to a final amplifier stage.

Adjust the gain of this stage to compensate for the volume of your voice by modifying the value of the feedback resistor connected between pins 6 and 13 of the op-amp. The output of the final amplifier is sent to a clipping comparator, which jumps to positive rail when the voice signal amplitude exceeds a certain preset comparator amplitude.

If you need a variable-sensitivity circuit, you can make the threshold level adjustable. Use the sensitivity control to make the circuit suitable for environments with different levels of ambient noise conditions. Adjust the threshold by replacing the 5.6-kΩ resistor (connected between pins 5 and 12 of the op-amp) in the comparator circuit with a 10-kΩ pot whose wiper connects to the positive input of the comparator (pin 12). You must also substitute a 1-kΩ resistor in place of the 4.7-kΩ resistor (connected between pin 12 and ground) that is a part of the bias network of the comparator circuit to complete the modifications.

Note the approximate total of these two resistances is 11 kΩ. This amount is necessary to maintain the 2.5-volt bias on the positive inputs of the preamplifier and the final amplifier stages that precede the comparator stage. The bias tricks these circuits into behaving as if a ±2.5-volt supply was powering them. As long as the total value of the threshold circuit resistors is 11 kΩ, the other op-amp circuits will be correctly biased and will operate properly. The larger the value of the potentiometer, the more range the threshold circuit will have.

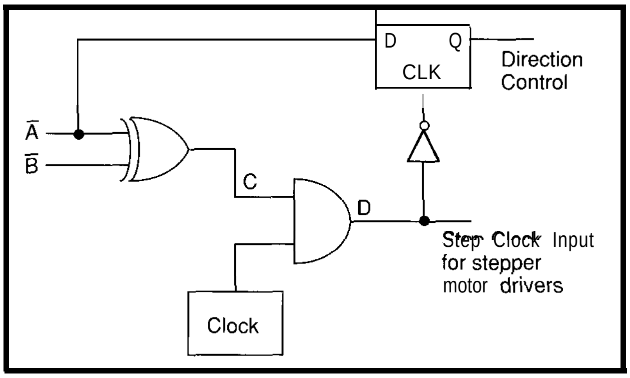


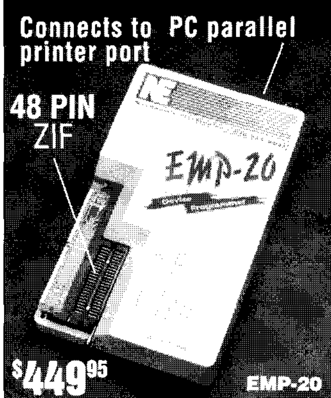
Figure 2—*When either input signal (A or B) is active, the clock signal is gated through to the latch. The latch uses the A input to determine the final state of the motor direction line.*

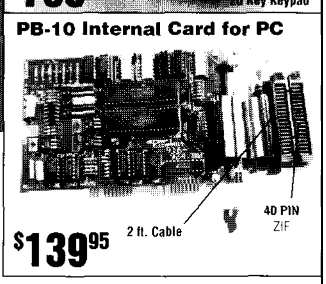
The frequency at which the voice signal crosses the comparator threshold voltage is closely akin to the frequency of the sound waves the speaker's voice produces. This succession of frequencies relates to the series of phonemes (or words) spoken. Thus, the threshold switching action of the comparator modulates the frequency of the human voice as a digital logic level pseudo pulse train. The frequency-modulated signal train represents a spoken word.

The VCP200 processes this digitized signal to match an internally stored pattern. The exact processes of the algorithm remain the property of Voice Control Products Inc., so I could only speculate about what they have written in the program stored in hard ROM code in the 6804.

When the VCP200 determines a pattern match, it toggles one of its eight output lines. The programming in the VCP200 is set to pattern match on the words *Lights, Go, Slow, Reverse, Left* Turn, *Turn Right, Stop,*

Device Programmers





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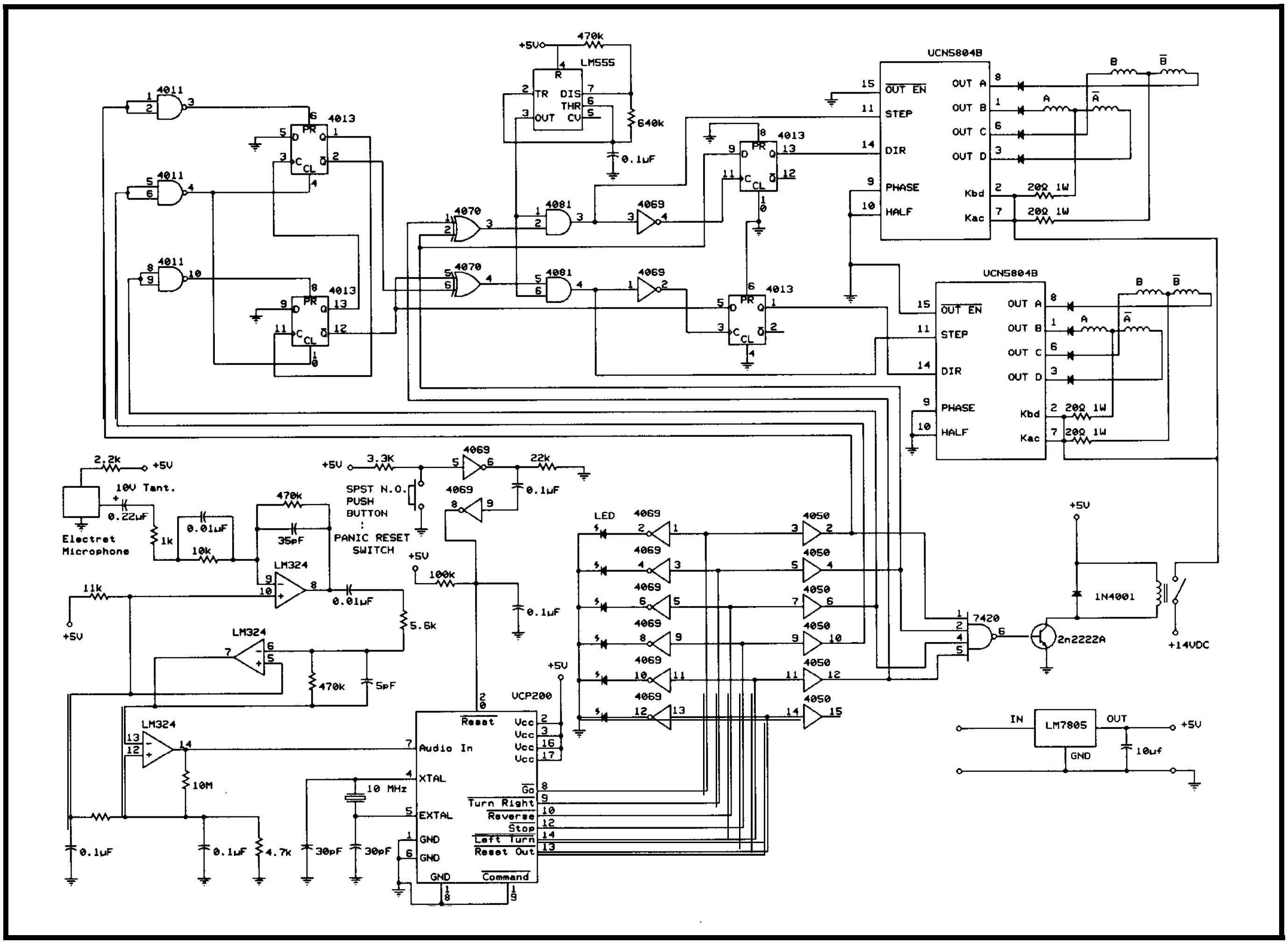

Figure 3—The heart of the Scope Commander is the VCP200 voice recognition chip. The UCN5804 takes care of the details of driving the stepper motors. With the addition of some gates and latches, the circuit eliminates the need for a separate microprocessor.

and *Reset.* The Scope Commander project uses Go, *Reverse, Left Turn, Turn Right, Stop,* and *Reset. Left Turn* and *Turn Right* are for right ascension fine adjustment. Go and *Reverse* set declination. *Stop* halts all motor rotation. The *Reset* line is buffered, but it is not implemented here.

The other two commands *(Lights* and Slow) are also not implemented here, but you may use them for focus control by duplicating one of the motor steering logic sections. The VCP200 output lines used in this project are sent to two gates. The first is an inverter that drives an LED indicator and shows which control line is low at the time. This feature is useful because sometimes the circuit will mistakenly trigger or misunderstand a speaker's intention. The second gate is a noninverting buffer and driver chip, which isolates the VCP200 from the rest of the circuit and gives the "bus" a little more current capacity.

The declination control lines (Go and *Reverse)* are inverted, so they can be active high, and are latched into a pair of Set/Reset latches. *Stop* resets these latches. This latching circuit lets the right ascension control bits *(Turn Right* and *Left Turn)* change states, while the state of the declination control bits (Go and *Reverse)* remain unchanged.

The latched circuit has three basic steering modes to the Scope Commander circuit: adjust right ascension, adjust declination, and simultaneous adjustment of both ascension and declination. These steering modes can be made independently of either motor's direction. Use Stop between commands to lessen the chance of mechanical binding or other anomalous behavior in the Scope Commander circuit. The circuit will change states without a hitch, but rapidly changing the stepper motor states could damage the motor armature. I included the reset switch as a safeguard to allow an emergency system halt.

The stepper motor interface is a straightforward application of a pair of "L/R" stepper motor driver chips and a 555 timer. The trusty old 555 is set up as a bistable multivibrator running at 10 Hz. You may use a higher rate if necessary as long as you stay within the limits of the drivers.

The pulse train from the 555 is used as the step clock for the stepper motor driver chip. The UCN5804 from Allegro Micro Devices (formerly sourced by Sprague Semiconductor) contains logic that generates the proper pulse sequences to drive the stepper motors. The 555 frequency output is routed through the AND gates in the motor logic steering section and applied to the logic clock input on the UCN5804.

Each of the motor direction control bits from the VCP200 is passed through an XOR gate. This gate will go high when one of the control bits connected to it goes low. Only one of these control lines can go low at a time when the VCP200 determines a word match. When both of its inputs are high, the XOR gate is in its "inactive" condition, and the word associated with that control bit has not been recognized.

Once a word is recognized, the VCP200 pulls the control bit associated with that word low, then the XOR gate is "activated" and goes to a high state. The high state goes to the input of an AND gate whose output then follows the toggle clock connected at its other input, passing the clock signal to the L/R driver chip clock input, which converts each incoming pulse to the next valid step state for the motor armature.

The output of the AND gate is also routed through an inverter, and

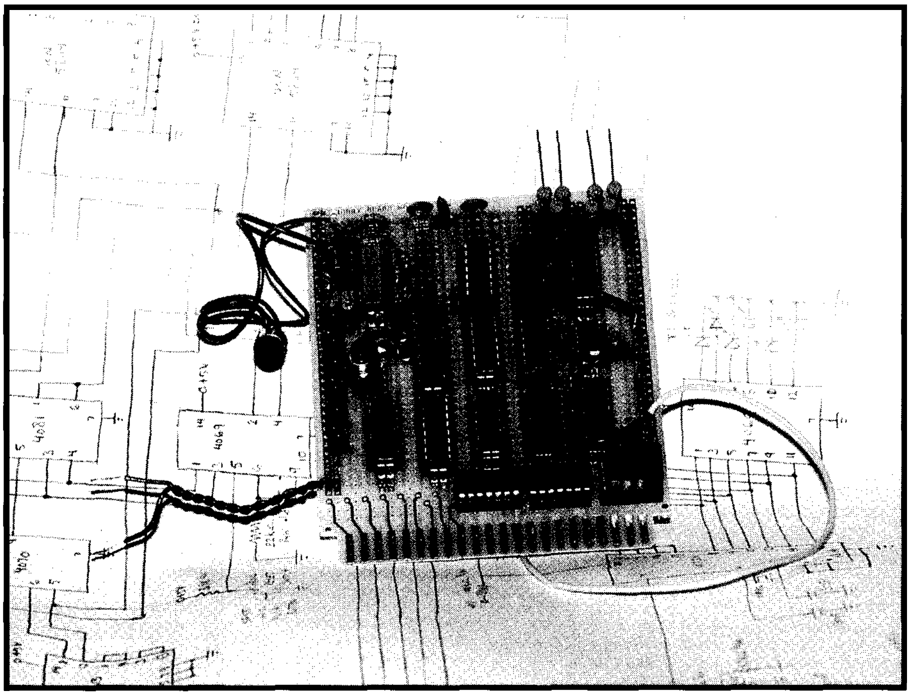

Photo 2—The final prototype is *built on protoboard* using *wire-wrap construction.*

this signal is used as the clock source for a *D* latch (see Figure 2). Its data bit connects to one of the channel's control bits. The output of the *D* latch changes state on the falling edge of the clock. The Q output from this gate sets the direction control line on the stepper motor driver chip. Because only one of these lines will be low, the Q output of this gate will be low or high depending on the state of its *D* line to activate the XOR gate, giving direction control to the UCN5804 chip. The inversion of the clock signal exiting the AND gate is required for properly changing the state of the L/R signal in relation to the clock's transition state.

The output of the UCN5804 operates up to 24 V and 1.5 A peak. This device has a maximum clock input of 320 Hz, so the clock speed of 10 Hz is well within its specification. The armature resistors on pins 2 and 7 are used as short circuit and current protection. The Schottky diodes, in series with the stepper motor driver chip's bipolar output devices and the stepper motor armature, are implemented to control back EMF from the collapsing fields of armature poles.

The stepper motors are 74-oz/in, four-phase (or two-phase center-tapped) unipolar steppers with a step angle of 1.8" per step. These motors require 14 volts and have a peak coil winding of 0.7 A. This circuit operates at 0.5 A while the motors are running, so they function well within their tolerance ratings. The motors are

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connected to the telescope adjustment controls through 9: 1 reduction gear boxes. The output shaft of the gear box directly drives the fine position adjustments on the optics system. The rotational velocity of the motor shaft is 18" per second because these motors are stepped at 10 pps. The end shaft on the gear box is rotating at 2" per second after gear reduction.

The motor windings do not have to be charged while the motor is not being stepped because the gear box provides a significant amount of holding torque. Therefore, you can shut off the armature current when the motors are not being moved. This feature keeps the motor's temperature down and lowers the constant current requirements of the system, an important factor because the circuit will usually be run on a battery-powered supply.

A quad input TTL NAND gate, whose output drives the base of a 2N2222 (or equivalent) transistor, controls the current for the stepper circuit. This transistor is wired as the classic grounded emitter switch. The current in the collector circuit drives a relay. A diode wired in the coil circuit protects the collector of the transistor from back-EMF fields. The output of the NAND gate will go high when any of the motor control lines (Go, *Reverse, Left Turn, Turn Right) goes* low. This change will close the relay contacts to power the stepper motor as long as it is being driven.

The system requires 5 VDC for the main logic board and from 12 to 14 VDC for the stepper motors. A car battery and a regulator should do quite nicely. Be sure to take care when transporting the battery to prevent fracturing the case or spilling acids; a carrying box with a handle might not be a bad idea. I also recommend equipping the system with a reverse voltage protection circuit to prevent backward battery mishaps.

MOTOR-MOUNTING CONSIDERATIONS

For me to address all the issues that could arise when mounting motors to the device is impossible. Many different scopes are available and they may have slightly different locations for declination and ascension adjustments, but you should follow these guidelines.

Take care when mounting the motor and gearhead assemblies to the telescope; don't just start drilling holes everywhere to mount the motors. Place the motor shafts and the fine adjust control shafts on a straight line to prevent or minimize mechanical binding. Mount the motors in a way that does not impair operation or storage of the telescope. Finally, the motors should be easily removed if you need to operate the telescope without them.

CONCLUSIONS

Scope Commander is a useful application for voice control technology. The thrill you'll feel when your device responds to a spoken command is well worth the time and effort you will have invested. This project is relatively inexpensive to build; the components for the logic assembly I described cost about $70 retail.

The Scope Commander brings a new level of enjoyment to deep-sky viewing. Finally, as a word of caution, don't let the scope ocular bump you in the eye as it is moving. I wish those of you who build this project many happy hours of star gazing. Remember, if there is a limit to the number of possibilities the universe has to offer, someone will probably find it in deep space. ❑

Michael Swartzendruber is an engineer with experience in network and communications design and Windows and Macintosh programming.

SOURCE

Voice Control Products, Inc.
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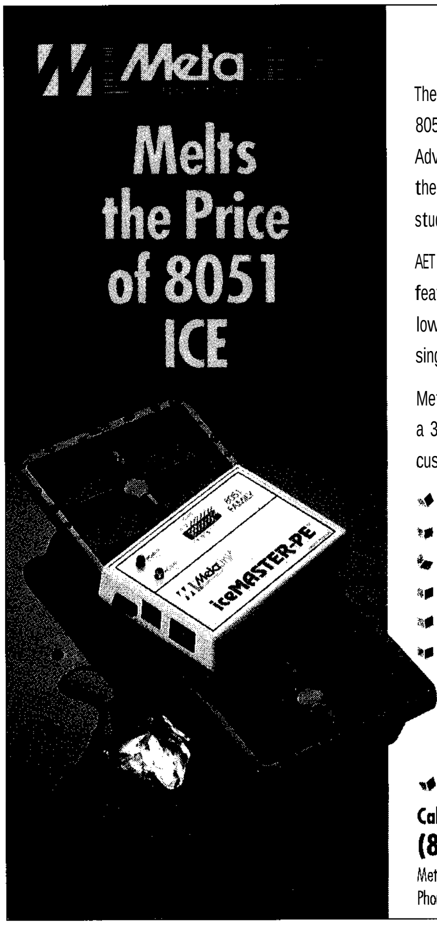
407 Very Useful
408 Moderately Useful
409 Not Useful



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