#20, April 1993

ENCODER

The Newsletter of the Seattle Robotics Society

A Trip to Toronto

by Bob Nansel

After reading about the first BEAM Robot Olympics held October '91, a robotics extravaganza created by Mark Tilden of the University of Waterloo, I decided that I *had* to get to the Second Olympics. For Love of Robotics, what's a few miles?

April 22—25 I realized my goal. I was dazzled by the number and variety of robots (I lost count of the robots, but I heard later that there were 150 different machines at the Olympics). I saw pancake flat robots less than a centimeter tall, solar powered light seekers, micromouse maze runners, Sumo wrestler robots and a robot powered by beer. I saw a robot the size and shape of a salt shaker. I saw all manner of walking robots, from eerily silent Nitinol powered spiders to assorted hexapod walkers and the potentially lethal GCC Wild Thing (a distinctly non-biological walking machine built for speed).

Wild Thing was easily the most annoying robot at BEAM; I had to step lively to get out of its way a couple of times as it lurched across the floor. To the unwary it could be an ankle buster because, though it was fast, it wouldn't be right to say it was fully controlled.

The micromouse maze runners were incredible. Like thoroughbred race horses, these machines are highly evolved maze solvers built for speed and grace. A micromouse might spend ten minutes exploring the maze, but once it had learned the maze, the run to the goal could be as fast as 12 seconds.

I will never forget the people I met and the robots I saw. I hope to go to the Third BEAM Olympics next year.

Above: Hexapod walking machine.
Left: BEAM Participants with twin robots.
Below: MITEE Mouse III and creator David Otten of MIT.

A Beginner's Mobile Robotics Taxonomy

Amateur robotics is far from being a homogeneous field. Whenever I'm confronted with a system of seemingly unmanagable complexity, I try to break it down into smaller parts. I believe that if you can classify the type of something, you are well on the way toward understanding and using it.

Jesse Jackson, newsletter editor of the Robot Society of Southern California, uses a four way classification of mobile amateur robots. In ascending order of complexity they are:

Tethered Robots are like the electrically operated puppets used in special effects work. They are the simplest place for a beginner to start in robotics. There was a time when most so called "Remote Control" toys were *wire* controlled toys..

RC toys can be converted to tethered robots by ripping the receivers out and replacing them with a bunch of switches and wires to make the motors go. In doing this the beginner quickly learns basic wiring practices and how to drive and reverse motors. Every motor will need two wires, plus you'll need two wires for B+ and Ground (B-).

The second step might be to use the switches to control transistors or relays located on the robot so that motor currents don't flow in the control tether. You can then use lighter gage, more flexible wire for the control tether. This is the method used in the SRS Tethered Robot contest.

For tethered robots with more than, say, four functions to control, the sheer number of wires needed for the tether makes it unwieldy; the next logical step is replacing the parallel tether wires with a serial cable. You might do this with a shift register at each end, a parallel to serial SR to turn the switch data into a serial bit stream, and at the robot end a serial tq parallel SR to convert the bit stream back to into parallel outputs. Those parallel outputs would drive the transistors which drive the motors as in the tethered robot.

A more sophisticated version could use a UART to perform the same function, allowing full duplex operation. With a UART it is also possible to use the serial port of a PC to directly control your robot, and with sensor feedback you now have the start of a fully autonomous robot (except it's tethered to your computer).

Teleoperated Robots or *Telerobots* are remote control robots. They do jobs like nuclear power plant maintenance, pipe/ductwork inspection, and undersea exploration, to name a few. For these jobs, telemetry information such as video, temperature, pressure, radioactivity, or force feedback is vital for the person controlling the telerobot.

RC toys can be converted to tethered robots by ripping the receivers out and replacing them with a bunch of switches and wires...

RC models shouldn't be called telerobots because they don't provide this telemetry feedback to the user. With ingenuity, though, you can add video cameras, bumper sensors and the like to stock RC models. This can be a great way to teach yourself how industrial telerobots work.

Some amateurs have even devised video and control signal delay systems to explore the problems involved in controlling telerobots from great distances, such as from Earth to the Moon. Earth/Moon round trip travel time for radio signals is about 2.5 seconds, making direct control impractical. This

It's your task as a robot amateur to work through these successively more difficult robots...

means the robot can't be just a radio controlled puppet, but must have some intelligence on board. These are called *Supervised Autonomous Robots*, the third major class of mobile robots.

SA robots not only have uses in space, but also in undersea exploration where radio signals can't penetrate. In the ocean depths, control and feedback must travel as soundwaves, so several seconds can elapse between sending a command and receiving confirmation from the robot sub. The robot must have enough onboard intelligence to carry out commands and stay out of trouble. Today amateurs can contribute directly to robotics research by experimenting with SA robot submersibles. When we return to the Moon next century, amateurs will have also helped paved the way for lunar SA robots with their experiments here on Earth.

Autonomous Robots , Jesse's fourth category, are the sort we normally think of when talk about robots. Truly autonomous robots do exist, but only for carefully controlled and specified environments.

It is your task as a new robot amateur to work your way through these successively more difficult robots, solving problems and honing your skills. By the time you're ready to work on fully autonomous robots, you will not only have learned what it takes to build robots, you will have earned your place at the cutting edge of robotics.

The Editor

Using HC11 Single Chip Mode

by Karl Lunt

The 68HC11 has gotten much press lately as a robot brain, so I thought I would spend some space describing its features and how to use it.

Motorola offers a huge variety of 68HC11s; the two or three letters following the "11" gives a clue to the resources available for that chip.

For example, the 68HC11A1 contains 256 bytes of RAM, 512 bytes of electrically eraseable PROM (EEPROM) and no on-chip ROM. The a0 variation looks like the A1, except it has no EEPROM, while the a8 has RAM, EEPROM, and 8K of ROM. The a8's ROM usually contains a copy of Motorola's BUFFALO monitor, useful for developing and testing small 68HC11 programs.

Besides various amounts of RAM, ROM, and EEPROM, the 68HC11 chips usually offer on-chip serial ports in either of two flavors. The SCI works like a standard asynchronous serial port; you have to provide external circuitry to convert the chip's TTL signals to/from RS-232 before you can connect it to your PC.

These chips also usually carry the SPI, a high-speed synchronous serial bus designed to let two or more 68HC11's talk to each other or to appropriate Motorola peripheral chips.

Most 'HC11s also contain eight channels of 8-bit A/D on board, making interface with external sensors very easy. Other goodies usually offered include a multi-channel 16-bit timer system, 24 or more bidirectional I/O lines, real-time clock, watchdog timer, and pulse-width modulation (PWM) system.

Two 68HC11 variants get the most attention in recent robotics articles. The 68HC11A1 is cheap (BG Micros sells them for $5.95 each) and its 512 bytes of EEPROM is enough room to write surprisingly powerful programs. The 'e2 version (actually, the 68hc811e2) offers 2K bytes of EEPROM, but isn't as easy to get.

```
iobase      equ     $1000         default start of I/O regs
toc2        equ     iobase+$18    output compare #2
toc3        equ     iobase+$1a    output compare #3

rmtr.fwd    equ     $f880         right motor, full speed fwd
lmtr.fwd    equ     $f140         left motor, full speed fwd
rmtr.toc    equ     toc2          addr of right motor timer reg
lmtr.toc    equ     toc3          addr of left motor timer reg

main        .
            ldaa    #$60          bits for OC2 and OC3
            staa    oc1m          OC1 will control these outputs
            ldaa    #$00          when OC1 times out...
            staa    oc1d          it will clear OC2 and OC3
            ldaa    #$f0          when OC2 and OC3 time
out...
            staa    tctl1         they will output 1s
            ldx     #$0000        get timeout value for OC1
            stx     toc1          and save in timer reg

            ldx     #rmtr.fwd     need to go forward
            stx     rmtr.toc      start right motor
            ldx     #lmtr.fwd     need to go forward
            stx     lmtr.toc      start left motor
            .
            .
            (add more robot code here...)
```

Listing 1: HC11 PWM Setup Routine

The EEPROM on both these chips serves as easily eraseable program storage. You can erase and reprogram this memory in milliseconds, with no special programming equipment. All you need is a PC and a copy of Motorola's PCBUG11; the PCBUG11 program is free from Motorola's FREEWARE BBS, (512) 891-3733 (9600/2400 8N1).

You can wire up a working 68HC11 computer board in just a few evenings. You will need a 52-pin PLCC solder-tail socket to hold the chip; you can order both socket and chip from BG Micros. Marvin Green recently published an article in these pages giving the schematic for such a board; look through the last couple of issues.

I had a heckuva time wiring up my first 68HC11 using a PLCC socket. I could not find a pinout for the socket anywhere. I finally ended up counting out the pins and writing up my own layout diagram (see Figure 1). At least none of you will have to go through the same hassle.

I wired my 68HC11 system a little differently than Marvin described in his article. For one thing, I carefully built up the MAX232 circuitry inside a plastic RS-232 connector shell, with an eight-inch length of four-conductor cable coming out the back end of it. The cable plugs into my 68HC11 board and carries the TTL-level serial signals (+5V, GND, TX, and RX) to/from the board.

This means I don't have to add the

Please see **HC11** *on p.4*

A Matter of Friction

by William Harrison

How fast can your robot accelerate or stop? Can it make controlled turns, or will your robot skid around corners? Understanding friction is key to answering questions like these.

How much push does it take to overcome an object's frictional force? We all could guess that if the surface were ice, a small force would do. With other materials, we'd guess a greater force would be needed. But how much? What is the maximum friction we can get for a given material?

Friction is a complex, nonlinear phenomenon. To make things simpler, engineers have come up with an equation to approximate frictional forces:

$$F=\mu\times N$$

Where F is the frictional force required to just start the object moving on a surface, N is the "normal" force perpendicular to the contact surface. For a horizontal surface, N would simply be the weight of the object. Finally, μ is the "Coefficient of Friction."

The Coefficient of Friction constant is an approximation of the relationship between the normal force and the frictional force. You can look up the Coefficient of Friction for most common material combinations in any Mechanical Engineering text.

The equation tells us something about frictional forces. For one thing, the minimum frictional force is zero if the surface is vertical (i.e. Normal force is zero), no matter what the coefficient of friction is. This is born out by experience: robots don't climb walls too well.

To get a maximum frictional force, two conditions must be met. First, the force must be perpendicular to the surface. Second, the coefficient of friction must be as big as possible. All Coefficients of Friction are less than one. For design purposes, then, the maximum frictional force that could ever be available for a given object would be equal to its weight.

For an object on a level surface, it's weight (the normal force) times the best possible Coefficient of Friction (one) gives the force parallel to the surface that would just begin to move the object. A six pound robot would need, at most, a force of six pounds be applied to it before it would start sliding.

If you can't find a table with the Coefficient of Friction for the material you are working with, you find it experimentally. Because there are so many variables, such as surface conditons, it's important to set up the experiment as close to the actual situation as possible. If a robot is tested on a different material than it would run on in use, it may not accelerate properly, it could bounce, or even lose control.

HC11 *continued from p.3*

MAX232 circuitry to every 68HC11 robot brain I build. Instead, I just plug my special serial cable into a board whenever I want to connect to the PC. This in turn saves me space on the computer board and money for parts.

Note that you can do even better with the MAX233 (available from Digi-Key); this chip saves you the four electrolytic capacitors needed by the MAX232.

I used 10K ohm SIP resistors (available from Active and Digi-Key) to save board space. Finally, I brought four of the A/D channels and two of the PWM lines out on the MTA-style connectors I favor in building robots.

The 3-pin MTA male connectors I used on the computer board are exact matches for the Futaba J-series servo motor connector. Since the Futaba S148 servo is cheap ($15.99 at Hobbytown, $13.99 mail-order from Tower Hobbies) and easy to modify, it worked out beautifully.

I was able to build a working 68HC11 robot brain, with lots of available features, on a Radio Shack experimenter board about 1.5 x 2.5 inches.

Marvin gave a code fragment some time ago that showed how to run some hobby servo motors with the 68HC11, using Forth. The code fragment in listing 1 (previous page) shows the same procedure in HC11 assembly language.

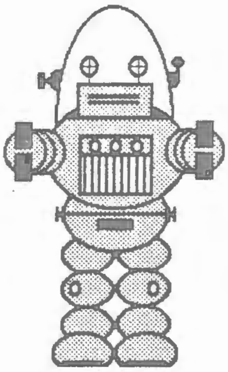
This assumes that you connect the right motor to output compare line 2 and the left motor to OC3 (pins 28 and 29, respectively).

As you can see, there just isn't much to it. You don't even need any interrupt support routines.

I will devote a couple of Nuts & Volts articles to robots using 68HC11 brains. You can get started early by using this information and Marvin's previous articles.

Remember to get in on the club purchase of copies of "Mobile Robots," by Anita Flynn and Joe Jones. This book contains a wealth of information and pointers, developed by various MIT robot builders. It offers complete plans for two working robots, plus excellent material on robo-subjects from motor control to construction, sonar to gyros. A truly must-have book; cost to club members will be $39.95 less 10% discount, plus shipping.

Keep on keeping on...



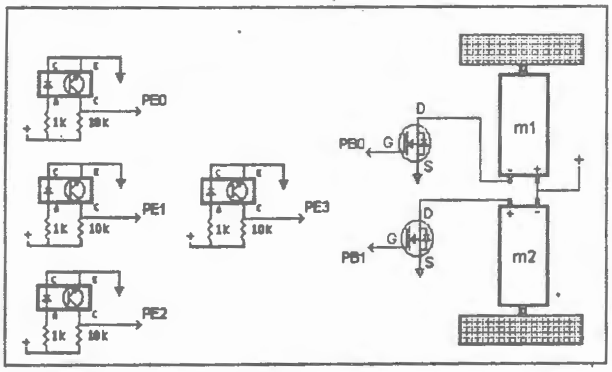
P.A.R.T.S

Portland Area Robotics Society

Issue # 06.5 By. Marvin Green (503) 656-8367.

Check out '**THE VOR**' by Tom Lonergan and Carl Frederick, Hayden Book Company.

ZippyJr. OVERVIEW.



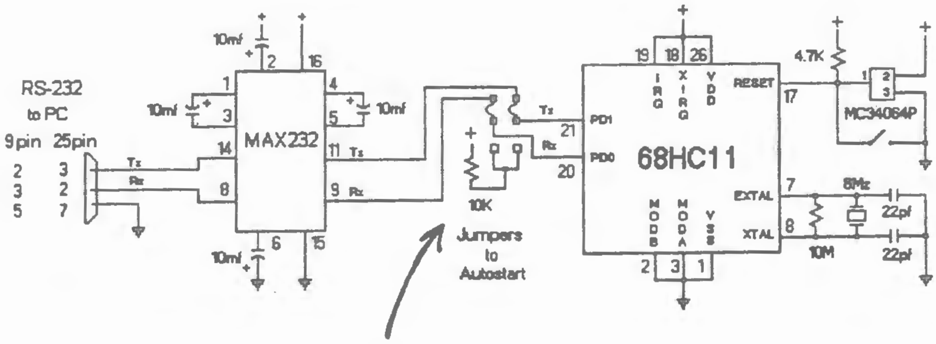
The challenge was to build a robot using only a one chip microcontroller. By combining the $15 Wonder Computer (see PARTS issue #05) two motors, four sensors (see Parts issue #02) and a few TMOS transistors (Radio Shack #276-2074), you have the hardware to make a tiny line following robot.

Here is the circuits that combines with the 68HC11 to create ZippyJr. This project just shows that vast amounts of money and time don't need to be spent to create a small versatile robot. The core program for ZippyJr is less than 200 bytes written in assembler and he runs off a nine volt battery. Next issue I will detail the software for ZippyJr.

Refer to the Motorola MC68HC11 Technical Data for chip specifics, and pin connections.

PC For Your ROBOT ?

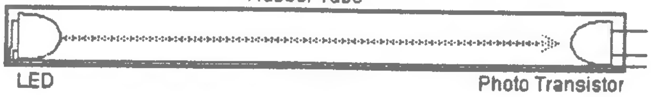
Megatel Computer Corp. has been advertising a small (4"x4") PC compatible embedded module. This computer comes with 256K memory 32K BIOS ROM, keyboard and speaker ports, with a 80C88 8Mhz CPU. Looks like it has definite robot potential, and is compatible with most PC type computers. The PC/104 has a price of only $99. Contact Megatel at 125 Wendell Ave., Weston, Ont. M9N 3K9. (416) 245-3324.



ERROR !
Last Issue.

There was an error in the Jumper section of the schematic, this should correct the autostarting... Thanks Karl.

QUICKIE *idea...*



Here is an idea for a simple whisker for a robot. It uses a low current LED and a photo transistor connected to the signal of a microcontroller. The LED and transistor are mounted inside rubber surgical tubing about 4" long. If anything bumps the whisker, the light path is broken and the photo transistor tells the CPU.

GET THESE CATALOGS!

Combined list of some good places to find robot parts mail order.

Marlin P. Jones & Assoc.
P.O. Box 12685
Lake Park, FL 33403-0685
(407) 848-8236
Motors, Electronic Surplus,
Lots of neat stuff.

HosFelt Electronics, INC.
2700 Sunset Blvd.
Steubenville, OH 43952-1158
(800) 524-6464
More Electronic surplus gages,

Kelvin Electronics
7 Fairchild Ave.
Plainview, NY 11803
(516)349-7620
Plenty of robot kits, educational
kits, from rockets to wire.

Winfred M. Berg, Inc.
499 Ocean Ave.
East Rockaway, NY 11518
(516) 599-5010
Gears, belts, couplings.

Edmund Scientific
101 East Gloucester Pike
Barrington, NJ 08007-1380
(609) 547-8880
Scientific kits, projects, lasers,
microscopes, and more.

SIG
401 South Front St.
Montezuma, Iowa 50171
(515) 623-5154
R/C Airplane parts store.
Great for robotic parts!

New Micros Inc.
1601 Chalk Rd.
Dallas, Texas 75212
(214) 339-2204
Best small computer board for the
money. Powerful 68HC11, with FORTH.
Good docs and good support.

Electronic Goldmine
P.O. Box 5408
Scottsdale, AZ 85261
(602) 451-7454
Lots of weird electronic stuff,
super prices, but the stock comes
and goes wildly.

Herbach and Rademan
P.O. Box 122
Bristol, PA 19007-0122
(800) 848-8001 (orders only)
(215) 788-5583 (office)
DC motors, power supplies, batteries.

Suncoast Technologies
P.O. Box 5835
Spring Hill, Florida 34606
(904) 596-7599
8051 SBCs, kits, and software.

American Science and Surplus
601 Linden Place
Evanston, Illinois 60202
(708) 475-8440
Just about everything

Digi-Key
P.O. Box 677
Thief River Falls, MN 56701-0677
Distributor for many lines of ICs,
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JDR Microdevices
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Lots of PC gear, EPROM programmers,
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and other electronic parts

Mouser Electronics
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Distributor for many lines of
ICs and other electronic parts

Ultrasonics and Robotics, part 2

by Jesse Jackson and Jerry Burton

[Jerry and Jesse of the Robot Society of Southern California continue their discussion started last issue on using Ultrasonic sensors for mobile robots. Figures 1 through 4 are contained in the March '93 Encoder— the Editor]

Range Data

The relatively long-range capability (approximately 35 ft.) of the Polaroid system makes it well-suited to gathering range data for both navigational planning and collision avoidance. Navigational planning involves determining the actual location of the robot and subsequently calculating the appropriate commands to move it to a new location and orientation.

The simplest case reduces the problem to two dimensions with a priori knowledge of the surroundings in the form of a memory map, or world model. The task becomes one of trying to correlate a realworld, sensor-generated image to the model and extracting position and orientation accordingly. Several factors complicate the problem.

For one, the real environment is three dimensional, and although the model represents each object as its projection on the X-Y plane, the sensor may see things differently, complicating the task of correlation. Second, large computational resources are required and the process is time consuming, requiring the robot to stop and think occasionally. Also, acquiring the data can take several seconds using ultrasonic ranging techniques, due to the relatively low velocity of sound waves in air. More important for the purposes of this discussion, however, are the effects of the various error sources previously described, which can act collectively to impede a solution.

Figure 2a depicts the results of 30 range values taken by a single sensor mounted on an azimuth table, with the sensor approximately 5ft. from the wall.

The exceptional quality of the plot is due primarily to the nature of the walls having a pebble grain finish that provided excellent beam return properties. The proper identification of the open doorway and the excellent correlation with the actual map would provide the robot with a highly accurate "fix." It should be noted that the room was fairly uncluttered, which is not always the case presented to our robots. In Figure 2b, the sensor was repositioned 7ft. from the wall and was unable to detect the opening.

For such situations, the robot needs help from other types of sensors or some type of narrowing or focussing of the beam.

Collision avoidance is a little easier to address, in that angular accuracies are less important and the computational overhead nowhere near so great. The intent is simply to be aware of obstructions in time to alter course. For this application the sequential array can outperform a single sensor, in that the array permits range measurements to be made in many different directions very quickly and with minimal power consumption.

Beam Splitting Technique

Sequential arrays can use beam-splitting to improve the angular resolution, already shown to be some what poor for a single transducer.

Beam splitting involves the use of two or more range finders with partially overlapping beam patterns. Figure 5 shows the simplest case of two transducers, twice the angular resolution can by obtained, along with a 50 percent increase in coverage area. The technique is simple. As the target is detected by both sensors A and B, then it (or at least a portion of it) must lie in the region of overlap shown by the shaded area. If detected by A but not B, the target lies in the region at the top of the figure, and so on. Increasing the number of sensors with overlapping beam patterns decreases the size of the respective regions and thus increases the angular resolution. The sensor pattern used on RSSCy allowed for an angular resolution of less than 20 degrees when locating a 1-in. vertical dowel 9 ft. from the robot, a significant improvement over the 30 degree resolution of a single transducer.

It should be noted, however, that this increase in resolution is limited to the case of a single target in relatively uncluttered surroundings, such as a box in the middle of the floor. No improvement is seen for the case of an opening smaller than an individual beam width, such as the doorway illustrated in Figure 2b. The entire beam from at least one sensor must pass through the opening without striking either door post in order for the opening to be detected, and the only way to improve resolution for this case is to decrease the individual beam widths by changing transducers or through acoustical focusing, which sometimes is impractical.

(Continued next page)

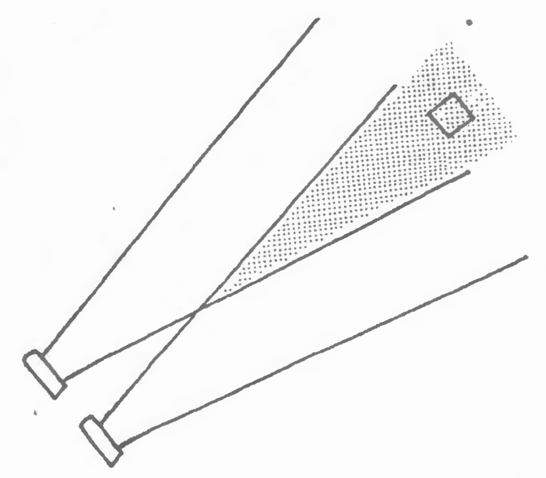

FIGURE 5

Timing Operations

To simplify the circuitry, all timing and time-to-distance conversions are done in software. Three control lines interface the Polaroid ultrasonic circuit board to a microprocessor. The first of these, referred to as VSW (Figure 6), initiates operation when brought high to +V. A second line, XLOG, signals the start of pulse transmission, while MFLOG line indicates detection of the first echo. The controlling microprocessor must therefore send VSW high, monitor the state of XLOG, commence timing when transmission begins (approximately 5 ms later), and then poll MFLOG until an echo is detected or time out when sufficient time elapses to indicate the absence of an echo.

The eight ultrasonic ranging units are interfaced to the microprocessor through a 3-circuit 8-channel multiplexer using single pole relays operating in the digital mode, as shown in Figure 7. This way the microprocessor "sees" only one ranging unit at a time through the multiplexer. Three I/O lines from the 68HC11 handle this enabling function. The binary number placed on these I/O lines by the microprocessor determines which channel is selected. Three other I/O lines carry the logic inputs to the microprocessor for VSW, XLOG, and MFLOP.

The implementation of the sequential ranging array using a small dedicated microprocessor offers several advantages to the mobile robot design.

Use of Multiple Transducers

Using RSSCy electronics as the base for the paralleling experiment, two transducers were connected in parallel to the drive electronics. No degradation of the operation was observed. This technique can be used to increase the detection coverage (ie. wider angular range) beyond that of a single transducer.

Each transducer looks to the drive electronics an a capacitor. We would think that even more additional units could be driven simultaneously as long as the drive capability of the small transformer is capable of applying the 350 volt pulse to all the units.

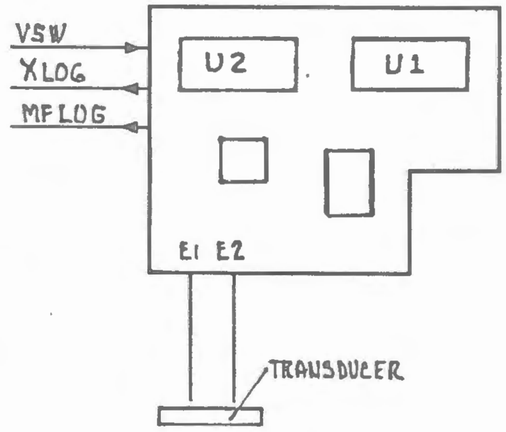

FIGURE 6

Polaroid Evaluation Kit

We suggest obtaining one of the Polaroid evaluation kits for your club if members are interested in getting into ultrasonic acoustical ranging.

The kit that has been available for years is a self contained kit with the timing board, readout board, ultrasonic transducer and battery pack. The read out board provides distance information on a small 3 digit LED unit. The information books included with the kit detail the timing circuits and the readout board capability. It also gives detailed directions on modifications for changes in range and readout.

Polaroid has just announced a second developers kit that contains the timing board, microprocessor board, software, ultrasonic transducer and battery pack. In place of the read out board it includes a microprocessor board with all the support software to write programs that allow control or modification of all the parameters needed in ultrasonic acoustical ranging systems.

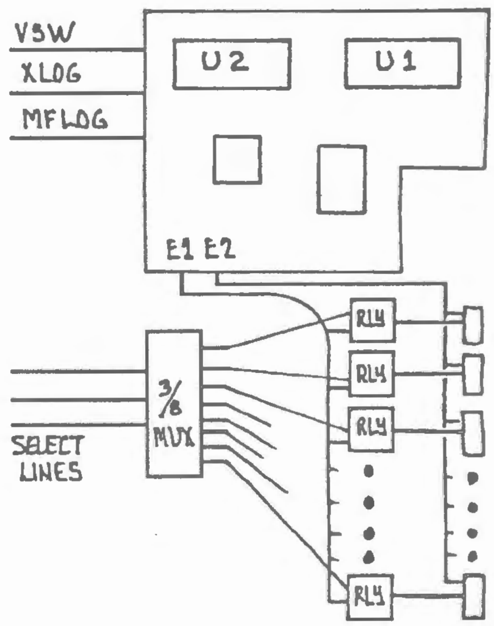

FIGURE 7

Summary

Several prepositioned sensors seem to be superior in performance to mechanically positioned single-sensor systems, in that they allow data to be taken at a faster rate, with less power consumption, and with fewer errors associated with actual sensor position.

Improvements in angular resolution can be gained through the use of beam-splitting techniques, and temperature/altitude correction can be employed to increase range accuracy.

Properly designed horns or tubes can be used to reduce the beam width of the transmission thereby increasing the angular accuracy of the return.

Gain compensation (reduction) can also help increase the angular accuracy by eliminating responses to side lobe energy.

The array concept exploits the properties of ultrasonic ranging for collision avoidance or object tracking, where absolute accuracy is less important than relative information.

For other applications in which precision is an important factor, such as navigation and map correlation in cluttered environments, complementary sensor sets with appropriate characteristics probably should be added. The relatively long wavelength, poor angular resolution, temperature dependence, and slow speed of sound in air can be significant drawbacks in the field of precision navigation or mapping. Infrared and laserbased rangefinders could be considered as alternative or supplementary approaches.

Ultrasonic sensors when carefully applied, still remain the lowest cost and simplest means of obtaining both collision detection and longer range navigation information for our robots.

Sources Of Equipment

From Digi-Key catalog:

Lists Panasonic Ultrasonic Microphone three types separate transmitter and receiver

From Sensor Magazine:

Massa Products Corp of Hingham, MA lists narrow-beam/no side lobe ultrasonic transducers in the 50, 100, 150, and 215 kHz transducer frequencies.

Polaroid Ultrasonic Components Group OEM Product List:

612366 7000 Transducer
604142 TransducerInstrument grade
607281 Environmental Transducer
607943 Environmental Housing
615077 6500 Ranging Board
614095 Coil for Ranging Board
614096 Transformer for Ranging Board
607220 Ceramic Resonator
604789 Cable Assembly
614904 Digital Chip TL851 (6" to 35')
614905 Polaroid Digital Chip (2' to 24')
614906 Polaroid Analog Chip

About the Authors

Jesse Jackson is a Registered Professional Engineer and is the Editor of the Robot Builder *newsletter. Jerry Burton is the president of the* Robot Society of Southern California *(RSSC) and owner of* Processing Innovations, *a company manufacturing smart modems.*

About the Seattle Robotics Society

The Seattle Robotics Society was formed in 1982 to serve those interested in learning about and building robots. We are a diverse group of professionals and amateurs, highschool students and college professors, engineers and tinkerers. Our passion is the creation of cybernetic creatures that challenge the old definitions of life, intelligence and practicality. We meet 10:00 a.m. to 12:00 noon the third Saturday of every month at North Seattle Community College in room 1652. If you are building a robot or just planning one, come down and meet the gang. We are on an exciting journey and welcome you to join us.

Upcoming Events

April 17 — **SRS Meeting.**

April 22-25 — **Second International BEAM Robot Olympics**
Ontario Science Center, Toronto, Ontario, Canada

May 22-23 — **Robofest in Austin, Texas**

July 22-25 — **Robothon Northwest 1993**
Mobile Robot Competition and Symposium
Contact: Karen Nansel
Robothon Northwest, Dept. E
816 N. 105
Seattle, WA 98133
(206) 782-5989, 8am-5pm PST

August 27-29 — **3rd G.E.A.R.**

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