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General Robotics Corporation Reference Manual

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Once you have installed your RB5X options, you should put their documentation in back of this Manual.

Thank you once again for purchasing a General Robotics Corporation product. We hope that this manual has and will provide quick and easy access to the workings of our robots. We hope that you enjoy your product.

Unpacking Your GRC Product

Important/Caution:
Do not try to lift the RB5X by the dome. Only lift it by grasping the cardboard ring fitted around the bottom of the RB5X.

Your RB5X, RobotLab, or Inner Component Kit, has been shipped to you as a complete unit, fully assembled, tested, and ready to operate. When you open the shipping carton, you will find:

RB5X

- RB5X Reference Manual.
- The robot's battery-charger nest and charge cable.
- An RS-232 cable in the top foam block.
- An RB5X hat and poster.

Lift off the foam block, and remove the robot from its carton by grasping it below the cardboard ring and lifting it out.

1. Remove the cardboard ring from the robot's lower skirt.
2. Save all the packing material and the shipping carton for later use or storage.
3. Inspect your RB5X for possible shipping damage. If you discover any, please contact your dealer or call General Robotics Corporation.

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Welcome--An Introduction to the GRC Robots

Did you Know?

Robot owners engage their robots in fascinating team sport competitions. By doing this they can have fun and refine their programming skills at the same time. They become the coach, and deliver plays to their players via a home computer.

Congratulations on your purchase of the RB5X Educational Robot. Thousands have learned, taught, and played using this wonderful robot. Your investment in the RB5X will carry you far into the future. With the ease of use and the flexibility of this robot you can learn the basics of electronics, computers and robotics. In addition, the RB5X will assist in the learning and teaching of Mathematics, Geometry, and English as a Second Language (ESL). Whether you are just beginning to explore the world of microprocessors and electronics, computers and robots, or have been involved in the field since its inception, RB5X has a great deal to offer.

As you begin working with RB5X, keep in mind that the "X" in its name stands for "experimenters model." And RB5X's open design makes it an experimenter's dream. Since it is fully programmable using any computer with serial communications capability, you can write software programs that are completely unique.

If, after going through the various check-lists in the following sections you have any problems with your RB5X or RobotLab, contact your local dealer or call our Customer Service department at 800-422-4265, from 9:00 a.m. to 5:00 p.m. Mountain Time, Monday through Friday. No customer support is available for the Inner Component Kit.



Using the GRC Robot Reference Manual

Caution/Important:
However you choose to use the GRC Reference Manual, we do urge that you read and follow, "Getting Started." It provides some basics that every user should have before starting out.

Caution/Important:
Please read the "Getting Started" section for an important notice on the unpacking of your robot.

FAQ

Q: *Where do I download updates to the user manual?*

A: www.edurobot.com

Who is this Manual for?

This manual has been designed to either be read from beginning to end and then refer to particular sections as you need them. Or, if preferred, the Table of Contents and the Index can be referenced to find the sections that interest you.

Like your robot, the GRC Robot Reference Manual is intended for use by people with a wide range of skill levels:

- Those who are familiar with computers.
- Those who are familiar with computers but may have no programming experience.
- Those who have programming experience but are new to robots.
- Those with extensive computer programming skills who also have a knowledge of robotics, either personal or industrial.

Using the Sidebars

The manual itself has also been set up to be structured yet flexible enough to make using it easy. As you have probably noticed, the GRC Robot Reference Manual is somewhat unique: we have designed it with you the user, in mind. The left sidebar is used to encompass 3 different categories of information: Frequently Asked Questions, (FAQ's) Caution/Important, and "Did you know?" We have set these up in an easy to view fashion-using icons to identify the different categories of information. Below is a brief description of the use of these sidebar notes. As you go through this manual you will get an even better feel for how these are actually used.

- **Important/Caution**
This category is meant to warn, advise, and direct attention to information that is a "must read" for the successful, problem free, workings of the RB5X.
- **Frequently asked questions (FAQ)**
This category is for the "what if", "how do I", and the "what do I do when" questions. These are included in the side column for easy accessibility and quick reference.
- **Did you Know?**
This final category is for the teacher & knowledge seeker in all of us. The content of these notes will be the pertinent "informative extras" that are meant to help with the comprehension of the related text.

Updating the Manual

The sidebar is extra wide not just for our 3 categories (see above), but more importantly for your meaningful notes. Please write all of your significant thoughts, ideas, etc. in the sidebars. In the same way the 3-ring binder system is for your benefit as well. Pages may be easily replaced with updates from the website (www.edurobot.com) in order that your manual stay current. Finally we hope that this binder will also be a place for you to house your own ideas and curricula. Make good use of it! All in all, we hope that this manual will grow and change with you and your GRC robot far into the future.

Getting to Know Your RB5X

FAQ

Q: RB5X does not go through the self diagnostic routine or sounds one long toot of its horn while flashing its LEDS?

A: It is possible that its battery charge level is low and the robot needs recharging. Switch the robot OFF and proceed to the next section, "Setting Up the Battery Charger Nest." Once the robot is fully charged, run the self-diagnostic routine again. If it still isn't working, call your local dealer or the General Robotics Corporation.

In this section we will take a closer look at RB's systems. Let's start with the construction. The RB5X base unit stands just under two feet. It has an aluminum body and polycarbonate dome, this construction makes the RB5X both sturdy and completely accessible through RB's dome. This dome is translucent which allows you to see inside and you need no tools to remove it. As you peek inside RB you may wonder, "what exactly is a robot anyway?" Well, keep reading and we will answer that question for you.

Running the RB5X's Self Diagnostic Routine

Your RB5X comes with a utility software cartridge already plugged into the Action Software (EPROM) socket. This utility cartridge contains several RB5X programs, including a self-diagnostic routine that allows the robot to check its motor functions, electronics, battery charge level, light-emitting diodes (LEDs), horn, and voice/sound synthesis capability. The utility cartridge also contains special programs that will put RB5X into various modes depending on the combination of bumpers that are pressed. All of these modes will be described in detail in the "Getting to Know RB5X" chapter of this manual.

As soon as you remove RB from the crate:

1. Place it on the floor in an open area.
2. Switch the power ON.

Push in the rocker switch on the back of the robot. RB5X should sound three short beeps, flash its LEDs, move forward for one second, spin clockwise for one second, spin counterclockwise one second, and move backward for one second. The RB5X then says, "Hello, I am the RB5X Intelligent Robot."

Caution/Important
The RB's 1-amp fuse protects the robot's electronics, and may, from time to time, need to be replaced. This fuse can be found on the base skirt next to the charge pins.

Did you Know?
Infrared is the spectrum of light detected and amplified by night vision goggles.

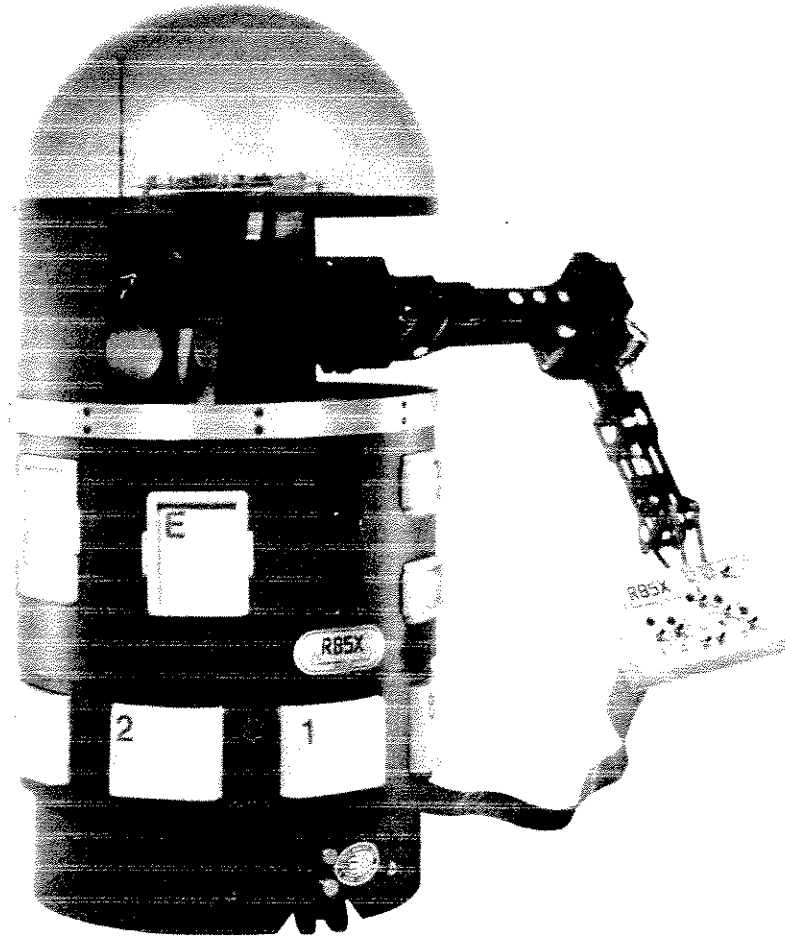
Did you Know?
Bats, like the RB5X use a sonar system called echolocation to navigate in the dark. Using sonar bats can detect size, texture, and even the direction of moving insects!

What is a Personal Robot?

One of the easiest ways to think of a personal robot is as an integrated system of:

- Sensory devices (such as the sonar transducer that allows your robot to detect obstacles in its path).
- Affecting devices (devices that allow your robot to affect its environment, such as its robotic arm or its wheels).
- Computer power (the computer chips that make your robot programmable).
- Or just a "Computer on Wheels".

By integrated, we mean that there is two-way communication among the robot's computer sensors, and affecting devices. Using this process RB can be programmed to perform simple to the most complex tasks. Before we begin thinking about the programming of tasks, let's take a closer look at the robot's various components.



Interface Panel

Take a look at the interface panel on the back of your robot. This “control panel” contains several elements:

- **Power Switch** — This rocker switch controls all power to the RB5X.
- **Power Reset Switch** — This round push-button to the right of the power switch resets the robot's automatic battery cutoff circuit, which cuts off power when the battery charge-level drops below 5.4 volts.
- **Software Reset Switch** — The square push-button to the left of the power switch stops the program currently running in the RB5X and either restarts the software module, if present, or puts the robot into command mode. In command mode, the robot is ready to receive another command from your computer, although it retains the last program in memory.
- **RS-232 Ports** — There are two RS-232 ports on the interface panel, to allow you to connect your robot to your computer by cable whenever you wish to transfer programs to RB5X. Only the standard port is utilized through the current software packages.
- **RS-232 Switch** — When communicating between your computer and RB5X, this switch should be set on standard (STD). The “option” position will be used later in conjunction with RS-232 Port 2.
- **Battery Charge Level indicator** — This LED bar enables you to visually check RB5X's charge level.
- **Action Software socket** — This socket, located at the top of the interface panel, allows you to run preprogrammed action software cartridges. These cartridges can be purchase from GRC or, if you know how, can be created by “burning” programs onto PROM (programmable, read-only memory) chips. This socket should currently hold the utility software cartridge. It is keyed so that the cartridges only fit one way.
- **Action Software Cartridge Indicator Switch** — This switch prepares the robot to accept either 2K (2716 PROMS) or 4K (2732 PROMS) software modules, and must be set to match the module in the software socket. The label attached to each RB Robot module gives the switch setting

The RB5X's Case and Components

- **Bumpers**

The eight white bumpers around the lower skirt of the robot are tactile, or touch, sensors that allow RB5X to know when it has encountered an obstacle. They represent "8 bits" and incorporate math 1-10 by using 1 & 2 for 0 and 8+1 for 9.
- **Optional Accessories/Experiment panels**

The white panels on the upper shell of the RB5X cover cut-outs in the body that can be used later as you add hardware options of your own invention or those available through General Robotics Corporation.
- **Brass Charging Pins**

Located on the RB5X's lower skirt directly under the sonar sensor are two brass cylindrical studs that correspond to brass strips on the robot's charger-nest and allow it to recharge its batteries.
- **Infrared**

Next to the power fuse on the motor (wheel) board, you will find the infrared sensor system, which can be used in conjunction with programs that allow the robot to seek out its charger nest and to recharge its batteries under its own power. The Getting a Charge section provides details on how you can use this sensor system in your RB5X.
- **Sonar**

RB5X sonar sensor is located on the front of the robot, attached to a small transducer. This sensor allows the robot to send out sonar signals and to detect obstacles directly in front of it before it actually collides with them.
- **Voice**

The RB5X may be programmed to speak many languages in the world using a standard set of international phonemes (see the Phoneme Speech Dictionary).
- **Action Software Cartridges**

Many Action Software Cartridges can be purchased through the General Robotics Cooperation. These Cartridges hold a variety of ready made pre-programmed code. The Utility and Pattern Programmer cartridges are some examples that will be discussed in-depth later in the manual.
- **RF Transmitter/Receiver**

This option allows a user to direct the RB5X using a software package to transmit data and have it perform tasks. Some software packages are able to transmit data in real-time allowing the user to direct RB5X with "joy-stick" like control.
- **Low-Battery Sense Circuit**

RB5X contains a low-battery sense circuit that constantly monitors the battery charge of both the robot's batteries. If either battery charge drops below 6.0 volts, the sense line is activated. Furthermore it has a built in shutdown circuit if batteries go below 5.3 volts.

Functions of the Utility Software Cartridge

Caution/Important
Software modules can be damaged by static electricity, so be sure to ground yourself by touching an unpainted surface on the robot before handling them.

FAQ

Q: Do I have to use the Utility Cartridge?

A: The RB5X can be programmed without the Utility Cartridge in place, however, the voice and sonar will not be active unless the enabling code is manually transmitted to the RB5X's memory.

FAQ

Q: How do I stop RB from roaming?

A: Switch it off or press the reset button. When you choose this routine, the robot continues to access it until you either switch the robot off or press the software reset button.

Utility Software Cartridge and Program

Your RB5X comes equipped with a utility software module, pre-programmed to enable the robot to perform certain tasks and functions without your having to do any programming yourself. The self-diagnostic routine we had you run when you first unpacked your robot is an example of these routines. To get familiar with all of these commands please follow the steps under each heading below.

1. Make sure the utility software module is in the socket and that the software switch is in the proper position (2K or 4K).
2. Now switch the robot on and let it run its self-diagnostic routine again.

After checking its systems, RB5X begins to monitor bumper presses. For software module purposes, the bumpers are numbered 1 through 8, starting with the bumper under the sonar as 1 and proceeding clockwise around the robot as you look down upon it.

To signal that RB5X is ready to receive commands through its bumpers it says, "Hello, I am the RB5X Intelligent Robot" while flashing its LED's in synch with its voice. Once the LEDs have stopped flashing, the robot waits for you to press a combination of bumpers to access the various routines on the utility software module. (If you press just one bumper, the robot says, "Press bumpers 2 and 4 to return to command mode." You may then press any combination of bumpers. For further information, see experimenting with RB5X or reference the side bar FAQs sections. The following sections will help you get acquainted with all 3 modes of the utility cartridge and will put these various modes into practice.

Auto Roam Mode

Bumpers 2 and 5 pressed simultaneously selects RB5X's sonar programs which allows the robot to move about using its sonar to detect objects in its Path and using intelligence to avoid them. When an obstacle comes into the sonar view, RB5X stops, flashes its LED's, beeps its horn, turns and moves forward. An RB5X with voice says, "Excuse me," "Beg your pardon," "Oops," or "May I pass?" At this time feel free to try out RB5X's auto roam mode.

1. Press Bumpers 2 and 5 (The robot will start to roam around.)
2. Listen to RB's sonar clicking as it navigates the room.
3. Try Stepping in front of RB and making it sense you, turn around and proceed.
4. When you are done watching RB roam around press the square software reset switch to stop the RB5X from roaming.
5. Proceed to the next section.

FAQ

Q: *What are those 3 modes again?*

A: *There are 3 important modes that you will need to know to successfully operate the RB5X. All three will be discussed in detail below, but for quick reference here is a short synopsis of each.*

Auto Roam:

By pressing bumpers 2 and 5 simultaneously RB5X will be put into this mode.

I'm Hungry:

By pressing bumpers 1 and 4 simultaneously, you select the charger finder routine.

Command Mode:

By pressing bumpers 2 and 4 simultaneously you put RB5X into the command mode, this mode lets you program the robot in a programming environment of your choice .

Charger Finder and Charge Maintenance Mode

If you press bumpers 1 and 4 simultaneously, you select the charger finder and charge maintenance routines discussed in detail in Getting a Charge. When 1 and 4 are pressed RB5X goes into this routine and begins to roam around in search of a guiding tape (masking) that leads to its charger nest to recharge its batteries. A robot with voice says, "Excuse me, I'm hungry" before beginning to look for its nest. Once it finds the charger, RB5X remains in charge-maintenance mode until you either switch the robot off or press the software reset button. Once again please try this routine to familiarize yourself with it.

1. Press Bumpers 1 and 4 simultaneously.
2. Watch RB roam around while looking for the guiding tape that leads it to the charger nest. When RB finds the tape it will move back and forth while aligning itself on the tape, the RB5X will then snuggle into the charger to recharge.
3. Push the software-reset button when the robot is charged or when you would like to move on to the next section.

Programming the Robot Through Command Mode

Pressing bumpers 2 and 4 simultaneously puts RB5X into command mode and prepares it to accept programming. After pressing these bumpers you are ready to attach RB5X with an RS-232 cable to your computer and download programs that you have created using an RB5X programming environment. If you have the RF transmitter/receiver installed on RB5X you can send your data through radio waves to your RB. For more information about programming environments currently available through GRC, please refer to your software packages manual or users guide.

Programming without the Utility EPROM

The RB5X can be programmed without the Utility Cartridge in place, however, the voice, sonar, and hypercard graphical controller for Macintosh will not be active unless the enabling code is manually transmitted to the RB5X's memory.

Please visit our website in order to learn more about most current software systems available for your computer.

Experimenting with the RB5X

Here's the fun part! Experimenting. Your robot is an experimenter's dream. In the following pages we will give you ideas and even some various things to try. When experimenting with your robot remember that, of its greatest assets, is the flexibility to respond to your imagination. You have an enormous amount of power over what the robot can do. Experiment in any way that you can imagine. If you are short of ideas though, here are a few thoughts on how to experiment with the robot.

Here are some different ways to experiment with the robot: by creating hardware options of your own, by making changes in the robot's physical environment, through software packages, and through software modules.

- **The Robot Hardware**

If you have knowledge of electronics you may find experimenting with the RB5X to be an exercise in creativity. The RB's is based upon a relatively open architecture with opportunity for you to add, modify, and otherwise experiment with its components. Some owners have even designed and built vacuum cleaner or fire extinguisher add-ons. You may also purchase General Robotics accessories or software modules, as listed in the "Installing Options" Appendix.

- **Interacting with the Robot's Physical Environment**

Make a robot accessible ramp for impassable elevation in RB's new environment. Design an obstacle course and have the robot navigate, using its sonar. Make RB into a personal house-hold assistant, a vacuum cleaner, a waiter, or even a FEAR (Fire Extinguishing Autonomous Robot.) Use your imagination to think up anything and everything.

- **Software Packages for Programming your Robot**

You can use RB programming environments to instruct the robot using a computer that allows you to transfer the programs you write yourself into the robot's memory. This can be done using the RS232 cable and port, or the optional RF transmitter/receiver installed in the RB5X.

- **Using the Action Software Cartridges: Pattern Programmer**

One simple way of experimenting with the RB5X is to use preprogrammed software modules. These modules plug into a socket on the back of the robot in much the same way a cartridge or a diskette plugs into a computer. You have already used the utility EPROM, but now lets experiment more with the RB5X by using the Pattern Programmer Module

Caution/Important
Push RB5X's bumpers firmly and deliberately and then watch for the flashing LED. This signifies that the command has been put into memory.

FAQ

Q: *What if I want the RB5X to play this pattern continuously?*

A: *Press bumpers 1 and 2 instead of 1 and 5.*

FAQ


Q: *How do I clear the memory and start a new pattern?*

A: *To clear RB's memory push bumpers 1 and 3 simultaneously, then press 1 and 5 again to get RB ready to accept commands.*

Pattern Programmer for the RB5X

The pattern programmer cartridge is an exciting way to get to know the RB5X and it allows you to program your RB5X to execute a series of movements. For example, you could make RB5X follow a particular path through your room. Each of the RB5X's bumpers corresponds to a specific movement command. By pressing the bumpers you are entering commands into your robot's memory. You are also using the bumpers to "play back" your pattern, to start your RB5X moving, dancing, spinning, etc. Follow the steps below to get familiar with this particular action software.

1. Carefully insert the Pattern Programmer Cartridge into the software module socket.
2. Press this Action Software cartridge right side up and firmly into place.
3. Make sure the action software indicator switch is in the 4K position.
4. Turn the RB5X on.
5. The four corner LEDs go on, then the center light-emitting diodes begin flashing. If this doesn't happen, check to be sure that module is installed correctly, the robot is fully charged and that the switch is set to the proper position.
6. Wait until the center LEDs beginning to flash before starting to program your robot. (This delay can be 10 to 20 seconds.)
7. Push bumpers 1 and 5 at the same time to initiate the pattern programmer and make it ready to accept commands. When you push 1 and 5 the corner diodes will go out



Caution/Important
RB will not remember the program once it is turned off. If you want to remember the pattern for later use please write down the order of the bumper presses.

Caution/Important
Always turn RB5X off before removing a software module.

8. Push any combination of bumpers to program the robot. Each bumper corresponds to a particular movement, direction, or action.

Bumper Command Description

Forward — RB moves forward (about 4 inches per press)

Pivot on right/forward — RB pivots forward on the right wheel (each press equals about 1/7th of a turn)

Spin Clockwise — RB rotates right on its axis (each press equals 1/4th turn)



Pivot on right/reverse — RB pivots backwards on right wheel

Reverse — RB moves backward (approximately four inches per press)

Pivot on left reverse — RB pivots back on left wheel

Spin Counter clockwise — RB rotates 90° turn left on axis

Pivot on left forward — RB pivots forward on left wheel

9. Play your pattern — When you have finished inputting your pattern push bumpers 1 and 5 to play it.
 10. Expect a 2 second delay before RB plays your pattern.
 11. Try to add some more movements to your pattern. To do this, simply push any combination of bumpers. This will add on to the end of the already stored program.
 12. Clear RB's memory and start over. Do this by pressing bumpers 1 and 3 at the same time.
 13. Have fun programming RB!
 14. Turn RB5X OFF and gently remove the Pattern Programmer Software Module
- 
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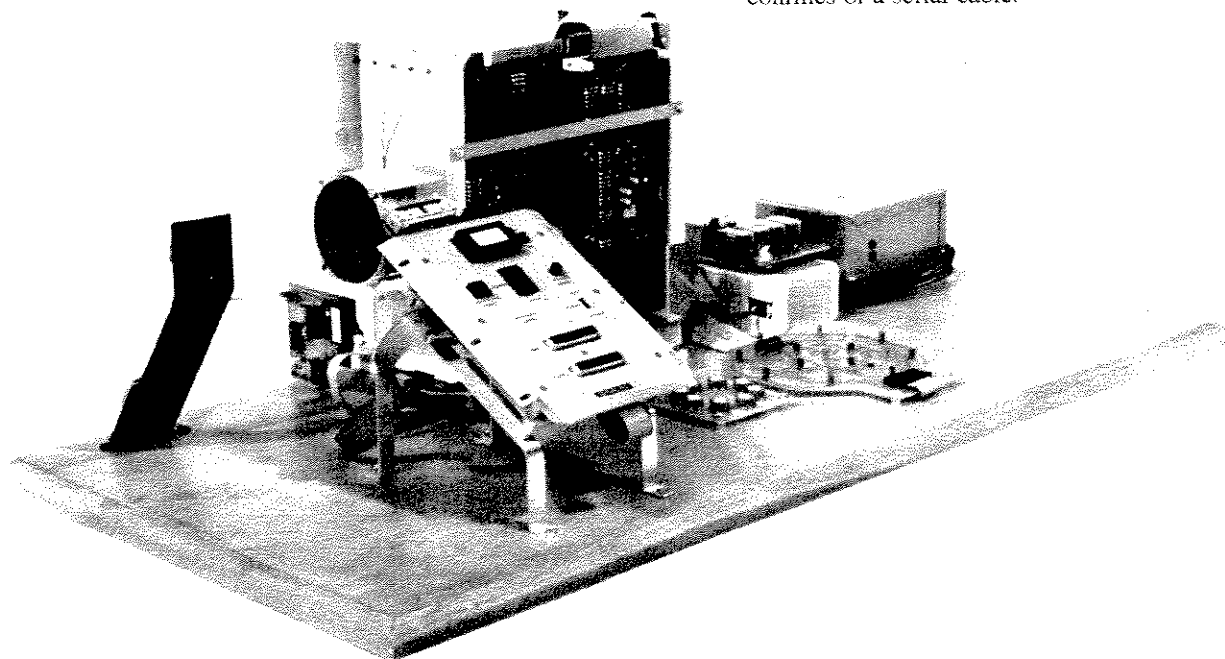
Appendices

Installing Options on the RB5X Base Unit

Once you have unpacked, tested and become familiar with the RB5X base unit you may want to install any options you bought for your RB5X or to make some other minor adjustments. Detailed installation instructions come with each RB5X option, but you should consider installing them in the following order. This is especially true if you have several options and wish to use them immediately.

You might also consider using a larger **electronics fuse** (the robot comes with a 1-amp fuse on the base skirt) to prevent circuit overload and the frequent blowing of this fuse.

- **Non-Volatile Extended Memory** — This option adds 18K of battery-backed-up RAM (random access memory), bringing RB5X's on-board memory to 26K, and allows you to store data or programs on the 18K board even when the power to your RB5X is switched off.
- **RB Robot Arm** — We recommend that this be the last option installed, since it is not easily removed and reattached.
- **Action Software** — Preprogrammed software modules that require no programming at all are also available, and we can even put you in touch with people who will, for a fee, write special, individualized software programs for your RB5X.
- **Video Camera** — Black/white or color video camera that transmits video signals from the RB5X unit to a base receiver. The video transmission may be watched on a television, studio monitor, or A/V capable computer.
- **RF Transmitter** — Allows you to program or direct the RB5X unit through "remote control" radio waves, much like a radio controlled car. This enables the RB5X to explore its surroundings without the confines of a serial cable.





Appendices

Action Software Overviews


1) PATTERN PROGRAMMER

"Pattern Programmer" software module lets you program any series of movements. You can instruct your robot to do a funny dance, spin in circles, or to follow a particular path around the room. Each of RB5X's eight bumpers corresponds to a specific movement command: forward, backward, spin clockwise, etc. You use the bumpers to play back your pattern, to start RB5X dancing, spinning, or moving around the room!

2) MATH WHIZ

"Math Whiz" allows RB5X to quiz children and adults in the elementary math skills of addition, subtraction, multiplication, and division. "Math Whiz" is a math quiz in a game format that may be played by up to eight people at one time. RB5X uses its random number generator to compose a math problem for each player in turn, tells players if they have given the right answer to the problem, and gives the correct answer if the player is in error. Players score one Point for each right answer, and after six rounds of play, RB5X announces the players' scores. The competitive challenge of "Math Whiz" and the lights, sounds, and robot motions that accompany the game motivate children to learn important math skills with RB5X!

3) HOP TO IT!



"Hop to It!" features an engaging, educational game that allows RB5X to use its sonar sensor to challenge players to accurately judge distance in feet and inches. When playing "Hop to It!" RB5X asks each player, in turn, to hop to it - to stand at a particular distance from the robot's sonar sensor. RB5X judges how far away the player really is, tells him or her, and stores the player's score in memory. The closer the player gets to the distance RB5X requests, the better his or her score will be. At the end of five rounds of play, RB5X calculates the players' scores, and announces the winner! "Hop to It!" can be played by up to eight people, or even by a single player, and is fun for both children and adults.

4) SIMON ROBOT

"Simon Robot" is hilarious fun for all ages and may be played by up to eight players. We recommend that you don't start to play until you have time to spare - you'll have a tough time walking away once you start playing!

As a supplemental classroom activity, "Simon Robot" helps strengthen listening skills, demonstrates concepts of sequence, and rigorously exercises the memorization abilities of every player.

The object of the game sounds simple enough: to press RB5X's bumpers according to the sequence in which the robot speaks their corresponding numbers. If you are successful in pressing the bumpers in the right order, RB5X adds a new number to the sequence and asks you to repeat this new combination of numbers, trying to stretch the limits of your abilities. In addition to the basic game described above, we have added three variations (games 2, 3, and 4). When you think you have mastered the game, try the most difficult version, Game 4, and be prepared for the real master, RB5X, to scramble your brain as you attempt to press bumpers as directed.

Action Software Overviews (continued)

5) DRIVE IT

"Drive It" allows the RB5X robot to be moved from place to place under its own power, avoiding the necessity for carrying it. Movement is controlled by pressing the various bumpers; depending on the bumper touched, the robot will execute a forward, backward, or turning movement, stating "Yes, Master" before performing the function.

6) DAISY, DAISY/INTRUDER ALARM

"Daisy, Daisy/Intruder Alarm" combines two different RB5X programs in a single module. The "Daisy, Daisy" program allows RB5X to both sing the words to the song "Daisy, Daisy" ("On a Bicycle Built for Two") and play the tune in two different octaves. The "Intruder Alarm" program allows RB5X to guard an area, and to teach the basics of using sonar. In "Intruder Alarm," RB5X uses its sonar system to detect intruders moving within 35 feet of the front of the robot, RB5X sounds an alarm or speaks one of three different phrases.

7) VOICE/SOUND DEMO

The "Voice/Sound Demo" demonstration software module shows the versatility of the RB5X voice/sound synthesis card. The sound card can generate up to three different sound frequencies at once and has a separate noise channel. The "Voice/Sound Demo" features speech, music, gunshot sounds, a falling "whistle", an alarm, rising 'bees!', clock chimes, and a series of musical tones.

8) CARNIVAL BARKER

The "Carnival Barker" demonstration software module provides RB5X dealers who have shopping mall or other high customer traffic locations with an animated, awareness-generating display. The robot portrays a charming android carnival barker and invites passers-by to ask for RB5X information.

9) RECORD TIME

"Record Time" gives new life to a good, old-fashioned foot race. RB5X gets the race off to a clean start with the sound of a starting pistol, and then times the event and forms an invisible finish line with its sonar. When a runner returns to the starting line and crosses the sonar beam, RB5X announces his or her time and prepares for the next racer. The robot keeps track of each runner's score, announces the time at the end of each race, and broadcasts any new record set.

Action Software Overviews (continued)

10) SPIN THE ROBOT

"Spin-the-Robot" contains a captivating game for young children. Place your RB5X in a circle of children, turn it on, and start the software routine by pressing one of the robot's bumpers. RB5X spins, stops, and points to a child, asking him or her to perform a simple task. RB5X responds enthusiastically before spinning, stopping, and selecting the next player. Children are fascinated for hours!

11) BUMPER MUSIC

"Bumper Music" module enables you and RB5X to make beautiful music together. To compose tunes using "Bumper Music" you press the eight bumpers like keys of a piano; each of the panels is assigned a musical note value by the software. When you have keyed in all the notes you want, you press a combination of bumpers, and RB5X plays back your tune.

12) NURSERY RHYMES

The "Nursery Rhymes" software module allows RB5X to entertain children of all ages by reciting seven different nursery rhymes at the press of a bumper. This module is not only entertaining, it also provides children with a fun, friendly introduction to RB5X Educational Assistant.

Appendices

Caution/Important

The infrared sensor on the bottom of RB works best when the white guiding tape is placed on a dark surface. This provides the contrast that is needed for RB to find the charger nest.

Battery Charge Life

Battery-charge life for the RB5X and, consequently, the amount of time the robot runs between charges depends on the total load used by all of the robot's various systems. The average run time of a fully charged RB5X is four to eight hours, depending on the number of peripherals attached to the robot and on the tasks you have asked your robot to perform since it was last charged. All devices on the robot use current to a greater or lesser degree;

When new and fully charged, RB5X's batteries are about 6.6 volts. When half discharged, the voltage drops to about 6.0 volts. If the robot is programmed to recharge its batteries on its own, it usually has enough power to seek out its charger-nest when the voltage has dropped to 6.0 volts. A rough rule to follow is that the robot needs as much time to find its nest as it used when it left to perform some function.

Your RB5X runs on the power generated by two sealed lead-acid, rechargeable batteries: one six-volt, 5 or 7 amp-hour battery handles the electronics; one six-volt, 10 amp-hour battery powers the LEDs, the sonar, the relays, and the motors. A battery charger-nest that operates on any 110 volt, 60 cycle, AC source allows the robot to charge its batteries when the voltage drops. This is also the same for charger-nests that require a 220 volt source.

- Brass charger pins located on the lower skirt of the robot that make contact with the brass strips on the charger-nest. A low battery sense circuit that enables the robot to monitor its charge.
- A charger-finder routine that allows you to program the robot to seek out its charger-nest.
- A light/dark infrared sensor system, used when the robot is programmed to find its nest on its own, which allows it to "see" a white tape on a dark floor and follow it to its charger-nest.
- A charge-maintenance routine that allows RB5X to establish and maintain contact with the nest until its batteries are fully charged.
- An automatic battery-shutdown circuit that switches the robot off when the voltage of either battery drops to about 5.4 volts.
- A battery charge-level LED bar on the interface panel that allows you to visually monitor the robot's charge.

The output of the charger-nest is about 7.5 volts at 1.5 amps, which is sufficient for an overnight charge should you operate your robot for long periods of time. The charger operates only on 110 volts AC; for any other voltage, you must use a converter. If that isn't possible, contact General Robotics Corporation and we will suggest an alternative.

The charger-nest was designed so that it will not overcharge the batteries. In fact, we suggest that you turn OFF your robot when not in use to ensure that it remains fully charge

Appendices

FAQ

Q: Can I add more components to RB5X?

A: See "Options" for more information on currently available optional components.

Caution/Important

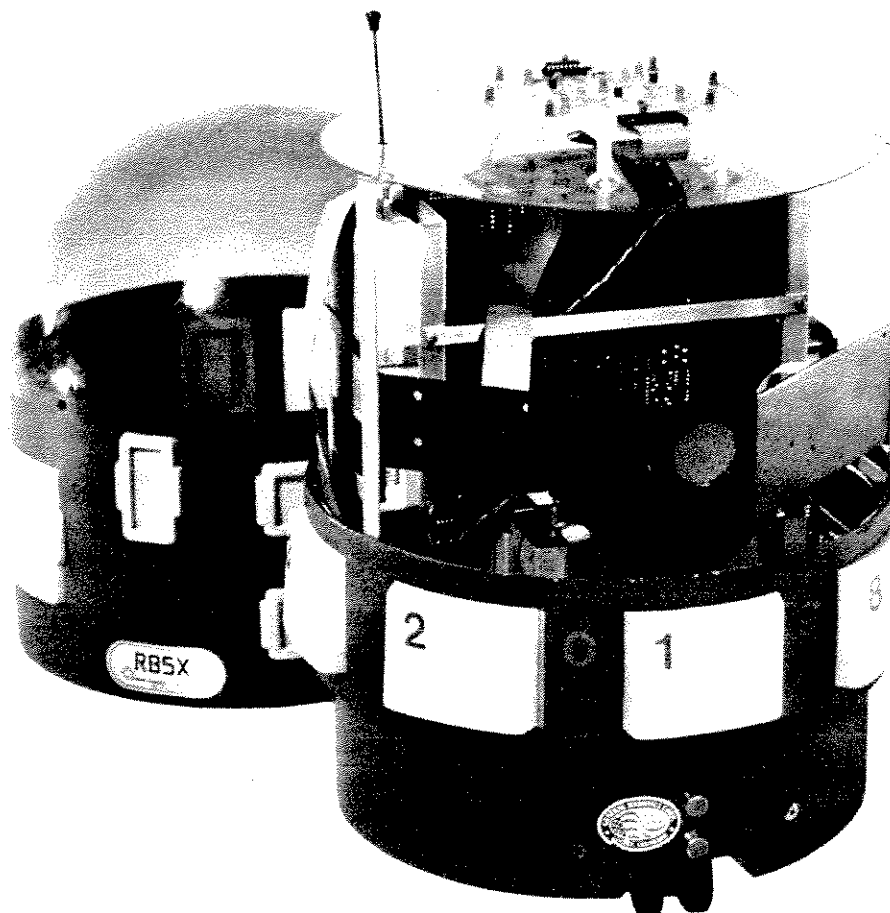
NEVER leave your robot ON for extended periods of time without checking the voltage and recharging the batteries as needed. If the charge of either battery is allowed to drop below 5.4 volts, the automatic battery-shutdown circuit switches the robot off.

Charging the RB5X with the Recharge Cable

Also included with the RB5X is a recharge cable. This cable gives you the option of using the telephone jack cable to hook the robot directly into the charger. This cable enables you to charge the RB5X, without it "snuggling" up to the nest. This method of charging also allows you to have the RB5X running certain programs at the same time. (All systems within the RB5X work while the robot is charging, except the sonar.)

To charge the RB5X using the cable follow the steps outlined below:

1. Carefully move the RB5X within cable reach of the already setup charger-nest.
2. Insert one end of the telephone jack cable into RB5X. The cable jack is located on the skirt of the robot approximately 1 inch to the right of the brass charging pins on the RB5X.
3. Insert the other end of the cable into the jack in the charger nest. The jack for the RB5X is located on the bottom right corner of the front of the charger-nest. As with the normal charging procedure, note that the red LEDs come on identifying that the robot is charging. See above for details.



Appendices

Setting Up the Battery Charger Nest

To set up RB5X battery charger nest:

1. Choose a location that will be accessible to your robot.
For example, if your home has two stories and you will be using your robot mostly on the upper level, don't situate the charger-nest on the lower level
2. Plug the nest into a 110-volt AC outlet or international at 220 volts.
3. Place the charger against the wall.
4. Notice that the lower red LED on the charger nest lights up when the charger is plugged into the outlet.
5. Push the robot into the charger and note that the upper red LED lights up when the charger pins make contact with the brass strips, if the robot's batteries need charging.

Whenever you notice the robot's battery charge dropping, you may push it into its nest, ensuring that it makes good contact with the charger.

FAQ

Q: *The upper light does not come on immediately?*

A: *Switch the robot ON and then OFF. If the robot is making contact or is plugged in, the upper LED should come on. When it goes out or pulses at a slow rate, this indicates that your RB5X is fully charged.*

FAQ

Q: *RB5X's charger pins are not making a solid contact with the brass strips on the charger-nest?*

A: *You may want to use the optional recharging cable.*

Appendices

FAQ

Q: What if the shutdown circuit switches the robot off?

A: Turn the power switch OFF, push RB5X into its charger nest, and fully recharge the batteries. After recharging, turn the power switch ON and press the power-reset button.

Setting Up RB5X's Charger-Finder Guidance Strip

Now that you have set up the charger nest in a good location you are ready to lay down the very sophisticated guiding device. This device, in conjunction with the robot's infrared sensor, will help the RB5X find and "snuggle" itself into the charger nest. Please follow the steps below very carefully.

1. Pull a strip of the sophisticated guiding device (the masking tape) off the roll. Three or four feet is good but you should experiment with the length so that RB will find the charger in a reasonable amount of time while following a random walk pattern.
2. Lay the strip down on the floor so that it is perpendicular to the nest and centered on the brass contact strips.
3. Stick the tape firmly to the floor, starting in the cradle of the charger nest and moving away.

When the charge finder routine is running, the RB5X will wander around, find the strip of tape and then follow it into the charger nest. This program allows RB5X to keep the batteries fully charged.

Appendices

Charge-Maintenance Program

Low-Battery Sense Circuit

RB5X contains a low-battery sense circuit that constantly monitors the battery charge of both the robot's batteries. If either battery charge drops below 6.0 volts, the sense line is active. It might be instructive for you to look at the low-battery sense bit.

Enter the following short program:

```
NEW #1000
NEW
10 @#7803 = #98:REM INITIALIZE I/O PORT
20 PRINT @#7802 AND #10:REM MASK VALUE AT PORT
30 GO TO 20:REM APPROPRIATE BIT
RUN (PRESS RETURN)
```

When the battery voltage is 6.0 or above, the number displayed on your computer's monitor is 16, which is the decimal equivalent of having all bits at location #7802 equal to 0 (zero), except the battery-sense bit itself, which is 1. If a 0 displays, one of the batteries is low.

You may adjust the level at which the sense bit changes using the R29 trimmer potentiometer located on the left side of the CPU board below the horn. The potentiometer was adjusted at the factory to change at 6.0 volts; you may want to set it so that the bit changes at 6.1 or 6.2 or 5.9.

NOTE: As the batteries age, the discharge curve may shift and you will need to adjust R29 slightly anyway.

After you have had your RB5X for a while, check the battery levels. If one is somewhere near the level you would like recharging to begin, adjust R29 using the preceding program until the number displayed is 0. Push the software reset button on the interface panel to stop the program.

Appendices

Charger-Finder Program

Did you Know?

The photodiode conducts a current if sufficient light falls on it, changing the state of the voltage comparator LM392. Potentiometer R30 sets the threshold at which this state changes. R30 is adjustable through a hole in the card cage, and is located just below R29.

Your RB5X utility software module contains a machine-code version of the charger-finder routine. A Tiny BASIC listing of this routine appears below in case you would like to include this code in any of the custom programs you write for the robot.

Whether you use the routine we provide or write one of your own, your charger-finder program should include a look at the low-battery sense bit, as described in the previous Appendix, to see whether or not the robot's batteries need charging.

One of the first subroutines in your program should also be a step that turns on the infrared LED on the robot's undercarriage. The light from this LED is directed down to the floor and is reflected back to the photodiode located near it.

Let's look at this bit.

Assume that your RB5X is on a dark floor and that the tape is white. Enter the following program:

```
NEW #1000
NEW
10 @#7803 = #98:REM INITIALIZE I/O PORT
20 @#7801 = #02:REM TURN ON IR LED
30 PRINT @#7802 AND #40:REM MASK VALUE AT PORT
40 GOTO 30:REM APPROPRIATE BIT
RUN (PRESS RETURN)
```

To check that the photodiode is turning on and off depending on whether it is over light or dark, place a piece of your tape on a narrow strip of cardboard or on a ruler. Move the tape back and forth under RB5X, and adjust the R30 potentiometer until bit 6 changes with the movement of the tape. A 0 indicates that the photodiode is conducting; and a 64 indicates that the light from the LED is not being seen by the photodiode.

To modify the provided charger-finder routine so that it works using a dark tape on a light floor, you must change the variable B in line 100, 270, and 470, which is the tape detect byte, to 64 instead of 0.

Once you have adjusted the photodiode system and set up the charger with tape on the floor, you are ready to test your program. Load your charger-finder routine and run it.

Charger-Finder Program (continued)

If RB5X's batteries are not actually low, adjust potentiometer R29 so that bit 4 at #7802 is low (a 0 displays on your screen), and RB5X will begin searching for its nest. When the robot detects the tape, it begins to make a left-to-right sweeping motion, rotating off-center across the tape until it finds the nest. If it happens to follow the tape away from the nest instead of toward it, it will come to the end of the tape, rotate 180 degrees and return to the nest.

Check to see that the upper LED is lit, indicating that RB5X has made good contact with its charger. Another way to determine if contact has been made is to connect your robot to your computer and to run the following program:

```
10 @#7803 = #98
20 PRINT @#7802 AND #20
30 GO TO 20
```

The number 32 is displayed on your monitor until contact is made, at which time 0 is displayed.

Charger-Finder / Charge-Maintenance Tiny BASIC Program

```
10 REM CHARGE - FINDER ROUTINE • 1998 DECEMBER 1
20 REM COPYRIGHT 1984-1998 GENERAL ROBOTICS CORPORATION •
   ALL RIGHTS RESERVED
30 REM INITIALIZE I/O AND CHARGE FINDER LED
40 GOSUB 2000
50 REM GO FORWARD AND START LOOKING FOR TAPE
60 @#7802=9
70 REM SET B EQUAL TO TAPE DETECT BYTE
80 B=@#7802 AND #40
90 REM TAPE ?
100 IF B=0 GOTO 200
110 GOTO 80
200 REM TAPE FOUND, NOW FOLLOW IT!
210 REM RE-INITIALIZE
220 GOSUB 2000
230 REM TURN LEFT OFF CENTER UNTIL TAPE IS FOUND
```

Charger-Finder / Charge-Maintenance Tiny BASIC Program (continued)

```
240 @#7802=8
250 DO
260 B=@#7802 AND #40
270 IF B=O GOTO 370
280 C=@#7802 AND #20
290 IF C=O GOTO 1000
300 DELAY 100
310 T=T+1
320 UNTIL T=200
330 CLEAR
340 REM RE-INITIALIZE
350 GOSUB 2000
360 GOTO 400
370 REM TAPE FOUND, FLASH LEDS AND PAUSE 300 MSEC
380 @#7801=#7C
390 DELAY 300
400 REM RE-INITIALIZE
410 GOSUB 2000
420 CLEAR
430 REM TAPE FOUND GOING LEFT, NOW GO RIGHT OFF CENTER
440 @#7802=1
450 DO
460 B=@#7802 AND #40
470 IF B=O GOTO 560
480 C=@#7802 AND #20
490 IF C=O GOTO 1000
500 DELAY 100
510 UNTIL T=200
520 CLEAR
```

Charger-Finder / Charge-Maintenance Tiny BASIC Program (continued)

```
530 REM RE-INITIALIZE
540 GOSUB 2000
550 GOTO 430
560 REM TAPE DETECTED, FLASH LEDS AND PAUSE 300 MSEC
570 @#7801=#7
580 DELAY 300
590 REM RE-INITIALIZE
600 GOSUB 2000
610 CLEAR
620 GOTO 230
1000 REM CHARGE-MAINTENANCE ROUTINE MAINTAINS CONTACT
    WITH NEST
1010 REM IF CONTACT LOST, THE ROBOT TRIES ONE OF TWO
    STRATEGIES:
1020 REM 1) IT PULSES FORWARD IN 100 MSEC PULSES FOR 5 TRIES
1030 REM 2) IF 1 IS NOT SUCCESSFUL, IT BACKS UP AND TRIES AGAIN
1040 REM INITIALIZE
1050 GOSUB 2000
1060 CLEAR
1070 REM TURN ON LED #2 AND FLASH DURING MAINTENANCE
    FUNCTION
1080 CLEAR
1100 @#7801=#04
1110 DELAY 1000
1120 @#7803=#98
1125 C=@#7802 AND #20
1130 REM CHECK TO SEE IF CHARGER IS STILL CONNECTED
1140 IF C=O GOTO 1090
1150 REM C<O -- CHARGER IS DISCONNECTED
1160 REM INITIALIZE
```

Charger-Finder / Charge-Maintenance Tiny BASIC Program (continued)

```
1170 GOSUB 2000
1180 REM PULSE FORWARD 5 TIMES
1190 FOR T=1 TO 5
1200 @#7802=9
1210 DELAY 100
1220 @#7802=0
1230 C=@#7802 AND #20
1240 IF C=0 GOTO 1090
1250 NEXT T
1260 CLEAR
1270 REM THAT DIDNT WORK, NOW BACK AND RETRY
1280 REM INITIALIZE
1290 GOSUB 2000
1300 @#7802=6
1310 DELAY 300
1320 @#7802=9
1330 DELAY 200
1340 @#7803=#98
1350 GOTO 1150
2000 REM INITIALIZATION SUBROUTINE
2010 @#7803=#98
2020 @#7801=#02
2030 RETURN
2040 REM END OF PROGRAM
```

Appendices

Phoneme Speech Dictionary

00	Eh3	jacket	2E	AE	dad
01	Eh2	enlist	2F	AE1	after
02	Eh1	heavy	30	AW2	safety
03	PA0	no sound	31	UH2	about
04	DT	butter	32	UH1	uncle
05	A2	made	33	UH	cup
06	A1	made	34	O2	for
07	ZH	azure	35	O1	aboard
08	AH2	honest	36	IU	you
09	I3	inhibit	37	U1	you
0A	I2	inhibit	38	THV	the
0B	I1	inhibit	39	TH	thin
0C	M	mat	3A	ER	bird
0D	N	sun	3B	EH	get
0E	B	bag	3C	E1	be
0F	V	van	3D	AW	call
10	CH	chip	3E	PA1	no sound
11	SH	shop	3F	STOP	no sound
12	Z	zoo			
13	AW1	lawful			
14	NG	thing			
15	AH1	father			
16	OO1	looking			
17	OO	book			
18	L	land			
19	K	trick			
1A	J	judge			
1B	H	hello			
1C	G	get			
1D	F	fast			
1E	D	paid			
1F	S	pass			
20	A	day			
21	AY	day			
22	Y1	yard			
23	UH3	mission			
24	AH	mop			
25	P	past			
26	O	cold			
27	I	pin			
28	U	move			
29	Y	any			
2A	T	tap			
2B	R	red			
2C	E	meet			
2D	W	win			

Phoneme Speech Dictionary (continued)

01 2D 32 31 0D
10 2A 02 00 0D
100 1B 32 31 0D 1E 2B 09 1E
1000 39 15 23 37 12 00 0D 1E
1000000 0C 0B 09 18 29 23 0D
11 02 18 02 00 0F 0A 0D
12 2A 2D 02 00 18 0F
13 39 3A 2B 2A 3C 29 0D
14 1D 35 34 2B 2A 3C 29 0D
15 1D 0B 09 1D 2A 3C 29 0D
16 1F 0B 09 19 03 1F 2A 3C 29 0D
17 1F 02 00 0F 02 00 0D 2A 3C 29 0D
18 05 05 29 2A 3C 29 0D
19 0D 15 00 29 0D 2A 3C 29 0D
2 2A 36 37 37
20 2A 2D 02 00 0D 2A 29
3 39 2B 3C 29
30 39 3A 2B 2A 29
4 1D 35 34 2B
40 1D 34 34 2B 2A 29
5 1D 15 00 29 0F
50 1D 0B 29 1D 2A 29
6 1F 0B 09 19 03 1F
60 1F 0B 09 19 03 1F 2A 29
7 1F 02 00 0F 0A 0D
70 1F 02 00 0F 02 00 0D 2A 29
8 05 05 29 2A
80 05 05 29 2A 29
9 0D 15 00 29 0D
90 0D 15 00 29 0D 2A 29
A 06 21 29
ABLE 06 29 0E 23 18
ABOUT 32 0E 31 08 37 2A
ACCOUNT 32 19 15 23 2D 0D 2A
ACROSS 32 19 2B 3D 1F
ACT 2F 00 19 2A
ADDITION 2F 00 1E 0B 09 11 23 0D
ADJUSTMENT 2F 00 1E 1A 32 31 1F
2A 0C 02 00 0D 2A
AFTER 2F 00 1D 2A 3A
AGAIN 32 1C 05 02 0D
AGREEMENT 32 1C 2B 3C 29 0C 02
00 0D 2A
AIR 01 01 2B
ALL 3D 18
ALMOST 3D 18 0C 35 37 1F 2A
AMONG 32 0C 23 32 14
AND 2F 00 0D 1E
ANGLE 2F 00 14 1C 23 18
ANGRY 2F 00 14 1C 2B 29
ANIMAL 2F 00 0D 0B 09 0C 23 18
ANSWER 2F 00 0D 1F 3A
ANY 01 01 0D 29
APPROVAL 32 35 2B 37 0F 23 18
ARCH 15 2B 2A 10
ARGUMENT 15 2B 1C 22 36 37 37 0C
02 00 0D 2A
ARM 15 2B 0C
ARMY 15 2B 0C 29
ART 15 2B 2A
AS 2F 00 12
AT 2F 00 2A
ATTACK 32 2A 2F 00 19
ATTENTION 32 2A 02 00 0D 11 23 0D
ATTRACTION 32 2A 2B 2F 00 19 11
23 0D
AUTOMATIC 3D 2A 31 0C 2F 00 2A
0B 19
AWAKE 32 2D 06 21 29 19
BABY 0E 06 21 29 0E 29
BACK 0E 2F 00 19
BAD 0E 2F 00 1E
BAG 0E 2F 00 1C
BALANCE 0E 2F 00 18 00 0D 2A 1F
BALL 0E 3D 18
BAND 0E 2F 00 0D 1E
BASE 0E 06 21 29 1F
BASKET 0E 2F 00 1F 19 00 2A
BATH 0E 2F 00 39
BE 0E 3C 29
BEAUTIFUL 0E 22 36 37 2A 0B 1D 16
18
BECAUSE 0E 29 19 3D 12
BED 0E 02 00 1D
BEE 0E 3C 29
BEFORE 0E 29 1D 34 34 2B
BEHAVIOR 0E 29 1B 06 09 29 0F 22
36 37 3A
BELIEF 0E 29 18 3C 29 1D
BELL 0E 02 00 18
BENT 0E 02 00 0D 2A
BERRY 0E 02 00 2B 29
BETWEEN 03 29 2A 2D 3C 29 0D
BIG 0E 0B 09 1C
BIRD 0E 3A 2B 1E
BIT 0E 0B 09 2A

Phoneme Speech Dictionary (continued)

BITE 0E 23 08 29 2A
BITTER 0E 0B 09 2A 3A
BLACK 0E 18 2F 00 19 19
BLOW 0E 18 35 37
BLUE 0E 18 36 37 37
BOARD 0E 35 34 2A 1E
BOAT 0E 35 37 2A
BODY 0E 15 23 1E 29
BOILING 0E 35 23 09 21 18 0B 14
BONE 0E 35 37 0D
BOOK 0E 16 16 19
BOOT 0E 37 37 2A
BOTTLE 0E 15 23 2A 23 18
BOX 0E 15 23 19 1F
BOY 0E 35 23 09 21
BRAIN 0E 2B 06 21 29 0D
BRAKE 0E 2B 06 21 29 19
BRANCH 0E 2B 2F 00 0D 2A 10
BREAK 0E 2B 06 21 29 19
BREATH 0E 2B 02 00 39
BRICK 0E 2B 0B 09 19
BRIDGE 0E 2B 0B 09 1E 1A
BRIGHT 0E 2B 23 08 29 2A
BROKEN 0E 2B 35 19 0A 0D
BROTHER 0E 2B 32 23 38 3A
BROWN 0E 2B 15 23 37 0D
BRUSH 0E 2B 32 31 11
BUCKET 0E 32 31 19 00 2A
BUILDING 0E 0A 0A 18 1E 0B 09 14
BURN 0E 3A 2B 0D
BURST 0E 3A 2B 1F 2A
BURY 0E 02 00 2B 29
BUSINESS 0E 09 0A 12 0D 02 1F
BUT 0E 32 31 2A
BUTTER 0E 32 31 2A 3A
BUTTON 0E 32 31 2A 32 0D
BUY 0E 15 00 29
BY 0E 15 00 29
BYE 0E 15 00 29
CAKE 19 06 21 29 19
CAMERA 19 2F 00 0C 3A 31 23
CARD 19 15 2B 1E
CARE 19 00 00 3A
CART 19 15 2B 2A
CAT 19 2F 00 2A
CAUSE 19 3D 12
CERTAIN 1F 3A 2A 0B 29 0D
CHAIN 2A 10 06 21 29 0D
CHANCE 2A 10 2F 00 0D 1F
CHANGE 2A 10 06 21 29 0D 1E 1A
CHEAP 2A 10 3C 29 25
CHEEP 2A 10 3C 29 25
CHEESE 2A 10 3C 29 12
CHEST 2A 10 02 00 1F 2A
CHIEF 2A 10 3C 29 1D
CHIN 2A 10 0B 09 0D
CHURCH 2A 10 3A 2B 2A 10
CIRCLE 1F 3A 2B 19 23 18
CLEAN 19 18 3C 29 0D
CLEAR 19 18 21 09 2B
CLOCK 19 18 15 23 19
CLOTH 19 18 3D 39
CLOUD 19 18 15 23 2D 1E
COAT 19 35 37 2A
COLD 19 34 34 18 18 1E
COLOR 19 32 18 3A
COME 19 32 23 0C
COMFORT 19 15 23 0C 1D 34 34 2B
2A
COMMITTEE 19 32 23 0C 0B 09 2A
3C 29
COMMON 19 15 23 0C 32 0D
COMPANY 19 32 23 0C 25 2F 00 0D 29
COMPLETE 19 32 23 0C 25 18 3C 29
2A
COMPLEX 19 15 23 0C 25 18 02 00 19
03 1F
CONDITION 19 32 0D 1E 0B 09 11 23
0D
CONSCIOUS 19 32 0D 11 32 1F
CONTROL 19 32 0D 2A 2B 35 34 18
COOK 19 16 16 19
COPY 19 15 23 25 29
COUGH 19 3D 1D
COUNTRY 19 32 0D 2A 2B 29
COVER 19 32 23 0F 3A
COW 19 15 23 37
CRACK 19 2B 2F 00 19
CREDIT 19 2B 02 00 1E 0B 2A
CRIME 19 2B 15 00 29 0C
CRUEL 19 2B 36 37 37 18
CRUSH 19 2B 32 31 11
CRY 19 2B 15 00 09 29
CUP 19 32 31 25
CURRENT 19 3A 2B 02 00 0D 2A
CURTAIN 19 3A 2B 2A 09 0D

Phoneme Speech Dictionary (continued)

CURVE 19 3A 2B 0F
CUSHION 19 16 36 11 23 0D
CUT 19 32 31 2A
DAMAGE 1E 2F 00 0C 0B 1E 1A
DANGER 1E 06 21 29 0D 1E 1A 3A
DARK 1E 15 2B 19
DAUGHTER 1E 3D 2A 3A
DAY 1E 06 09 29
DEAD 1E 02 00 1E
DEAR 1E 21 09 2B
DEATH 1E 02 00 39
DEBT 1E 02 00 2A
DECISION 1E 29 1F 0B 07 23 0D
DEEP 1E 3C 29 25
DEER 1E 21 09 2B
DEGREE 1E 29 1C 2B 3C 29
DELICATE 1E 02 18 0B 19 0B 2A
DEPENDENT 1E 29 25 02 00 0D 1E 02
00 0D 2A
DESIGN 1E 29 12 15 00 29 0D
DESTRUCTION 1E 29 1F 2A 2B 32 31
19 11 23 0D
DETAIL 1E 3C 29 2A 06 21 29 18
DEVELOPMENT 1E 3C 29 0F 02 18 15
23 25 0C 02 00 0D 2A
DEW 1E 36 37 37
DIFFERENT 1E 0B 09 1D 3A 02 00 0D
2A
DIRECTION 1E 3A 02 00 19 2A 11 32
0D
DIRTY 1E 3A 2B 2A 29
DISCOVERY 1E 0B 1F 19 32 23 0F 3A
29
DISGUST 1E 0B 09 1F 1C 32 31 1F 2A
DISTANCE 1E 0B 1F 2A 00 0D 2A 1F
DISTRIBUTION 1E 0B 1F 2A 2B 0B 09
0E 22 36 37 37 11 23 0D
DIVISION 1E 0B 0F 0B 07 23 0D
DO 1E 36 37 37
DOG 1E 3D 1C
DOOR 1E 35 34 2B
DOUBT 1E 31 08 37 2A
DOWN 1E 15 23 2D 0D
DRAIN 1E 2B 06 21 29 0D
DRAWER 1E 2B 3D 2D 3A
DRESS 1E 2B 02 00 1F
DRINK 1E 2B 0B 09 14 19
DRIVING 1E 2B 15 00 29 0F 0B 14
DROP 1E 2B 15 23 25
DRY 1E 2B 15 00 09 29
DUE 1E 36 37 37
DUST 1E 32 31 1F 2A
EAR 3C 0A 2B
EARLY 3A 2B 18 29
EARTH 3A 2B 39
EAST 3C 21 1F 2A
EDGE 02 00 1E 1A
EDUCATION 02 1E 1A 36 19 06 29 11
23 0D
EFFECT 02 00 1D 02 00 19 2A
EIGHT 05 05 29 2A
EIGHTEEN 05 05 29 2A 3C 29 0D
EIGHTY 05 05 29 2A 29
ELECTRIC 02 18 02 00 19 2A 2B 0B 09
19
ELEVEN 02 18 02 00 0F 0A 0D
EMPTY 02 00 0C 25 2A 29
END 02 00 0D 1E
ENGINE 02 00 0D 0D 1E 2A 0B 0D
ENOUGH 29 0D 32 23 1D
EQUAL 29 19 2D 23 18
ERROR 00 00 00 2B 3A
EVEN 29 0F 0A 0D
EVER 02 0F 3A
EVERY 02 0F 3A 29
EXAMPLE 02 00 1C 03 12 2F 00 0C 25
23 18
EXISTENCE 02 00 1C 03 12 0B 09 1F
2A 02 00 0D 1F
EXPERIENCE 02 00 19 03 1F 25 0B 2B
29 02 00 0D 1F
EXPERT 02 00 19 03 1F 25 3A 2A
EYE 15 00 09 29
FACE 1D 06 21 29 1F
FACT 1D 2F 00 19 2A
FALL 1D 3D 18
FALSE 1D 3D 18 1F
FAMILY 1D 2F 00 0C 18 29
FAR 1D 15 23 2B
FARM 1D 15 2B 0C
FAT 1D 2F 00 2A
FATHER 1D 15 23 38 3A
FEAR 1D 21 0A 2B
FEATHER 1D 02 00 38 3A
FEEBLE 1D 3C 29 0E 23 18
FEELING 1D 3C 29 18 0B 14

Phoneme Speech Dictionary (continued)

FEMALE 1D 3C 29 0C 06 21 29 18
FIELD 1D 3C 29 18 1E
FIFTEEN 1D 0B 09 1D 2A 3C 29 0D
FIFTY 1D 0B 09 1D 2A 29
FIGHT 1D 23 08 29 2A
FINGER 1D 0B 09 0D 14 1C 3A
FIRE 1D 15 00 21 2B
FIRST 1D 3A 2B 1F 2A
FIVE 1D 15 00 29 0F
FIXED 1D 0B 19 03 1F 2A
FLAG 1D 18 2F 00 1C
FLAME 1D 18 06 21 29 0C
FLAT 1D 18 2F 00 2A
FLIGHT 1D 18 23 08 29 2A
FLOOR 1D 18 35 34 2B
FLOWER 1D 18 15 2D 3A
FLY 1D 18 15 00 29
FOLD 1D 34 34 18 18 1E
FOOD 1D 37 37 1E
FOOLISH 1D 37 37 18 0B 11
FOOT 1D 16 16 2A
FOR 1D 34 34 2B
FORCE 1D 34 34 2B 1F
FORM 1D 34 34 2B 0C
FORTY 1D 34 34 2B 2A 29
FORWARD 1D 34 34 2B 2D 3A 1E
FOUL 1D 15 23 2D 18
FOUR 1D 35 34 2B
FOURTEEN 1D 35 34 2B 2A 3C 29 0D
FOWL 1D 15 23 2D 18
FREE 1D 2B 3C 29
FRIEND 1D 2B 02 01 0D 1E
FROM 1D 2B 32 23 0C
FRONT 1D 2B 23 32 0D 2A
FULL 1D 16 18
FUNNY 1D 32 31 0D 29
FUTURE 1D 22 36 37 37 2A 10 3A
GAME 1C 06 21 29 0C
GARDEN 1C 15 2B 1E 0A 0D
GENERAL 1E 1A 02 00 0D 3A 23 18
GET 1C 02 00 2A
GIRL 1C 3A 2B 18
GIVE 1C 0B 09 0F
GLASS 1C 18 2F 00 1F
GLOVE 1C 18 32 23 0F
GO 1C 35 37
GOAT 1C 35 37 2A
GOLD 1C 34 34 18 18 1E
GOOD 1C 16 16 1E
GOVERNMENT 1C 32 23 0F 3A 0D 0C
02 00 0D 2A
GRAY 1C 2B 06 09 29
GREAT 1C 2B 06 29 2A
GREEN 1C 2B 3C 29 0D
GRIP 1C 2B 0B 09 25
GROUP 1C 2B 37 37 25
GROWTH 1C 2B 35 37 39
GUIDE 1C 15 00 29 1E
GUN 1C 32 31 0D
HAIR 1B 01 01 2B
HAND 1B 2F 00 0D 1E
HANGING 1B 2F 00 14 0B 09 14
HAPPY 1B 2F 00 25 29
HARD 1B 15 2B 1E
HARMONY 1B 15 2B 0C 23 0D 3C
HAT 1B 2F 00 2A
HATE 1B 06 21 29 2A
HAVE 1B 2F 00 0F
HE 1B 3C 29
HEAD 1B 02 00 1E
HEALTHY 1B 02 00 18 39 29
HEARING 1B 3C 09 2B 0B 14
HEART 1B 15 23 2B 2A
HEAT 1B 3C 21 2A
HELP 1B 02 00 18 25
HERE 1B 21 0B 2B
HIGH 1B 15 00 29
HISTORY 1B 0B 09 1F 2A 2B 29
HOLE 1B 35 37 18
HOOK 1B 16 16 19
HOPE 1B 35 37 25
HOUR 15 23 2D 3A
HOUSE 1B 23 08 37 1F
HOW 1B 15 34 37
HUG FC C5
HUMOR 1B 22 36 37 37 0C 3A
HUNDRED 1B 32 31 0D 1E 2B 09 1E
HURRY 1B 3A 2B 29
I 15 00 09 29
ICE 23 08 29 1F
IDEA 15 29 1E 21 29 31
IF 0B 09 1D
ILL 0B 09 18
IMPORTANT 0B 09 0C 25 34 34 2B 2A
00 0D 2A
IMPULSE 0B 09 0C 25 32 31 18 1F

Phoneme Speech Dictionary (continued)

IN 0B 09 0D
INCH 0B 09 0D 2A 10
INCREASE 0B 29 0D 19 2B 3C 29 1F
INDUSTRY 0B 09 0D 1E 32 31 1F 2A
2B 29
INTEREST 0B 09 0D 2A 3A 02 00 1F
2A
IRON 15 29 3A 0D
is 0B 09 29 12
ISLAND 15 00 29 18 00 0D 1E
IT 0B 29 2A
JELLY 1E 1A 02 00 18 29
JEWEL 1E 1A 36 37 37 23 18
JOB 1E 1A 15 23 0E
JOIN 1E 1A 35 23 09 21 0D
JOKE 1E 1A 35 37 19
JUDGE 1E 1A 32 31 1E 1A
JUMP 1E 1A 32 31 0C 25
KEEP 19 3C 29 25
KETTLE 19 02 00 2A 23 18
KEY 19 21 29
KICK 19 0B 09 19
KIND 19 15 00 29 0D 1E
KISS 19 0B 09 1F
KNEE 0D 3C 29
KNIFE 0D 23 08 29 1D
KNOT 0D 15 23 2A
KNOWLEDGE 0D 15 23 18 00 1E 1A
KNOWS 0D 35 37 12
LAND 18 2F 00 0D 1E
LANGUAGE 18 2F 00 14 1C 2D 0B 1E
1A
LAST 18 2F 00 1F 2A
LATE 18 06 21 29 2A
LAUGH 18 2F 2F 1D
LAW 18 3D
LEAD 18 29 21 1E
LEAF 18 3C 21 1D
LEARNING 18 3A 2B 0D 0B 09 14
LED 18 02 00 1E
LEED 18 29 21 1E
LEFT 18 02 00 1D 2A
LEG 18 02 00 1C
LET 18 02 00 2A
LETTER 18 02 00 2A 3A
LEVEL 18 02 00 0F 23 18
LIBRARY 18 15 29 0E 2B 00 00 3A 29
LIFT 18 0B 09 1D 2A
LIGHT 18 23 08 29 2A
LIKE 18 23 08 29 19
LIMIT 18 0B 0C 0B 2A
LINE 18 15 00 29 0D
LIP 18 0B 09 25
LIST 18 0B 09 1F 2A
LITTLE 18 0B 09 2A 23 18
LIVING 18 0B 0F 0B 14
LOCK 18 15 23 19
LONG 18 3D 14
LOOK 18 16 16 19
LOOSE 18 37 37 1F
LOSS 18 3D 1F
LOUD 18 15 23 2D 1E
LOVE 18 32 23 0F
LOW 18 35 37
MACHINE 0C 31 11 3C 29 0D
MAIL 0C 06 21 29 18
MAKE 0C 06 21 29 19
MALE 0C 06 21 29 18
MAN 0C 2F 00 0D
MANAGER 0C 2F 00 0D 02 1E 1A 3A
MAP 0C 2F 00 25
MARK 0C 15 2B 19
MARKET 0C 25 2B 19 00 2A
MARRIED 0C 01 00 2B 29 1E
MASS 0C 2F 00 1F
MATCH 0C 2F 00 2A 10
MATERIAL 0C 32 2A 0B 2B 29 23 18
MAY 0C 06 09 29
MEAL 0C 3C 21 18
MEASURE 0C 00 02 07 3A
MEAT 0C 3C 29 2A
MEDICAL 0C 02 00 1E 0B 19 23 18
MEET 0C 3C 29 2A
MEETING 0C 3C 29 2A 0B 14
MEMORY 0C 02 00 0C 34 34 2B 29
METAL 0C 02 00 2A 23 18
MIDDLE 0C 0B 09 1E 23 18
MILITARY 0C 0B 18 0B 2A 00 00 3A
29
MILLION 0C 0B 09 18 29 23 0D
MIND 0C 15 00 29 0D 1E
MINE 0C 15 00 29 0D
MINUTE 0C 0B 0D 00 2A
MIST 0C 0B 09 1F 2A
MIXED 0C 0B 19 03 1F 2A
MONEY 0C 23 32 0D 21 29

Phoneme Speech Dictionary (continued)

MONTH 0C 23 32 0D 39
MOON 0C 37 37 0D
MORNING 0C 34 34 2B 0D 0B 09 14
MOTHER 0C 32 23 38 3A
MOTION 0C 34 34 11 23 0D
MOUNTAIN 0C 15 23 2D 0D 2A 09 0D
MOUTH 0C 31 08 37 39
MOVE 0C 37 37 0F
MUCH 0C 32 31 2A 10
MUSCLE 0C 32 31 1F 23 18
MUSIC 0C 22 36 37 37 12 0B 19
NAIL 0D 06 21 29 18
NAME 0D 06 21 29 0C
NARROW 0D 01 00 2B 35 37
NATION 0D 06 29 11 23 0D
NATURAL 0D 2F 00 2A 10 3A 23 18
NEAR 0D 21 09 2B
NECESSARY 0D 02 00 1F 02 00 1F 00
00 3A 29
NECK 0D 02 00 19
NEED 0D 3C 29 1E
NEEDLE 0D 3C 29 1E 23 18
NERVE 0D 3A 0F
NET 0D 02 00 2A
NEW 0D 36 37 37
NEWS 0D 36 37 37 12
NIGHT 0D 23 08 29 2A
NINE 0D 15 00 29 0D
NINETEEN 0D 15 00 29 0D 2A 3C 29
0D
NINETY 0D 15 00 29 0D 2A 29
NO 0D 35 37
NOISE 0D 35 23 09 21 12
NORMAL 0D 34 34 2B 0C 23 18
NORTH 0D 34 34 2B 39
NOSE 0D 35 37 12
NOT 0D 15 23 2A
NOTE 0D 35 37 2A
NOW 0D 15 23 37
NUMBER 0D 32 31 0C 0E 3A
NUT 0D 32 31 2A
OF 32 23 0F
OFF 3D 1D
OFFER 3D 1D 3A
OFFICE 3D 1D 0B 1F
OFTEN 3D 1D 02 00 0D
OIL 35 23 09 21 18
OLD 34 34 18 18 1E
ON 15 23 0D
ONE 2D 32 31 0D
ONLY 35 34 0D 18 29
OPEN 35 25 0A 0D
OPINION 35 37 25 0B 09 0D 29 23 0D
OPPOSITE 15 23 25 32 1F 0B 2A
OR 34 34 2B
ORANGE 34 34 2B 0B 0D 1E 1A
ORDER 34 34 2B 1E 3A
OTHER 32 23 38 3A
OUR 15 23 2D 3A
OUT 23 08 37 2A
OVEN 32 0F 0A 0D
OVER 35 34 0F 3A
OWNER 35 37 0D 3A
PAGE 25 06 21 29 1E 1A
PAIN 25 06 21 29 0D
PAINT 25 06 21 29 0D 2A
PANE 25 06 21 29 0D
PAPER 25 06 21 29 25 3A
PART 25 15 2B 2A
PAST 25 2E 1F 2A
PASTE 25 06 21 29 1F 2A
PAYMENT 25 06 09 29 0C 02 00 0D 2A
PEACE 25 3C 21 1F
PEN 25 02 00 0D
PENCIL 25 02 00 0D 1F 31 18
PEOPLE 25 3C 29 25 23 18
PERSON 25 3A 1F 32 0D
PICTURE 25 0B 09 19 2A 10 3A
PIG 25 0B 09 1C
PIN 25 0B 09 0D
PIPE 25 23 08 29 25
PLACE 25 18 06 21 29 1F
PLAIN 25 18 06 21 29 0D
PLANE 25 18 06 21 29 0D
PLANT 25 18 2F 00 0D 2A
PLAY 25 18 06 09 29
PLEASE 25 18 3C 21 12
POCKET 25 15 23 19 00 2A
POINT 25 35 23 09 21 0D 2A
POISON 25 35 23 09 21 12 32 0D
POLISH 25 15 23 18 0B 11
POLITICAL 25 35 37 18 02 2A 0B 19
23 1B
POOR 25 35 34 2B
POSSIBLE 25 15 23 1F 0B 09 0E 23 18
POT 25 15 23 2A

Phoneme Speech Dictionary (continued)

POTATO 25 32 2A 06 29 2A 35 37
POUR 25 35 34 2B
POWDER 25 15 23 2D 1E 3A
POWER 25 15 23 2D 3A
PRESENT 25 2B 02 12 02 00 0D 2A
PRICE 25 2B 23 08 29 1F
PRINT 25 2B 0B 09 0D 2A
PRISON 25 2B 0B 09 12 32 0D
PRIVATE 25 2B 15 00 29 0F 09 2A
PROCESS 25 2B 15 23 1F 02 00 1F
PRODUCE 25 2B 32 1E 36 37 37 1F
PROFIT 25 2B 15 23 1D 0B 2A
PROPERTY 25 2B 15 23 25 3A 2A 29
PROTEST 25 2B 32 2A 02 00 1F 2A
PUBLIC 25 32 31 0E 18 0B 09 19
PULL 25 16 16 18
PUMP 25 32 31 0C 25
PUNISHMENT 25 32 0D 0B 11 0C 02
00 0D 2A
PURPOSE 25 3A 2B 25 23 1F
PUSH 25 16 36 11
PUT 25 16 16 2A
QUESTION 19 2D 02 00 1F 2A 10 23
0D
QUICK 19 2D 0B 09 19
QUIET 19 2D 15 00 21 0A 2A
QUITE 19 2D 23 08 29 2A
RAIN 2B 06 21 29 0D
RANGE 2B 06 21 29 0D 1E 1A
RAT 2B 2F 00 2A
RATE 2B 06 21 29 2A
RAY 2B 06 09 29
REACTION 2B 29 2F 00 19 11 23 0D
READING 2B 3C 29 1E 0B 14
READY 2B 02 00 1E 29
REASON 2B 3C 29 12 32 0D
RED 2B 02 00 1E
REGULAR 2B 02 1C 22 36 18 3A
RELATION 2B 3C 18 06 29 11 23 0D
RELIGION 2B 3C 18 0B 1E 1A 23 0D
REQUEST 2B 3C 19 2D 02 00 1F 2A
RESPECT 2B 3C 1F 25 02 00 19 2A
RESPONSIBLE 2B 02 1F 25 15 23 0D
1F 0B 09 0E 23 18
REST 2B 02 00 1F 2A
REWARD 2B 3C 2D 34 35 2B 1E
RHYTHM 2B 0B 38 23 0C
RIGHT 2B 23 08 29 2A
RING 2B 0B 09 14
RIVER 2B 0B 0F 3A
ROAD 2B 35 37 1E
ROBOT 2B 35 37 0E 15 23 2A
ROD 2B 15 23 1E
ROLL 2B 35 23 18
ROOF 2B 37 37 1D
ROOM 2B 37 37 0C
ROOT 2B 37 37 2A
ROUGH 2B 32 23 1D
ROUND 2B 15 23 2D 0D 1E
RUB 2B 32 31 0E
RULE 2B 36 37 37 18
RUN 2B 32 31 0D
SAD 1F 2F 00 1E
SAFE 1F 06 21 29 1D
SAIL 1F 06 21 29 18
SALE 1F 06 21 29 18
SALT 1F 3D 18 2A
SAME 1F 06 21 29 0C
SAND 1F 2F 00 0D 1E
SAY 1F 06 09 29
SCALE 1F 19 06 21 29 18
SCHOOL 1F 19 37 37 18
SCIENCE 1F 15 09 21 02 00 0D 1F
SCISSORS 1F 0B 09 12 3A 12
SCREW 1F 19 2B 36 37 37
SEA 1F 3C 29
SEAT 1F 3C 21 2A
SECOND 1F 02 00 19 32 0D 1E
SECRET 1F 3C 19 2B 09 2A
SECRETARY 1F 02 00 19 2B 02 00 2A
00 00 3A 29
SEE 1F 3C 29
SEED 1F 3C 29 1E
SEEDY 1F 3C 29 1E 29
SEEM 1F 3C 29 0C
SELECTION 1F 02 00 18 02 00 19 11
23 0D
SELF 1F 02 00 18 1D
SEND 1F 02 00 0D 1E
SENSE 1F 02 00 0D 1F
SEPARATE 1F 02 00 25 32 2B 06 21 2A
SEPARATE 1F 02 00 25 3A 0A 2A
SERIOUS 1F 0B 2B 29 32 1F
SERVANT 1F 3A 0F 02 00 0D 3A
SEVEN 1F 02 00 0F 0A 0D
SEVENTEEN 1F 02 00 0F 02 00 0D 2A

Phonome Speech Dictionary (continued)

3C 29 0D
SEVENTY 1F 02 00 0F 02 00 0D 2A 29
SEX 1F 02 00 19 03 1F
SHADE 11 06 21 29 1E
SHAKE 11 06 21 29 19
SHAME 11 06 21 29 0C
SHARP 11 15 2B 25
SHE 11 3C 29
SHEEP 11 3C 29 25
SHELF 11 02 00 18 1D
SHIP 11 0B 09 25
SHIRT 11 3A 2B 2A
SHOCK 11 15 23 19
SHOE 11 37 37
SHORT 11 34 34 2B 2A
SHUT 11 32 31 2A
SIDE 1F 15 00 29 1E
SIGN 1F 15 00 29 0D
SIMPLE 1F 0B 09 0C 25 23 18
SISTER 1F 0B 09 1F 2A 3A
SIX 1F 0B 09 19 03 1F
SIXTEEN 1F 0B 09 19 03 1F 2A 3C 29
0D
SIXTY 1F 0B 09 19 03 1F 2A 29
SIZE 1F 15 00 29 12
SKIN 1F 19 0B 09 0D
SKIRT 1F 19 3A 2B 2A
SKY 1F 19 15 00 09 29
SLEEP 1F 18 3C 29 25
SLIP 1F 18 0B 09 25
SLOPE 1F 18 35 37 25
SLOW 1F 18 35 37
SMALL 1F 0C 3D 18
SMASH 1F 0C 2F 00 11
SMELL 1F 0C 02 00 18
SMILE 1F 0C 15 00 09 23 18
SMOKE 1F 0C 35 37 19
SMOOTH 1F 0C 37 37 38
SNAKE 1F 0D 06 21 29 19
SNEEZE 1F 0D 3C 29 12
SNOW 1F 0D 35 37
SO 1F 35 37
SOAP 1F 35 37 25
SOCIETY 1F 34 34 1F 15 00 21 0A 2A
29
SOCK 1F 15 23 19
SOFT 1F 3D 1D 2A
SOLID 1F 15 23 18 0B 1E
SOME 1F 32 23 0C
SON 1F 23 32 0D
SONG 1F 3D 14
SORT 1F 34 34 2B 2A
SOUND 1F 15 23 2D 0D 1E
SOUTH 1F 15 23 37 39
SPACE 1F 25 06 21 29 1F
SPADE 1F 25 06 21 29 1E
SPECIAL 1F 25 02 00 11 23 18
SPRING 1F 25 2B 0B 09 14
SQUARE 1F 19 2D 02 2B
STAGE 1F 2A 06 21 29 1E 1A
STAMP 1F 2A 2F 00 0C 25
STAR 1F 2A 15 23 2B
START 1F 2A 15 2B 2A
STATEMENT 1F 2A 06 29 2A 0C 00 0D
2A
STATION 1F 2A 06 29 11 23 0D
STEAL 1F 2A 3C 29 18
STEAM 1F 2A 3C 21 0C
STEEL 1F 2A 3C 29 18
STEM 1F 2A 02 00 0C
STEP 1F 2A 02 00 25
STICK 1F 2A 0B 09 19
STICKY 1F 2A 0B 09 19 29
STIFF 1F 2A 0B 09 1D
STILL 1F 2A 0B 09 18
STITCH 1F 2A 0B 09 2A 10
STONE 1F 2A 35 37 0D
STOP 1F 2A 15 23 25
STORE 1F 2A 34 34 2B
STORY 1F 2A 34 34 2B 29
STRAIGHT 1F 2A 2B 06 21 29 2A
STRANGE 1F 2A 2B 06 21 29 0D 1E
1A
STREET 1F 2A 2B 3C 29 2A
STRETCH 1F 2A 2B 02 00 2A 10
STRONG 1F 2A 2B 3D 14
SUCH 1F 32 31 2A 10
SUDDEN 1F 32 31 1E 0A 0D
SUGAR 11 16 1C 3A
SUGGESTION 1F 32 31 1C 1E 1A 02
00 1F 2A 10 23 0D
SUMMER 1F 32 31 0C 3A
SUN 1F 23 32 0D
SUPPORT 1F 32 31 25 34 34 2B 2A
SURPRISE 1F 3A 2B 25 2B 15 00 29 12
SWEET 1F 2D 3C 29 2A

Phoneme Speech Dictionary (continued)

SWIM 1F 2D 0B 09 0C
SYSTEM 1F 0B 1F 2A 02 00 0C
TABLE 2A 06 29 0E 23 18
TAIL 2A 06 21 29 18
TAKE 2A 06 21 29 19
TALK 2A 3D 19
TALL 2A 3D 18
TASTE 2A 06 21 29 1F 2A
TAX 2A 2F 00 19 03 1F
TEACHING 2A 3C 21 2A 10 0B 09 14
TEN 2A 02 00 0D
TENDENCY 2A 02 00 0D 1E 02 00 0D
1F 29
TEST 2A 02 00 1F 2A
THAN 39 2F 00 0D
THAT 38 2F 00 2A
THE 38 32 23
THEM 38 00 02 0C
THEN 38 00 02 0D
THEORY 39 21 0A 2B 29
THERE 38 00 05 00 2B
THEY 38 06 21 29
THICK 39 0B 09 19
THIN 39 0B 09 0D
THING 39 0B 09 14
THIRTEEN 39 3A 2B 2A 3C 29 0D
THIRTY 39 3A 2B 2A 29
THIS 38 09 0A 1F
THOUGH 38 34 34 37
THOUGHT 39 3D 2A
THOUSAND 39 15 23 37 12 00 0D 1E
THREE 39 2B 3C 29
THROUGH 39 2B 36 37
THUMB 39 32 31 0C
THUNDER 39 32 31 0D 1E 3A
TICKET 2A 0B 09 19 00 2A
TIGHT 2A 23 08 29 2A
TILL 2A 0B 09 18
TIME 2A 15 00 29 0C
TIRED 2A 15 00 21 2B 1E
TO 2A 37 37
TOE 2A 35 37 2D
TOGETHER 2A 37 1C 02 00 38 3A
TOMORROW 2A 37 0C 15 2B 35 37
TONGUE 2A 32 23 14
TOO 2A 37 37
TOOTH 2A 37 37 39
TOP 2A 15 23 25
TOUCH 2A 32 23 2A 10
TOW 2A 35 37 2D
TOWN 2A 15 23 37 0D
TRADE 2A 2B 06 21 29 1E
TRAIN 2A 2B 06 21 29 0D
TRAY 2A 2B 06 21 29
TREE 2A 2B 3C 29
TRICK 2A 2B 0B 09 19
TROUBLE 2A 2B 23 32 0E 23 18
TRUE 2A 2B 36 37 37
TRY 2A 2B 15 00 09 29
TURN 2A 3A 2B 0D
TWELVE 2A 2D 02 00 18 0F
TWENTY 2A 2D 02 00 0D 2A 29
TWIST 2A 2D 0B 09 1F 2A
TWO 2A 36 37 37
UMBRELLA 32 31 0C 0E 2B 02 00 18
31 23
UNDER 31 31 0D 1E 3A
UNIT 22 36 37 0D 0B 09 2A
UP 32 31 25
UPON 32 25 15 23 0D
US 32 31 1F
USE 22 36 37 37 12
USEFUL 22 36 37 37 1F 1D 16 18
VALUE 0F 2F 00 18 22 36 37
VERSE 0F 3A 1F
VERY 0F 02 2B 29
VESSEL 0F 02 00 1F 23 18
VIEW 0F 22 36 37 37
VIOLENT 0F 15 21 23 18 02 00 0D 2A
VOICE 0F 35 23 09 21 1F
WAIT 2D 05 05 29 2A
WAITING 2D 06 21 29 2A 0B 14
WALK 2D 3D 19
WALL 2D 3D 18
WAR 2D 35 34 2B
WARM 2D 35 34 2B 0C
WASH 2D 3D 11
WASTE 2D 06 21 29 1F 2A
WATCH 2D 15 23 2A 10
WATER 2D 15 23 2A 3A
WAVE 2D 06 21 29 0F
WAX 2D 2F 00 19 03 1F
WAY 2D 06 09 29
WE 2D 3C 29
WEAK 2D 3C 29 19
WEATHER 2D 02 00 38 3A

Phoneme Speech Dictionary (continued)

WEEK 2D 3C 29 19
WEIGHT 2D 05 05 29 2A
WELL 2D 02 00 18
WEST 2D 02 00 1F 2A
WET 2D 02 00 2A
WHEEL 2D 3C 29 18
WHEN 2D 02 00 0D
WHERE 2D 00 05 00 2B
WHILE 2D 15 00 09 23 18
WHISTLE 2D 0B 09 1F 23 18
WHITE 2D 23 08 29 2A
WHO 1B 36 37 37
WHY 2D 15 00 09 29
WIDE 2D 15 00 29 1E
WILL 2D 0B 09 18
WIND 2D 0B 0D 1E
WINDOW 2D 0B 0D 1E 35 37
WINE 2D 15 00 29 0D
WING 2D 0B 09 14
WINTER 2D 0B 09 0D 2A 3A
WIRE 2D 15 00 21 2B
WISE 2D 15 00 29 12
WISH 2D 0B 09 11
WITH 2D 0B 09 39
WOMAN 2D 16 0C 01 0D
WOOD 2D 16 16 1E
WORD 2D 3A 2B 1E
WORK 2D 3A 2B 19
WORM 2D 3A 2B 0C
WOULD 2D 16 16 1E
WOUND 2D 37 37 0D 1E
WRITING 2B 23 08 29 2A 0B 14
WRONG 2B 3D 14
YEAR 22 21 09 2B
YELLOW 22 02 00 18 35 37
YES 22 00 02 1F
YESTERDAY 22 00 02 1F 2A 3A 1E 06
09 29
YOU 22 36 37 37
YOUNG 29 23 32 14

Appendices

7-Bit Hexa-Decimal Numbers and Associated Characters

00	NUL	20	SP
01	SOH	21	!
02	STX	22	"
03	ETX	23	#
04	EOT	24	\$
05	ENQ	25	%
06	ACK	26	&
07	BEL	27	'
08	BS	28	(
09	HT	29)
0A	LF	2A	*
0B	VT	2B	+
0C	FF	2C	!
0D	CR	2D	-
0E	SO	2E	.
0F	SI	2F	/
10	DLE	30	0
11	DC1	31	1
12	DC2	32	2
13	DC3	33	3
14	DC4	34	4
15	NAK	35	5
16	SYN	36	6
17	ETB	37	7
18	CAN	38	8
19	EM	39	9
1A	SUB	3A	:
1B	ESC	3B	;
1C	FS	3C	<
1D	GS	3D	=
1E	RS	3E	>
1F	US	3F	?

7-Bit Hexa-Decimal Numbers and Associated Characters (continued)

40	@	60	
41	A	61	a
42	B	62	b
43	C	63	c
44	D	64	d
45	E	65	e
46	F	66	f
47	G	67	g
48	H	68	h
49	I	69	i
4A	J	6A	j
4B	K	6B	k
4C	L	6C	l
4D	M	6D	m
4E	N	6E	n
4F	O	6F	o
50	P	70	p
51	Q	71	q
52	R	72	r
53	S	73	s
54	T	74	t
55	U	75	u
56	V	76	v
57	W	77	w
58	X	78	x
59	Y	79	y
5A	Z	7A	z
5B	[7B	
5C	\	7C	
5D]	7D	ALT
5E		7E	ESC
5F		7F	DEL/RUB

Appendices

Tiny BASIC Language Summary

NEW expr	Establishes a new start-of-program address equal to the value of 'expr'. NSC Tiny BASIC then executes its initialization sequence which clears all variables, resets all hardware/software stacks, disables interrupts, enables BREAK capability from the console, and performs the nondestructive RAM search.
NEW	Sets the end-of-program pointer equal to the start-of-program pointer so that a new program may be entered. If a program already exists at the start-of-program address, it will be lost.
RUN	Runs the current program
CONT	Continues execution of the current program from the point where execution was suspended (via a STOP, console interrupt, or reset).
LIST (expr)	Lists the current program (optionally starting at the line number specified by (expr)).
REM anything	Remark (no operation)
CLEAR	Initializes all variables to 0, disables interrupts, enables BREAK capability from the console, and resets all stacks (GOSUB, FOR-NEXT, DO-UNTIL).
[LET] var = expr	Assigns expression value to variable.
[LET] STAT = expr	Sets the STATUS word equal to the least significant byte of 'expr'.
[LET] @factor = expr	When the STATUS word is used to enable interrupts at the hardware, processing will be deferred for one statement.
[LET] \$factor = "string"	Sets the memory location pointed to by 'factor' equal to the least significant byte of 'expr'.

Tiny BASIC Language Summary (continued)

[LET] factor = factor	Assigns a string in RAM starting at the address 'factor'. Strings are terminated by carriage return.
PRINT expr	Memory to memory string assignment, (copy).
PRINT "string"	Prints the value of 'expr'.
PRINT sfactor	Prints the string.
IF expr [THEN] statements(s)	Prints the string starting at the memory address 'factor'.
FOR var = expr TO expr	Remainder of the program line is executed if expr is true (non-zero).
[STEP expr]	FOR loop initialization. FOR loops may be nested up to four levels deep.
NEXT var	FOR loop termination.
DO	DO loop initiation. DO loops may be nested up to eight levels deep.
UNTIL expr	DO loop termination.
GO TO expr	Transfer control to statement number 'expr'.
GOSUB expr	Call subroutine at statement number 'expr'. Subroutine (including those servicing interrupts).
RETURN	Return from subroutine.
INPUT var	Read value from console into variable.
INPUT sfactor	Read string from console into memory beginning at address 'factor'.
LINK expr	Links to an assembly language subroutine which begins at the address 'expr'.

Tiny BASIC Language Summary (continued)

ON expr1, expr2	Interrupt processing definition. When interrupt number expr1 occurs, NSC Tiny Basic will execute a GOSUB beginning at line number expr2. If expr2 is zero, the corresponding interrupt is disabled at the software level. Interrupt numbers may be 1 or 2. Use of the ON statement disables console interrupts (BREAK function). Interrupts must also be enabled at the hardware level by setting the Interrupt Enable bit in the status register (using STAT=1, for example).
DELAY exor	Delay for expr time units (nominally milliseconds, 1-1040). Delay 0 gives the maximum delay of 1040 milliseconds.
STOP	Terminate programs execution. A message is printed and NSC Tiny BASIC return to COMMAND mode.
OPERATORS	
Arithmetic operators:	Addition + Subtraction - multiplication * division /
Relational operators:	less than < greater than > equal to = not equal to <> less than or equal to <= greater than or equal to >=
Logical operators:	logical AND AND logical OR OR logical NOT NOT
@factor	Read a byte from memory/peripheral, or write a byte to memory/peripheral. Factor is the memory/peripheral address.
FUNCTIONS	
STAT	Status Register contents.
TOP	Top-Of-Program address (first available memory address after end-of-program byte).

Tiny BASIC Language Summary (continued)

INC (X), DEC (X)	Increment or decrement a memory location (non-interruptible for multiprocessing).
MOD (X,Y)	Modulus function (remainder of x/y).
RND (X,Y)	Random number generator (in interval x,y).
COMMANDS (not to be used as statements) NEW expr	Establishes a new start-of-program address equal to the value of expr. NSC Tiny BASIC then executes its initialization sequence which clears all variables, resets all hardware/software stacks, disables interrupts, enables BREAK capable from the console, and performs the non-destructive RAM search described in Section II. If the value of expr points to a ROM address, the NSC Tiny BASIC program which begins at this address will be automatically executed and program memory (including the end-of-program pointer used by editor) is not altered by this command.
NEW	NEW followed only by a carriage return sets the end-of-program pointer equal to the start-of-program may be entered. If a program already exists at the start-of-program address, it will be lost.
RUN	Runs the current program
CONT	Continues execution of the current program from the point where execution was suspended (via a STOP, console interrupt or resets).
LIST expr	Lists the current program (optionally starting at the line number specified by expr).

Appendices

K-6 Curriculum Overview

by Niki Delgado

RB5X Robots as Members of Society

Value of Robots in Education

Computers in education have provided the opportunity to broaden children's experiences in the schools. Properly used, computers allow the teaching of concepts that were previously very difficult to teach. The development of a robot suitable for classroom use permits the introduction of concepts and classes of learning to the elementary schools that could not be addressed even with the use of computer technology.

The RB5X robot is a concrete object that can physically respond to the desires of its operator. The robot operator sees, in physical results, the effects of his/her own decisions. This physical result is extremely useful in enhancing learning in the elementary-school child. As Piagetian theory points-out, children of elementary-school age rely heavily on concrete experience and examples in deriving meaningful knowledge.

About this Curriculum Guide

This document has been developed as an introduction and overview to compliment the complete RB5X K-6 Curriculum Development Guide, by Niki Delgado. The subject areas covered by the following material include:

- English as a Second Language (ESL)
- Language Arts
- Social Studies
- Science
- Mathematics

Niki Delgado is available to answer any questions that you may have through the following email address: < ndelgado@edurobot.com >.

English as a Second Language (ESL) Guide

Philosophy.

With many minority groups residing in this country, the teaching of English as a second language is a major part of many schools' curricula. Quite often children who are speakers of a language other than English have a limited opportunity to use English outside of the instructional setting. As a result, the students find little to motivate them toward a mastery of English, even though the attainment of mastery depends on motivation.

There is ample research that shows that computers are highly motivating, particularly to minority students, but there is a serious lack of ESL instructional material in this area. One of the obvious reasons is the absence of computer voice simulation to help students master pronunciation of English.

The addition of an RB5X robot with unlimited speech potential can help to fill this gap. The RB5X robot can further allow students to explore the impact of language and realize the importance of correct grammar and syntax due to the robot's ability to act and follow instructions. Students will be able to extend their vocabularies through additional practice' time and activities that do not require the teacher to be directly involved. Because the RB5X robot can be programmed (taught) using English instead of a more obscure programming language, students are provided additional motivation and opportunities to use their second language.

Much technology related ancillary learning will occur by including the RB5X robot as a tool in the instructional setting. Many non-English speaking students come from lower socioeconomic background. These students do not have an opportunity to have contact with technological advances. Due to a limited knowledge of English, these students are also excluded from school programs designed to acquaint young people with these advances.

Through the process of using robots and computers to learn English, students will also learn about computer operation, computer programming and the integration of robotics into society. In this manner, students not only learn English, but become computer/robot literate as well.

About the Strand Design.

The overall objective is to help students who are non- or limited English speakers learn to adequately function in their second language in a supportive and stimulating environment.

At the conclusion of this strand, students should see the value of mastering English and have gained enough strategies to allow them to continue as independent learners. The units are designed around the belief that to teach something is to learn it well. In all but the introductory unit, students are involved teaching the RB5X robot what they are learning themselves. Without the RB5X robot, this approach would not be practical. Although each unit is listed as being suitable for a particular grade level, the component need not be limited to this application. If more intensive language learning is desired for older students, the basic outline can be followed, but focus of activities changed to reflect the age and world view of the students. The units are designed to follow in a logical sequence in learning a second language and learning about the RB5X robot.

Long-range Goals:

1. Students will gain sufficient command of English to allow them to progress in other academic areas at a normal rate.
2. Students will gain enough language learning strategies to allow them to become independent language learners.
3. Students will be sufficiently motivated to continue second language learning at the completion of this strand.

Language Arts Curriculum Guide

Focus.

Robots help us understand language and communication.

Philosophy.

In an increasingly complex world, the need for clear, concise communication is essential. Through a better understanding of language and the impact of language on society, we can become better communicators of ideas, information, and emotions. Robots, because of their literal response to commands, give us the opportunity to directly observe the effects of those various types of communications.

We are now able to track subtler aspects of communication at an earlier age. To effectively communicate, we must be able to listen and observe, as well as speak. The RB5X robot provides an excellent vehicle to allow for the analysis of many facets of communication.

Long-range Goals

1. Students will understand the value of clear communication in a complex society.
2. Students will understand the role of language in communication.
3. Students will understand and be able to apply the skills of analysis to create meaningful communication.



Social Studies Curriculum Guide: Grades K -6

Focus.

Robots as members of society



Philosophy.

Technology is bringing about rapid changes in society today. In order to cope with these rapid advances, we must learn how to bring about a positive integration of technological advances into modern society at all levels.

Robots will be part of these technological changes; their ability to capture the imaginations of young and old make them an excellent vehicle for studying the effects of the technological revolution.

Young people who understand the potential roles of robots and computers in the home and at work will have the ability to later make more informed career choices as they pursue more advanced education.

Long-range Goals.

1. Students will appreciate the positive contributions that robots can make to society.
 2. Students will understand the differences between the roles of robots and humans in a society.
 3. Students will understand how to integrate robots into the home and workplace.
- 
- 

Science Curriculum Guide: Grades K -6

Focus.

Comparison of human anatomy and abilities with those of robots.

Philosophy.

The concept of system to refer to many classes of both objects and life is becoming widespread. It is important that young people be allowed to explore and understand the meaning of a system as a collection of many interactive parts that function as a integrated unit. By studying the RB5X robot, and contrasting the robot's functions with those of their own body's, children can more effectively grasp the concept of systems. An effective understanding of the concept of the system will better enable children to understand their own bodies' functions and the importance of proper care and nutrition, as well as how intelligent machines function and the care they require.

Long-range Goals:

1. Students will gain meaningful insights into the functions and interdependence of the parts of the body individually and as parts of a system.
2. Students will understand the basic elements that allow a robot to function as a system.
3. Students will understand and be able to apply principles that will aid in maintaining optimal personal health.

Mathematics Curriculum Guide: Grades K -6

Focus.

Concrete exploration of arithmetical operators, geometrical figures, area concepts, and algebraic notation.

Philosophy.

Elementary school children are capable of learning many complex concepts, but for a good understanding of these concepts and a knowledge of why they are important, children of elementary school are need concrete experiences.

Mathematics is often presented in an abstract manner, which many younger students are unable to internalize. The effect is to instill a long-term dislike of the subject. Through the use of an RB5X robot, abstract concepts can be related to concrete action. A willingness to learn additional abstractions can be established, and the danger of student aversion to mathematics is avoided.

Allowing children to play with numbers and to observe the results in a non-judgemental environment provides for the development of an acceptance of mathematical concepts, an intuitive understanding of them, and readiness for continued growth.

Long-range Goals:

1. Students will gain a concrete understanding of arithmetical operations.
2. Students will understand the characteristics of plane geometric figures, the ways in which they are generated, and the calculation of areas of squares and rectangles.
3. Students will understand and be able to apply basic algebraic notational concepts.

**SECTION C:
ELECTRONICS**

OVERVIEW

RB5X's electronics were designed specifically to foster the enhancement and adaptation of the base unit robot, and to make repairing the robot a simple task. You can use RB5X just as it is, purchasing hardware and software options that we develop for the machine. Or, with a little more training and experience, you can design options of your own, interfacing them easily with RB5X's existing electronic components.

To enable you to experiment with RB5X's electronics, we have included complete schematics at the end of this section for the following:

- CPU Board
- Mother Board and Wire Diagram
- Motor Control Board
- LED Board
- Sonar Card, Connection
- Interface Board
- Power Board
- EPROM Extension Board

There are several elements incorporated into RB5X's design that make its electronics easy to work with.

Like the inside of a typical microcomputer, RB5X's mother board has five empty sockets for the PC boards that operate such hardware options as voice/sound synthesis or a robotic arm. (These are just two of the RB5X accessories developed by General Robotics. Our users have developed others and have even designed their own boards.) These sockets are numbered

from J0 to J5, with the robot's main PC board, the CPU board, occupying slot J0. You can add up to 15 PC boards, piggy-backing three boards in each slot.

In addition to providing space for added electronics, RB5X's design makes use of flat, ribbon-type cables. This type of cable reduces electrical noise, allows for easy and accurate assembly, and offers more flexibility than conventional round cable.

When installing options that use ribbon cables, make sure the cable is safe from being pinched between two metal parts. Also, don't crease or tightly twist ribbon cables. And **NEVER** pull on the ribbon cable itself to unplug it. Instead, pull on the cable's connector. As with all electronic parts, treat ribbon cables with respect and they'll never give any trouble.

Some cable connectors used on the RB5X have a positive retaining mechanism; others depend on friction fit to hold them in place.

Some cable connector/socket units (usually the smaller ones) have a hook-like feature to hold them together. When joining these connectors and sockets, the hooks can be used as a guide to proper orientation. When separating these units, hold the cable connector itself, rock it gently from side to side, and pull. **NEVER** pull on the wires coming out of the connector.

Other sockets have latches to hold the connector in positive contact. These latch mechanisms have levers that lift the connectors out of the socket during removal. When inserting connectors in latch sockets, hold the latches open just far enough to let the connector slip past them. When the connector is started into the socket, release the latch and push the connector the rest of the way into the socket. If you hold the latch too far open, the lower part of the extraction lever projects into the connector's path and prevents it from fully seating into the socket.

The connector is fully seated when the retaining latch-hooks slip over the top of the connector. To remove the connector, move the latch ears away from the connector. The extraction levers at the bottom of the latches gently lift the connector out of the socket, and the connector can be manually moved out of the way.

Electronic connectors always have some indication of the proper orientation for insertion into a socket. If there is any

question about proper orientation of connectors, contact your local dealer or General Robotics Corporation.

Like all PC boards, those used in the RB5X are generally very sensitive to static electricity. Before installing or removing any PC board, make sure that you have discharged any static electricity in your body by touching an unpainted surface on the RB5X (such as the vertical, metal struts, for example).

Always handle PC boards with care, making sure not to bend or warp them during installation or removal. When installing a PC board, avoid wiggling it to seat it in its socket. Push straight down on the board or gently rock it along the long axis until you feel it snap into place.

As you begin working with RB5X's electronics, there are a few points to keep in mind:

- **NEVER** pull on the ribbon cable itself when unplugging it from its socket. Pull on the connector.
- Make sure that cables are properly oriented and firmly plugged into their connectors.
- Ground yourself before handling PC boards so as not to damage them with the static electricity your body might be carrying.
- Make sure not to bend or warp PC boards.
- Push straight down on the board or gently rock it to seat it in its socket. Don't ever wiggle it.

THE RB5X BUS STRUCTURE AND MOTHER BOARD

The electronic bus used in the RB5X was specially designed for this robot. Although the bus itself is tailor-made for RB5X, it uses standard connectors -- 2 x 22 pin sockets on .156-inch centers -- on the mother board to interface with the PC boards. (See Figure 3, Mother Board, and Figure 4, Mother Board Interconnect List.) This enables you to use standard boards, available at electronics and computers stores, when adding custom-built hardware options to your robot.

Figure 3.
Mother Board

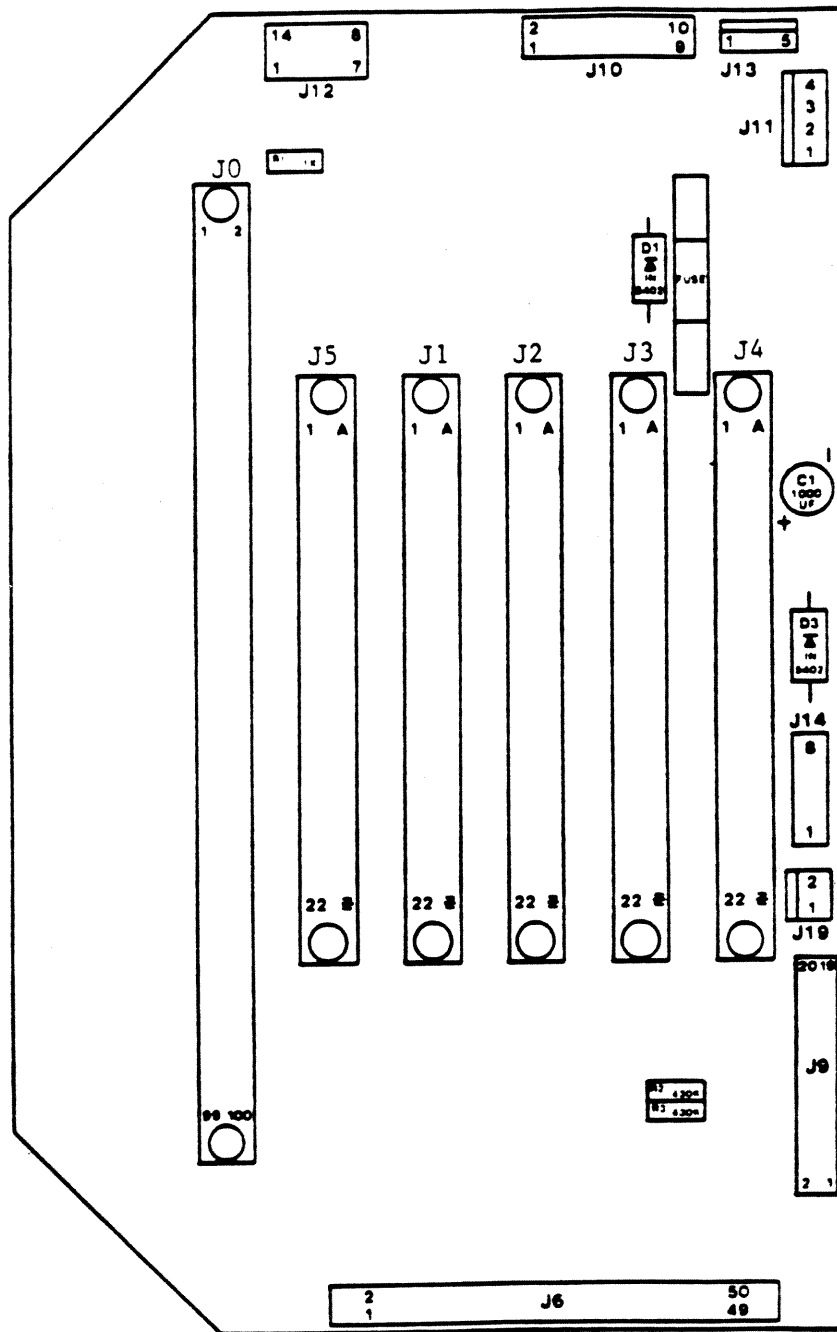


Figure 4.
Mother Board Interconnect List

Connector	Configuration	Pin Centers	Intended Use
J0	2x50 pin	.125 centers	CPU board
J5	2x22 pin	.156 centers	Memory option
J1 & J2	2x22 pin	.156 centers	I/O boards (parallel from INS8255 A)
J3 & J4	2x22 pin	.156 centers	I/O boards (parallel from INS8255 B)
J6	50 pin	.100 centers	Mother board to CPU board
J9	20 pin	.100 centers	LED card
J10	10 pin	.100 centers	Bumper switches
J11	4 pin	.156 centers	Main battery and recharge lines
J12	14 pin	DIP socket	Interface panel
J13	5 pin	.100 centers	Sonar cable
J14	8 pin	.100 centers	Motor control board
J19	2 pin	.156 centers	Sonar/LED switch cable

NOTE: If you plan to design your own PC boards for options that you add to RB5X, we recommend you become very familiar with the mother board schematic contained later in this section so that you can make the appropriate pin assignments.

The mother board is fused for 1 amp. The electronics that run the base unit draw about 1/4-amp; an RB5X with optional voice/sound synthesis and the RB Arm draws just over 1/2-amp. If you plan to install other options, you may want to use a larger fuse.

In addition to power and input/output (I/O) lines, sockets J1, J2, J3, and J4 on the mother board also have bus request, reset, disconnect, and clock lines available. J5 has all of these lines plus address and data lines. (See Figure 3, Mother Board.)

THE RB5X CPU BOARD

Like the CPU in a microcomputer, RB5X's CPU board contains the bulk of the electronics dedicated to control of the robot, its functions, and options.

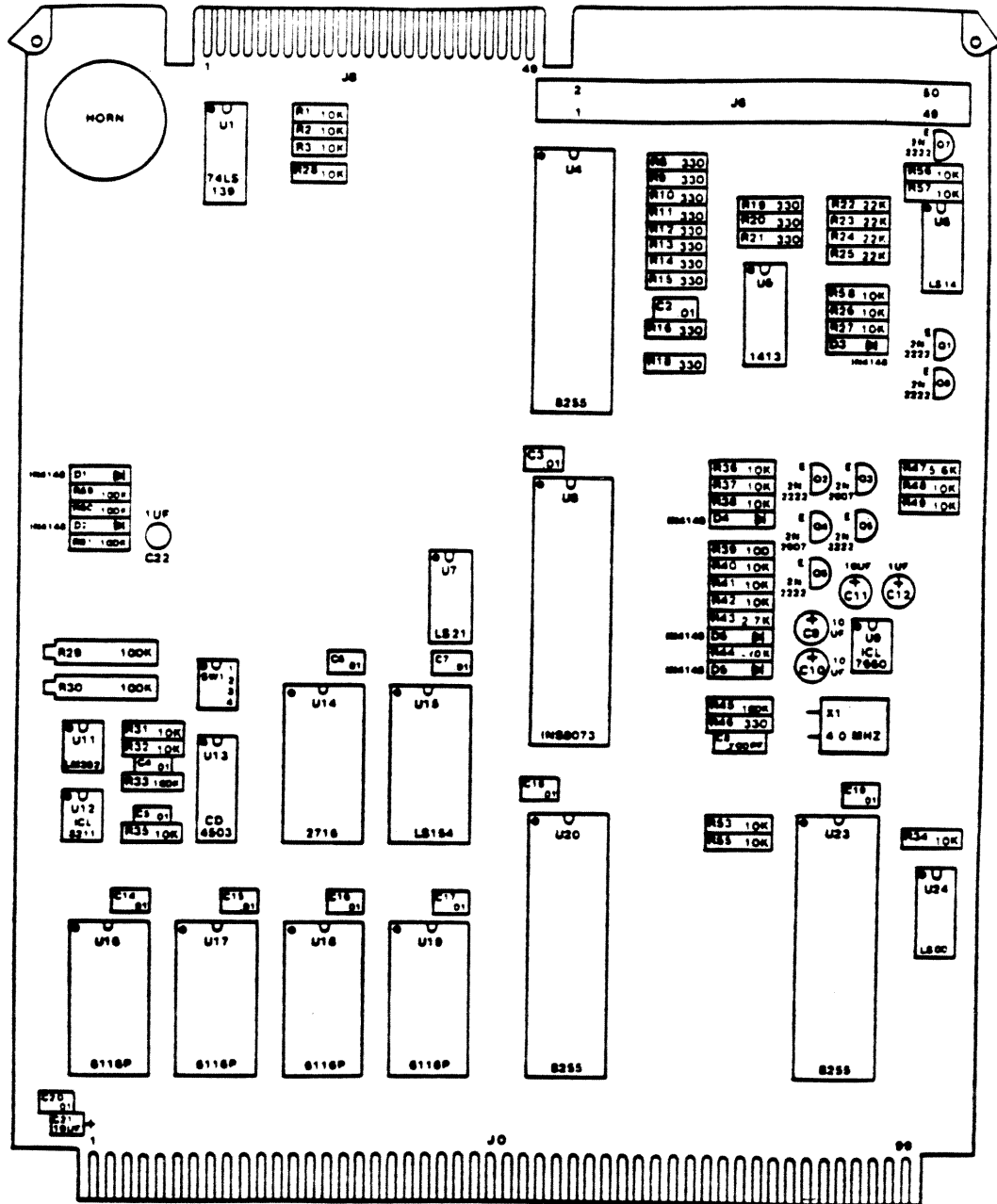
NOTE: You should be familiar with the various chips and devices that are housed on the CPU board. But since this is the "command center" for the RB5X, we recommend that -- unless you have considerable experience in electronics -- you leave the repair or modification of this board to your local dealer or to RB Robot Customer Service.

Microprocessor and I/O Operations

RB5X's microprocessor is the INS8073 from National Semiconductor, and resides at socket U8 on the CPU board (see Figure 5, CPU Board). This chip has a built-in Tiny BASIC interpreter, and affords direct access to all addresses in the robot's memory using the PEEK and POKE functions of Tiny BASIC, making it ideal for machine control. Externally, the INS8073 is an 8-bit chip, although it is 16-bit internally.

The CPU board also contains three INS8255 chips, which offer simultaneous I/O. (Having the two functions available on one chip saves both space and power.)

Figure 5.
CPU Board



The 8255 at position U4 (see Figure 5) handles the internal I/O of the control devices standard to the base unit. The 8255s at U20 and U23 are connected for external I/O through slots J1 through J4 on the mother board. (See the Figure 6, Memory Map.)

Each 8255 drives 24 lines of I/O, arranged in three bytes of eight bits each. They may be set up in any of three modes -- basic I/O, strobed I/O, or bidirectional I/O.

CAUTION: The 8255s can sink considerable current from whatever peripheral they are driving. However, care should be taken not to exceed the power dissipation capabilities of the chip.

For further information on the 8255 chip, see Appendix 4, "INS8255 Programmable Peripheral Interface."

Additional Electronics

RB5X's standard 8K of RAM is contained on the four chips at sockets U16, U17, U18, and U19 along the lower edge of the CPU board. (See Figure 5.)

Notice that there are six, blank chip positions on this board, which you can use as you become more familiar with RB5X's electronics and begin to experiment with adding options, such as a real-time clock, for example. There are positions for four, 16-pin dual in-line pin (DIP) sockets; one, 14-pin DIP socket; and one, eight-pin DIP socket. (If you plan to use these positions, you first need to remove the solder that fills the pin holes.)

To see how the INS8073, the INS8255s, and the memory chips connect to the other systems within the RB5X, refer to Figure 7, "RB5X Block Diagram."

RS-232 CONNECTIONS

Figure 8 illustrates the pin assignments within the RB5X for the RS-232 socket labelled Port 1 on the interface panel. (The Port 2 RS-232 socket is not yet being used; it will be employed later, to port such peripherals as a detachable keyboard for the RB5X.) This is a standard D-subminiature, 25-pin socket that connects to the robot at J26 on the interface board. (See the Interface Board schematic later in this section.)

Notice in Figure 8 that pin 25 is connected directly to RB5X's electronics battery without the use of a current-limiting resistor like the ones on lines 5, 6, 8, and 20. This pin is for powering peripheral devices connected directly to Port 1. Check to make sure that the computer you use to communicate with the robot does not have pin 25 grounded at the terminal (as is the case with Radio Shack Models III and IV). If pin 25 at your terminal is grounded, snip the two leads farthest from the red conductor on the RS-232 cable that came with your RB5X so that the connection is broken.

Lines 2 and 3 (data in and data out, respectively) may be reversed by changing the position of SW1 (see Interface Board schematic at the end of this section) on the back of the printed circuit board upon which the RS-232 connectors are soldered. (Down is the normal position of this switch, as shown in Figure 8.) If your terminal requires that it receive data on line 2 and send data on line 3, push the switch up.

Pin 20 can be opened up by removing jumper JP3 if necessary.

Jumper JP1 may be added to light all of the LEDs in the bar display below and including the one indicating the state of charge of the batteries.

Figure 6.
Memory Map

92 + 7FF - 2K

First 32 K

100 0111 1111 1111

#87FF	PROM or EPROM (2K or 4K switch-selectable)	
#8000		
#780B	Status byte, J1 and J2	
#780A	Port C	User-defined
#7809	Port B	User-defined
#7808	Port A	User-defined
#7807	Status byte, J3 and J4	
#7806	Port C	User-defined
#7805	Port B	User-defined
#7804	Port A	User-defined
#7803	Status byte, set at #98	
#7802	Port C	Motors, battery and charge sense, sonar and tape sense
#7801	Port B	Horn, LEDs, and sonar on/off
#7800	Port A	Bumper switch inputs
#77FF	2K User-expandable	
#7000		
#6FFF	16K optional RAM	
#3000		
#2FFF	8K RAM	
#1000		
#0FFF	Internal Use	
#0A00		
#09FF		
#0000	2.5K Tiny BASIC ROM	

Figure 7.
Block Diagram

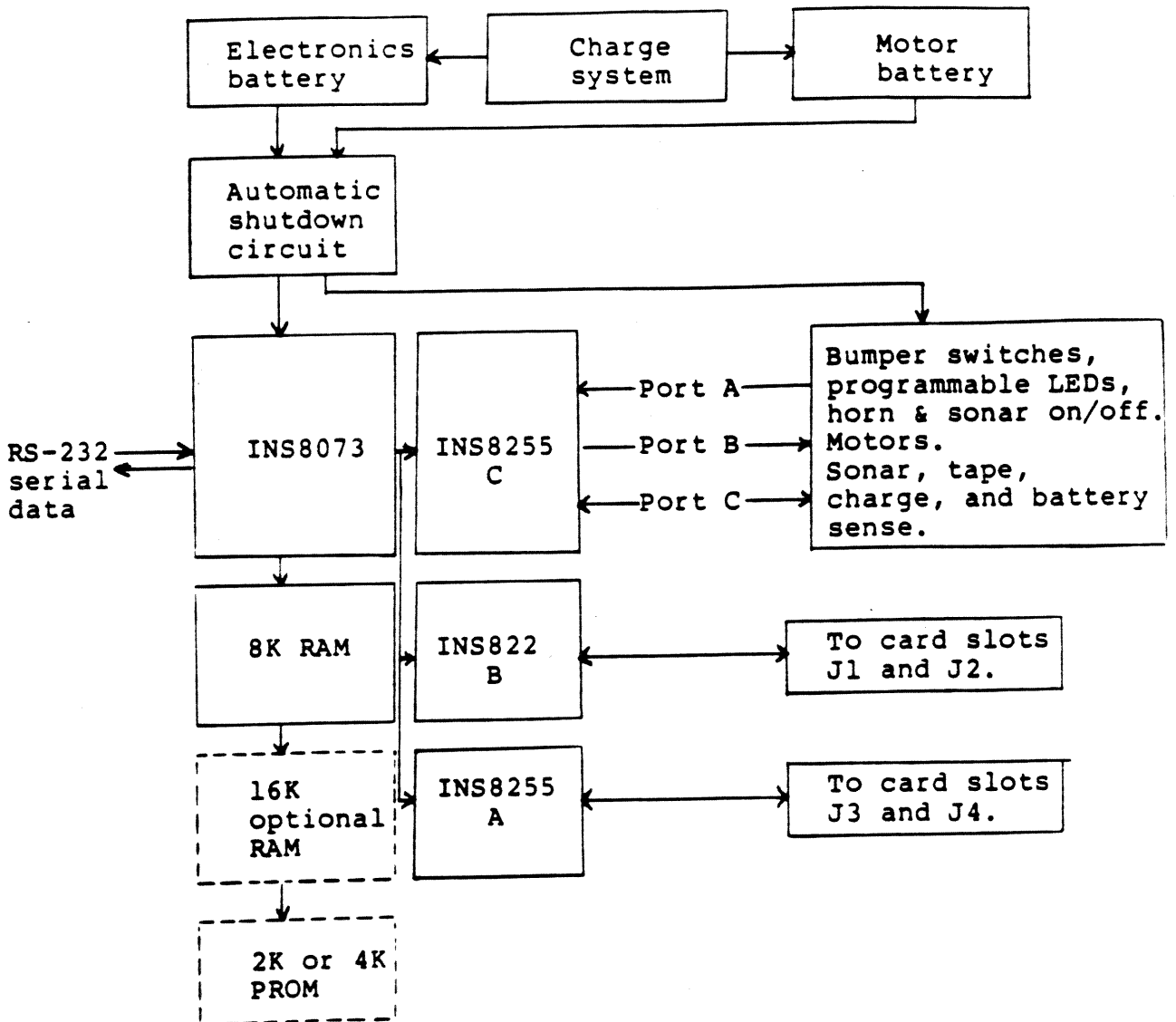
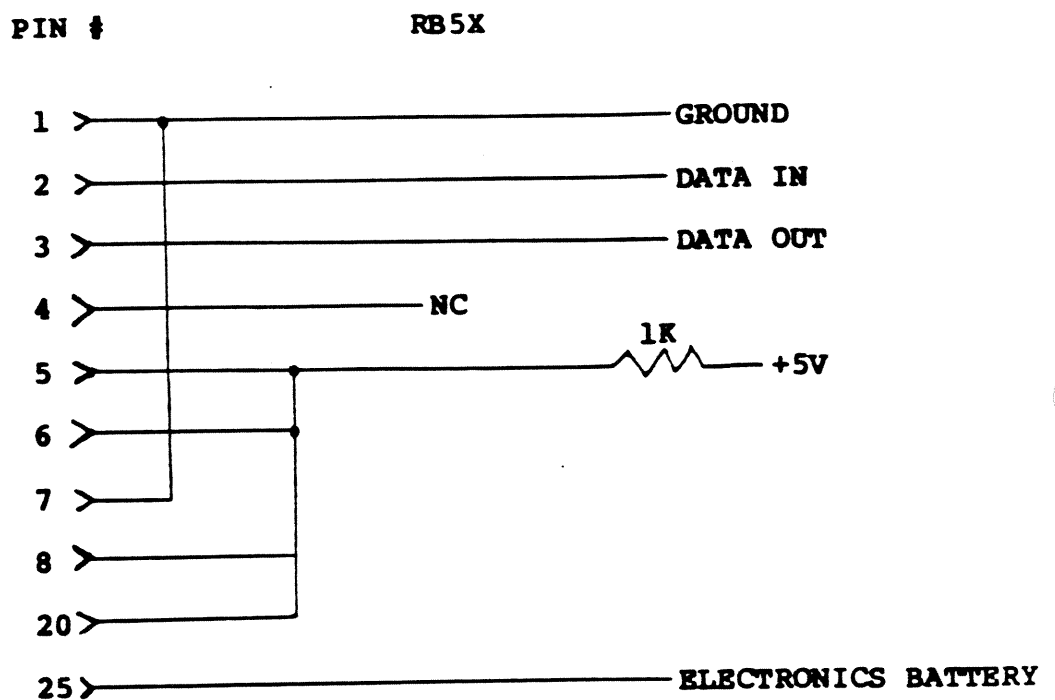


Figure 8.
RS-232 Connections within RB5X

The wiring for the RS-232 connector within RB5X is as follows:



ELECTRONICS PARTS LIST

The following pages contain the designators, descriptions, and value or type of the electronic parts that comprise the RB5X.

If you have experience in the repair and modification of electronic equipment, this list will be useful when ordering spare parts from General Robotics Corporation.

CPU Board

Designator	Description	Value, Type
R1, R2, R3, R26, R27, R28, R31, R32, R34, R35, R36, R37, R38, R40, R41, R42, R48, R49, R53, R55, R56, R57, R58	Resistor	10K OHM, 5%, 0.25 watt
R8, R9, R10, R11, R12, R13, R14, R15, R16, R18, R19, R20, R21, R46	Resistor	330 OHM, 5%, 0.25 watt
R22, R23, R24, R25	Resistor	22K OHM, 5%, 0.25 watt
R29, R30	Potentiometer	100K OHM, 5%
R33, R45, R59, R60, R61	Resistor	100K OHM, 5%, 0.25 watt
R39	Resistor	100 OHM, 5%, 0.25 watt
R43	Resistor	2.7K OHM, 5%, 0.25 watt
R44	Resistor	10K OHM, 5%, 0.25 watt
R47	Resistor	5.6K OHM, 5%, 0.25 watt
C2, C3, C4, C5, C6, C7, C14, C15, C16, C17, C18, C19, C20	Capacitor	0.01 UF, 20%, 100 volt

CPU Board (continued)

Designator	Description	Value, Type
C8	Capacitor	300PF, 20%, 100 volt
C9, C10, C11, C21	Capacitor	10 UF, 20%, 16 volt
C12, C22	Capacitor	1 UF, 20%, 16 volt
U1	Decoder	SN74LS139
U4, U20, U23	Programmable I/O	INS8255
U5	Driver	MC1413
U6	Inverter	SN74LS14
U7	Dual AND	SN74LS21
U8	Microprocessor	INS8073
U9	Voltage inverter	ICL7660
U11	Comparator	LM392
U12	Voltage sensor	ICL8211
U13	Hex buffer	CD4503
U14	PROM	2732 socket

CPU Board (continued)

Designator	Description	Value, Type
U15	Decoder	74LS154
U16, U17, U18, U19	Memory 2KX8	HM6116
U24	Quad NAND	74LS00
Q1, Q2, Q5, Q6, Q7, Q8	Transistor	PN2222
Q3, Q4	Transistor	PN2907
D1, D2, D3, D4, D5, D6	Diode	IN4148
X1	Crystal	4.0 MHZ
H1	Horn	Constant tone
SW1	DIP switch	4 position

Mother Board

Designator	Description	Value, Type
R1	Resistor	1K OHM, 5%, 0.25 watt
R2, R3	Resistor	430K OHM, 5%, 0.25 watt
D1, D3	Diode	IN5402
C1	Capacitor	1000 UF, 20%, 16 volt
F1	Fuse	1 amp, 3AG

Motor Control Board

Designator	Description	Value, Type
C1, C2, C3	Capacitor	0.01 UF, 20%, 100 volt
D1	Diode	IN5402
D2	Photodiode	TIL413
D3	Infrared LED	TIL39
ZD1, ZD2, ZD3, ZD4	Zener diode	IN4740, 10 volt
K0, K1, K2, K3	Relay	5 volt coil 3 amp contacts
U1	Driver	MC1413
F1	Fuse	6 amp, 3AG

LED Board

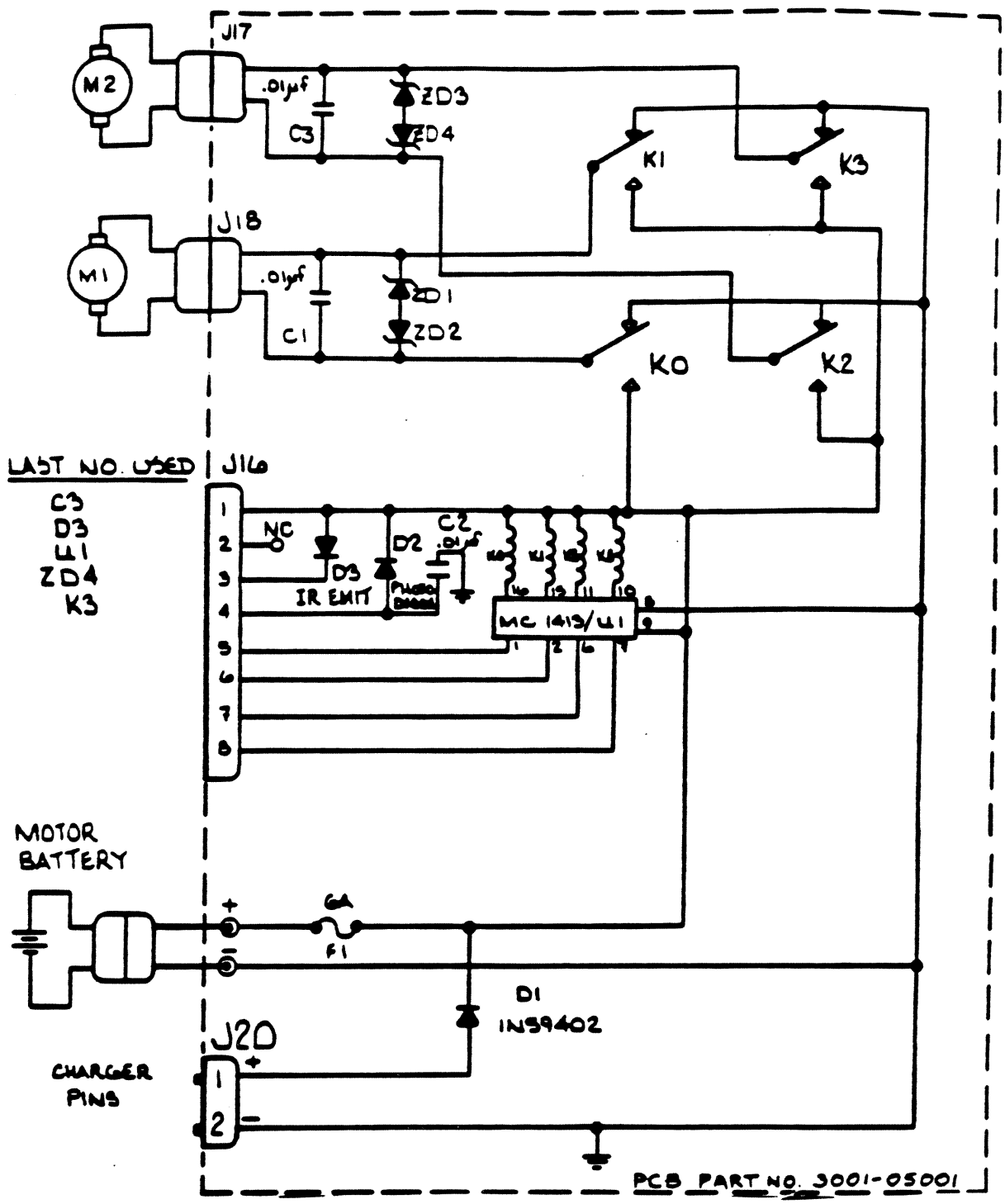
Designator	Description	Value, Type
R1, R2, R3, R4, R5	Resistor	330 OHM, 5%, 0.25 watt
D1	Diode	IN4001
U1, U2, U3, U4	Flasher	FCC92
U5	Driver	MC1413
LED 1 to LED 21	Light-emitting diode	5 colors

Interface Board

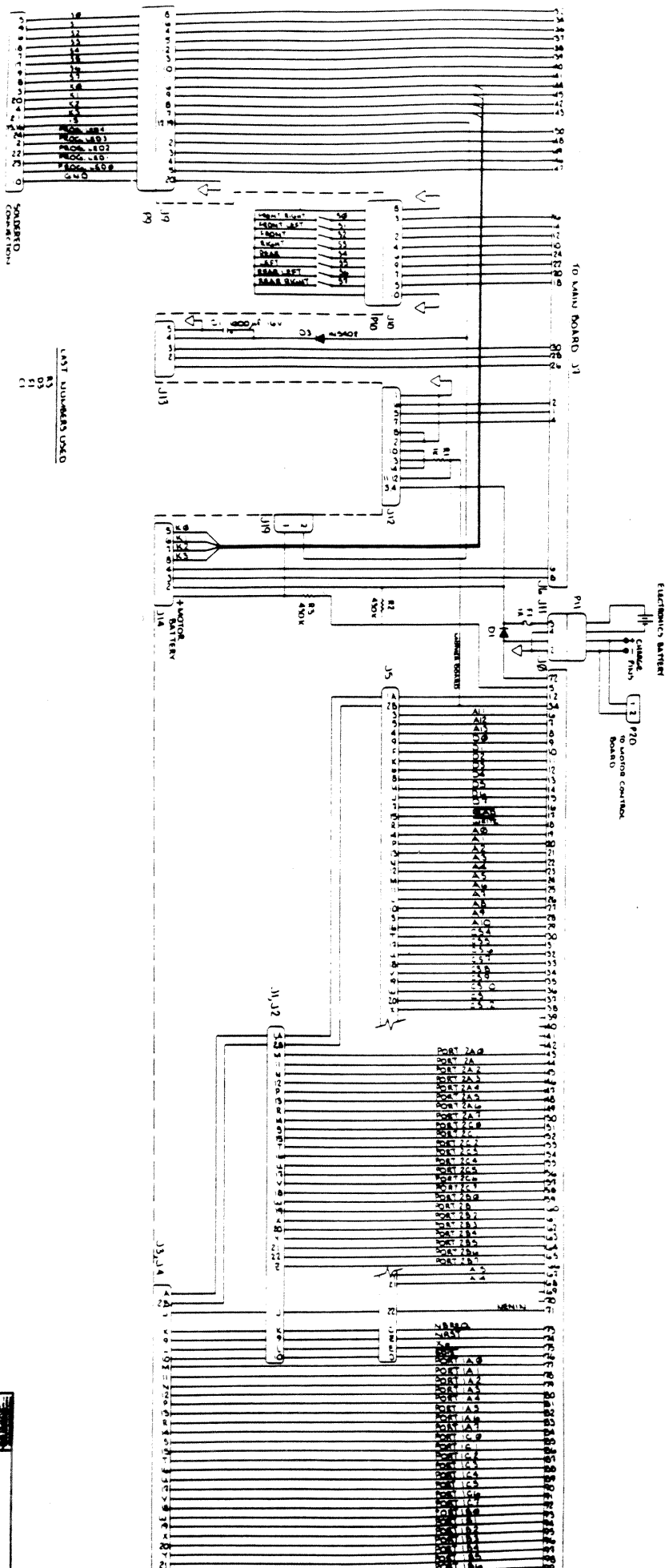
Designator	Description	Value, Type
U1	Dot/bar display driver	LM3914
U2	LED bar	HDSP4830
R1, R2	Resistor	10K OHM, 1%, 0.25 watt
R3	Potentiometer	100K OHM, 10 turn
R4	Resistor	10K OHM, 5%, 0.25 watt
D1	Diode	IN4148
SW1	Switch	DPDT, right angel, slide
SW2	Switch	4PDT, slide

Power Board

Designator	Description	Value, Type
R1, R7	Resistor	33.2K OHM, 1%, 0.25 watt
R2, R8	Resistor	10.0K OHM, 1%, 0.25 watt
R3, R5, R6, R9	Resistor	1K, 5%, 0.25 watt
R4	Resistor	100K OHM, 5%, 0.25 watt
CR1, CR3, CR4	Diode	IN4001
U1, U2	Voltage sensor	ICL8211
VR1	Regulator	L4805
C1, C2, C3	Capacitor, electrolytic	100mf, 16 volt
C4	Capacitor, electrolytic	1000mf, 16 volt
Q1	Transistor	2N2907
Q2, Q3	Transistor	2N2222
K1	Relay	DPDT, latching



TITLE				COMM
SCHEMATIC				
MOTOR CONTROL BD.				
CHGD BY	DATE	ECO NO.	INTENT	PART STATUS
LATEST CHANGE				
PART NO.			REV	SMT / 0



ELECTRONIC BATTERY
 TO MAIN BOARD J1
 MOTOR
 CHARGE BOARD
 SOLDERED CONNECTIONS
 R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17 R18 R19 R20 R21 R22 R23 R24 R25 R26 R27 R28 R29 R30 R31 R32 R33 R34 R35 R36 R37 R38 R39 R40 R41 R42 R43 R44 R45 R46 R47 R48 R49 R50 R51 R52 R53 R54 R55 R56 R57 R58 R59 R60 R61 R62 R63 R64 R65 R66 R67 R68 R69 R70 R71 R72 R73 R74 R75 R76 R77 R78 R79 R80 R81 R82 R83 R84 R85 R86 R87 R88 R89 R90 R91 R92 R93 R94 R95 R96 R97 R98 R99 R100

SCHEMATIC CPU BOARD

5 X006

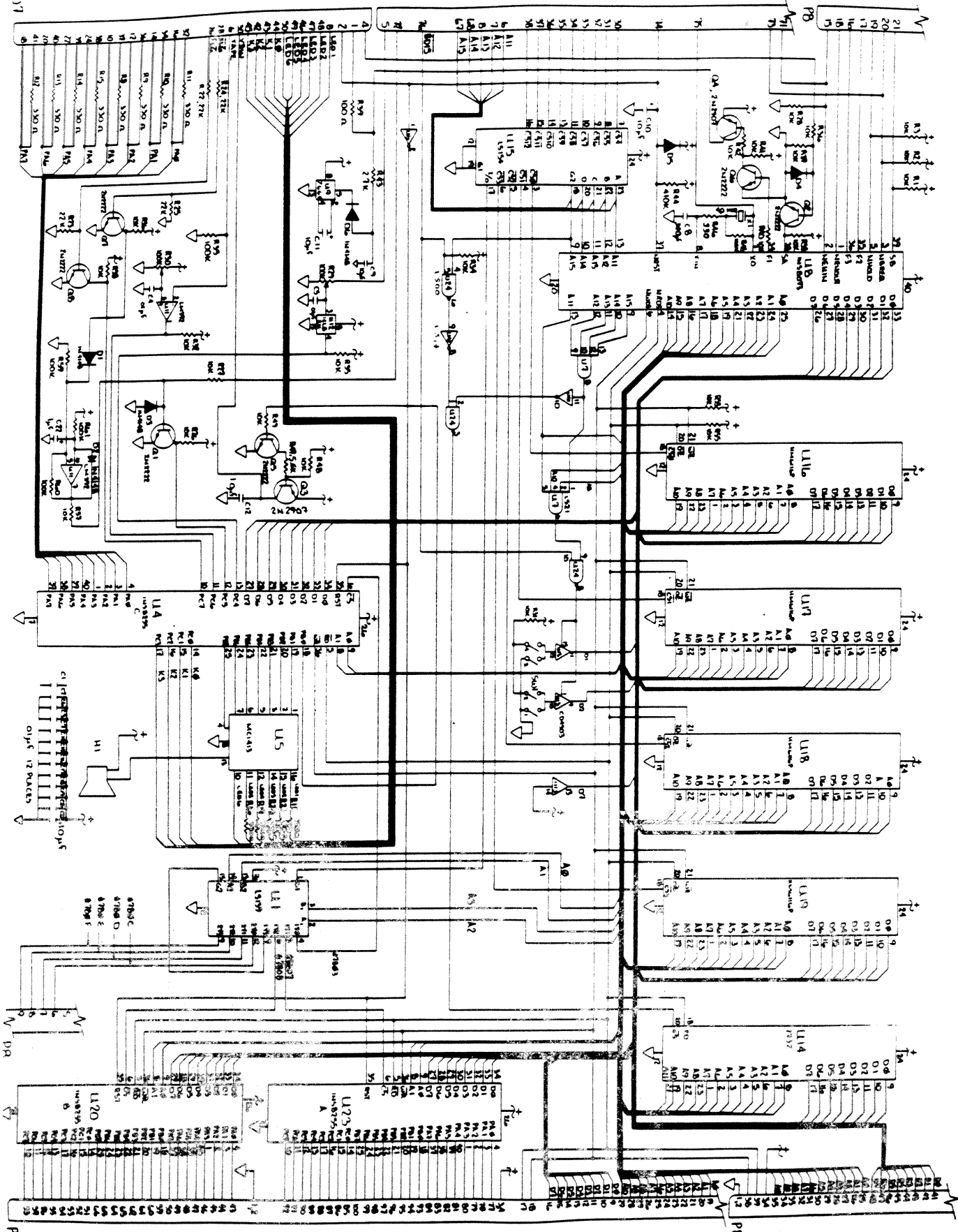
INVERTED GATES

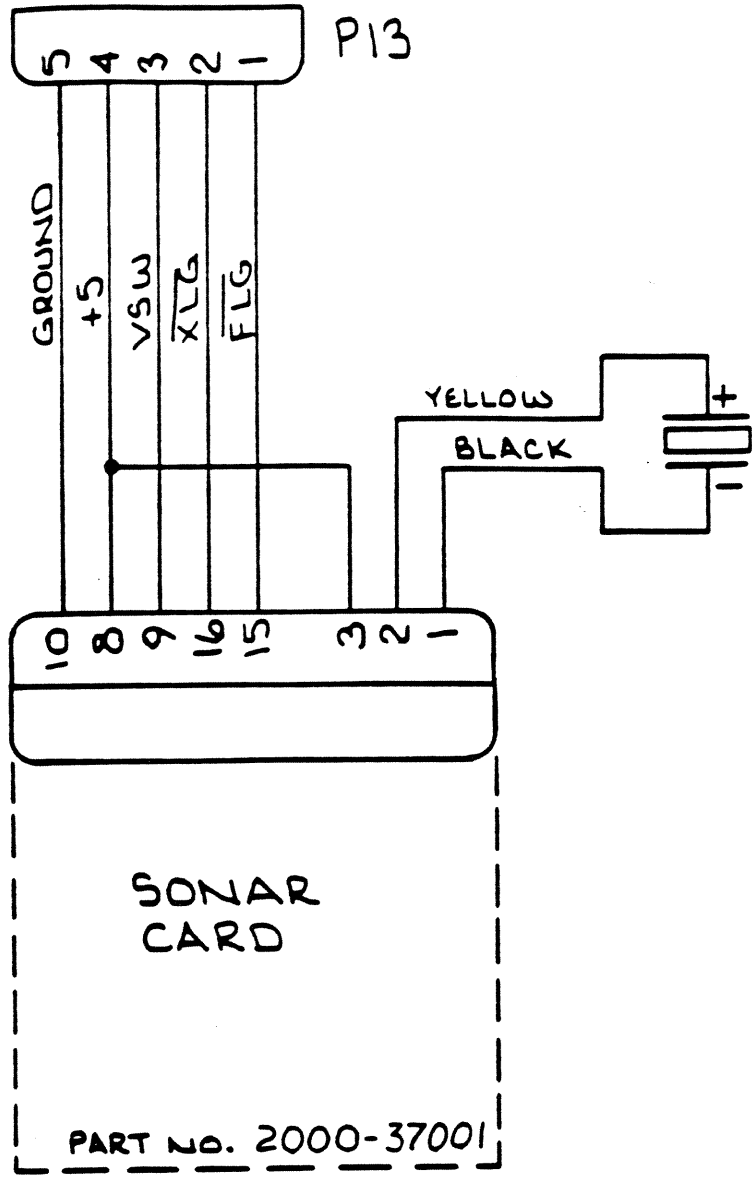
1. (input)
 2. (input)
 3. (input)
 4. (input)
 5. (input)
 6. (input)

AST NUMBERS

B612
 C372
 D175
 U75
 C28

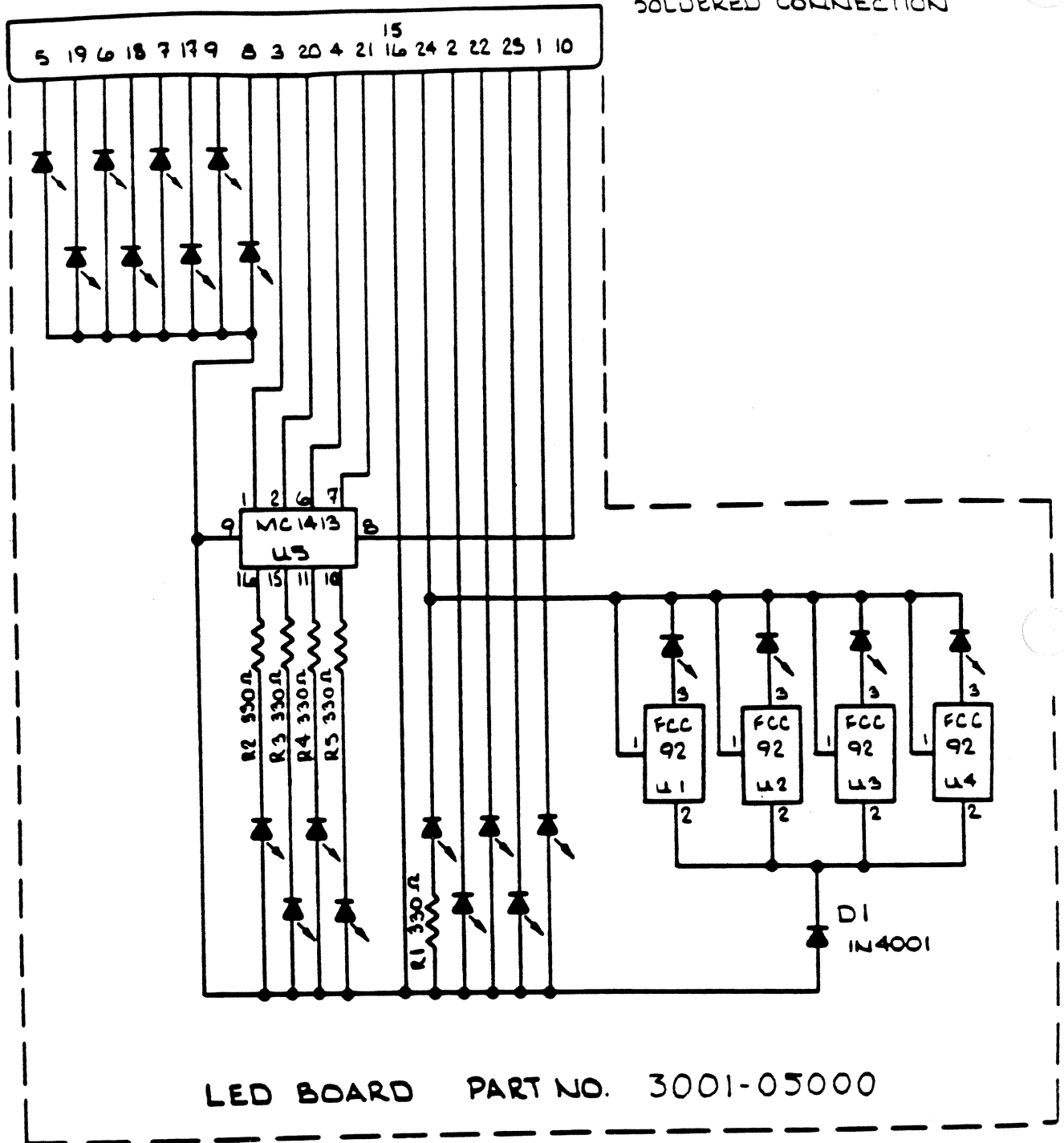
+	↓	↑	+
U001	U002	U003	U004
U005	U006	U007	U008
U009	U010	U011	U012
U013	U014	U015	U016
U017	U018	U019	U020
U021	U022	U023	U024
U025	U026	U027	U028
U029	U030	U031	U032
U033	U034	U035	U036
U037	U038	U039	U040
U041	U042	U043	U044
U045	U046	U047	U048
U049	U050	U051	U052
U053	U054	U055	U056
U057	U058	U059	U060
U061	U062	U063	U064
U065	U066	U067	U068
U069	U070	U071	U072
U073	U074	U075	U076
U077	U078	U079	U080
U081	U082	U083	U084
U085	U086	U087	U088
U089	U090	U091	U092
U093	U094	U095	U096
U097	U098	U099	U100
U101	U102	U103	U104
U105	U106	U107	U108
U109	U110	U111	U112
U113	U114	U115	U116
U117	U118	U119	U120
U121	U122	U123	U124
U125	U126	U127	U128
U129	U130	U131	U132
U133	U134	U135	U136
U137	U138	U139	U140
U141	U142	U143	U144
U145	U146	U147	U148
U149	U150	U151	U152
U153	U154	U155	U156
U157	U158	U159	U160
U161	U162	U163	U164
U165	U166	U167	U168
U169	U170	U171	U172
U173	U174	U175	U176
U177	U178	U179	U180
U181	U182	U183	U184
U185	U186	U187	U188
U189	U190	U191	U192
U193	U194	U195	U196
U197	U198	U199	U200



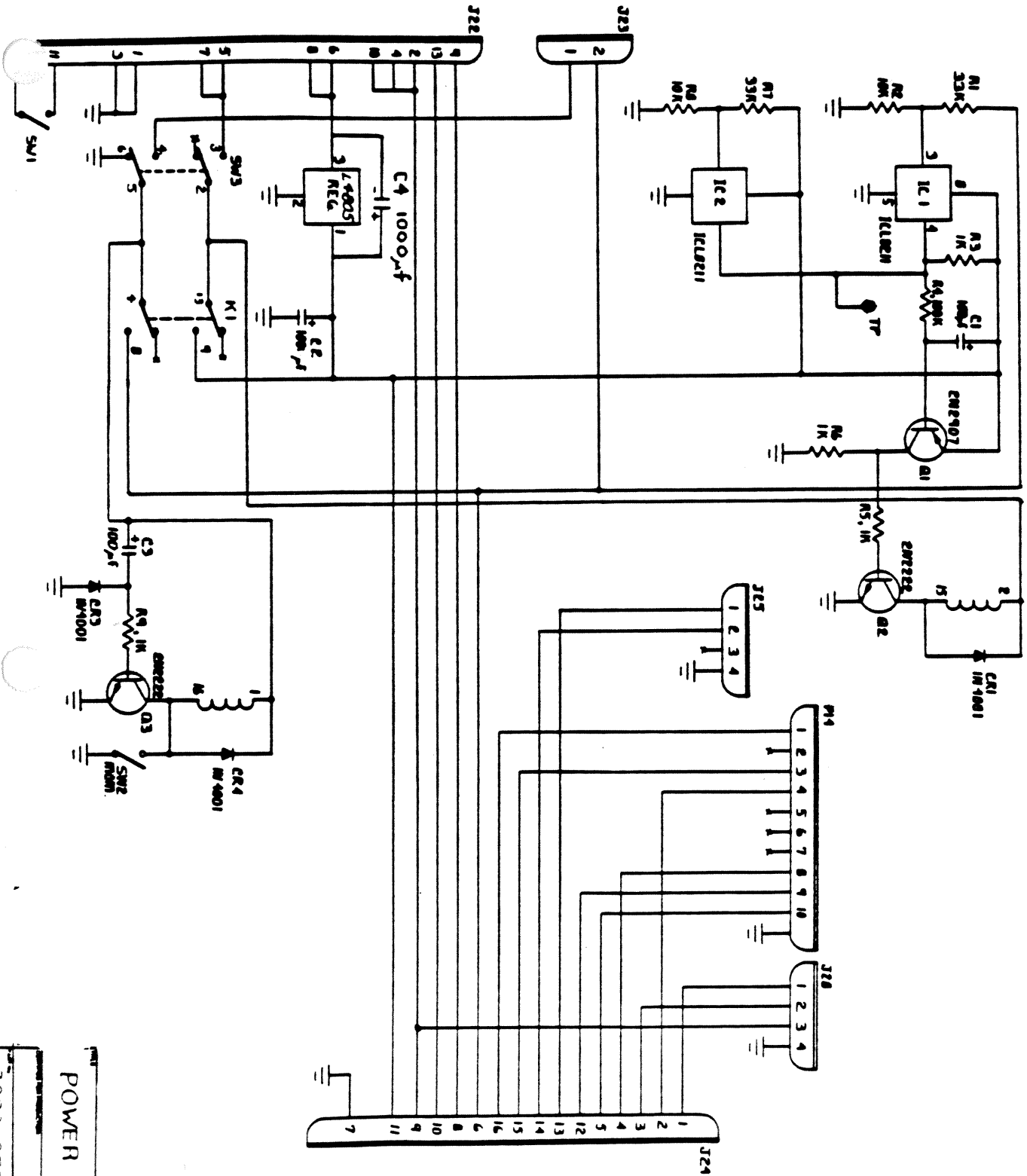


TITLE				COM
SONAR CARD, CONNECTION				CLA
CHGD BY	DATE	ECO NO.	INTENT	PAR
LATEST CHANGE				STAT
PART NO.			REV	SHT

SOLDERED CONNECTION

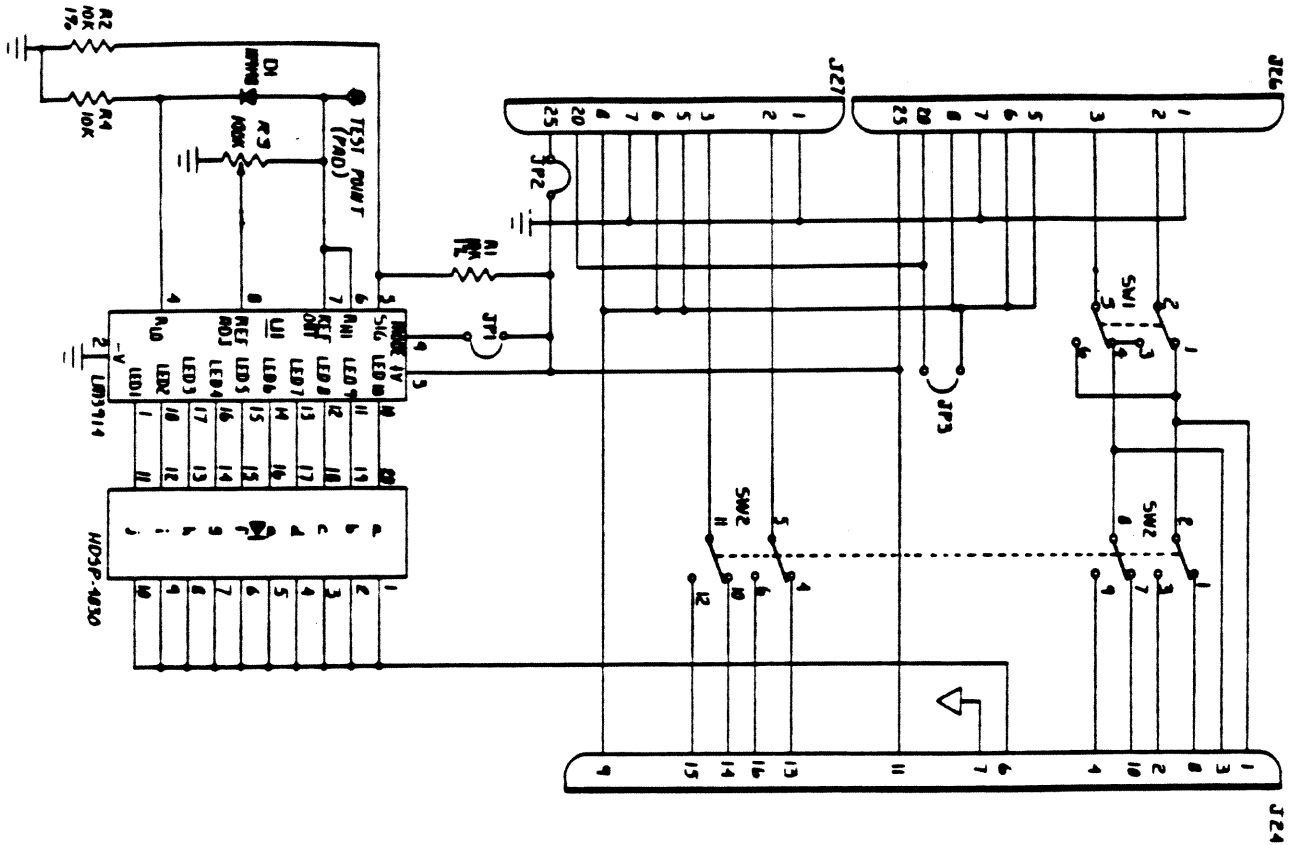


TITLE				COMM
SCHEMATIC,				CLASS
LED BOARD				
CHGD BY	DATE	ECO NO.	INTENT	PART
LATEST CHANGE				STATU
PART NO.			REV	SMT
			A	/



POWER BOARD

3002-05001

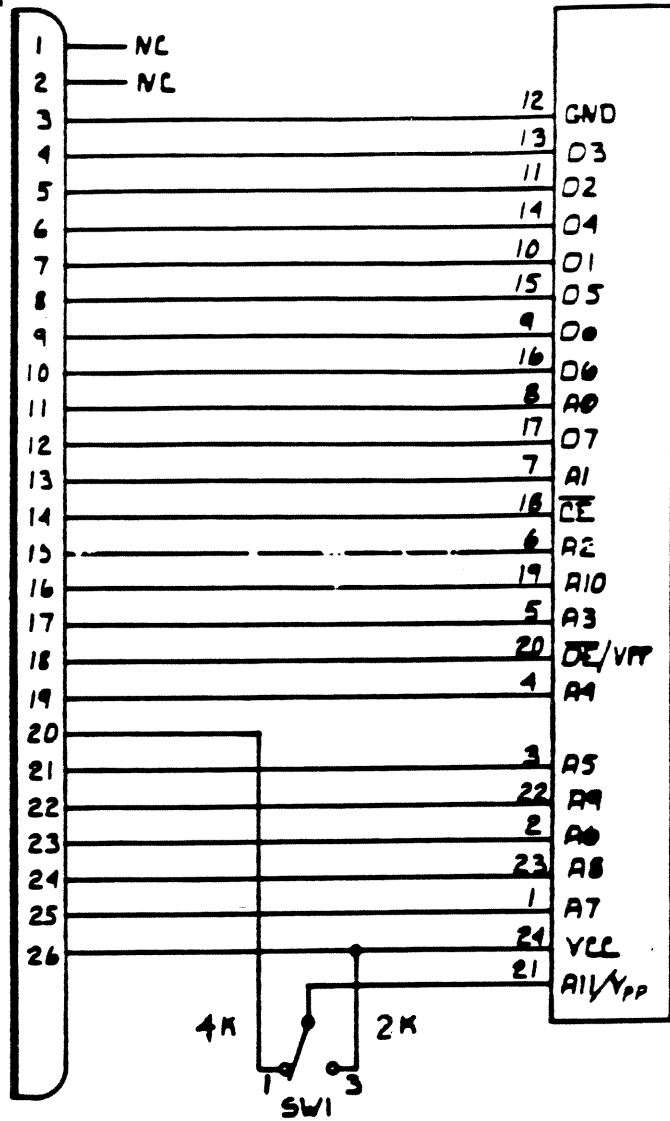


REV	DATE	BY	CHKD

INTERFACE BOARD

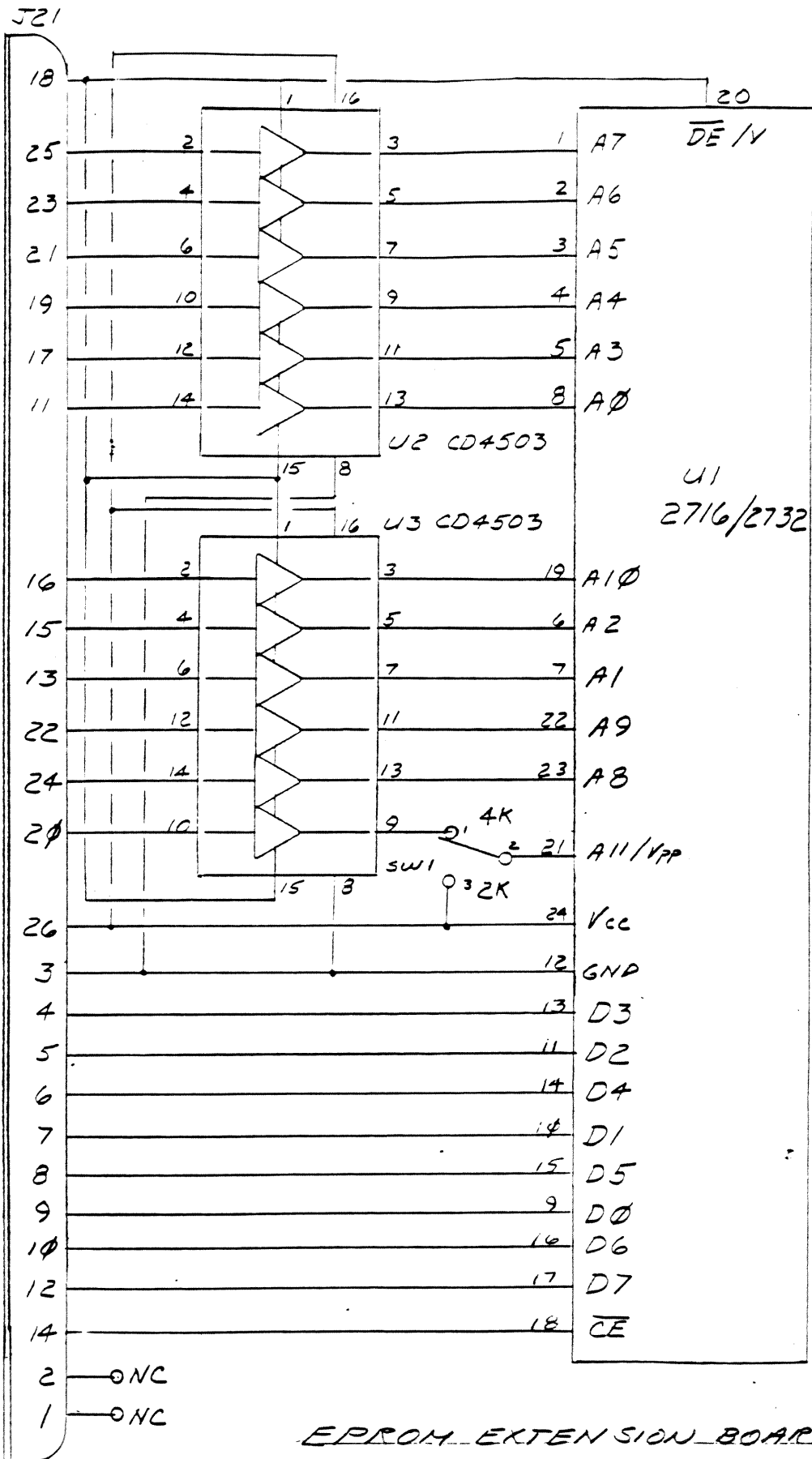
3002-05000

J21



U1
2716/2732

TITLE		PROJ NO	
EPROM EXTENSION BOARD			
CERTIFIED FOR PRODUCTION	DATE	INTERNAL REVISION	
PART NO	3002-05002	REV ISSUE	SH OF
		1	



EPROM EXTENSION BOARD

GENERAL ROBOTICS CORP.

PART NO. 3002-05002 REV 2

DRAWN BY: WJA DATE 5/26/88

