PART I - OPERATIONS

1.1 Introduction

The Parker Compumotor Model 52 microcontroller is a small computer designed to perform input and output signal control. For the sake of brevity, the Model 52 will be referred to as the "B52" throughout this document.

As a controller, the B52 is most often employed in a dedicated control function which it remembers and executes when power is turned on.

As a computer, it is flexible enough to store multiple operations, and may be reprogrammed to perform new tasks, permanent or temporary, at any time.

Programming requires familiarity with the BASIC programming language. Parker Compumotor Corporation does not assume responsibility for providing instruction in BASIC programming.

1.2 This Manual

This manual is organized in five parts, follwoed by several Appendices. The five include Operations Guide, Hardware Reference, Programming Fundamentals, I/O Programming, and Sample Programs.

The Operations section provides an overview of how the B52 is organized, and what is required to apply it to a given task.

The Hardware Reference section goes into detail on Input and Output characteristics, and how to make connections to B52 I/O (Input/Output hardware).

The Programming Fundamentals section describes the B52's BASIC language and goes into detail on how to manipulate memory, and implement I/O functions.

The I/O Programming section deals with B52 BASIC I/O instructions, interrupts, and machine language tools.

Refer to the Table of Contents for details on subjects of interest. Much specific reference information is included in the various Appendices.

BASIC programming code examples are printed as follows:

```
100 PRINT "Example"
```

In the text, B52 connector names are printed as follows:

CONSOLE

1.3 Model 52 Description

The B52 is designed for small scale industrial process control. Many I/O functions and a high level programming language are built in. A standard terminal device is all that is required to program the Model 52, standard I/O signal conditioning equipment is all that is necessary to meet most control requirements. The input and output functions supported are as follows:

2 RS232C ports for remote device control
1 RS232C port for operator console
1 RS232C port for printer output
4 On board optically isolated inputs
4 On board optically isolated outputs
2 24 channel I/O connectors for signal conditioning
1 Differential pulse output
1 Differential level output
3 Differential encoder inputs with quadrature detection
4 16 bit counter/timers
4 Analog input channels
1 Analog output

All RS232C ports have selectable baud rates from 300 to 19200. A real-time clock function is built in. Interrupts are available on elapsed time, or from two external inputs, three counters, four timers, and two RS232C ports.

The B52 uses the Intel 8052 microprocessor clocked at 11Mhz. The internal BASIC interpreter provides fast execution with simple BASIC instructions for I/O control. Floating point math functions are supported.

The B52 comes equipped with 16 kilobytes of read/write memory (RAM) and 16 kilobytes of solid state non-volatile read/write memory (EEPROM) for power-off program storage. Multiple programs can be stored in EEPROM and run from either EEPROM

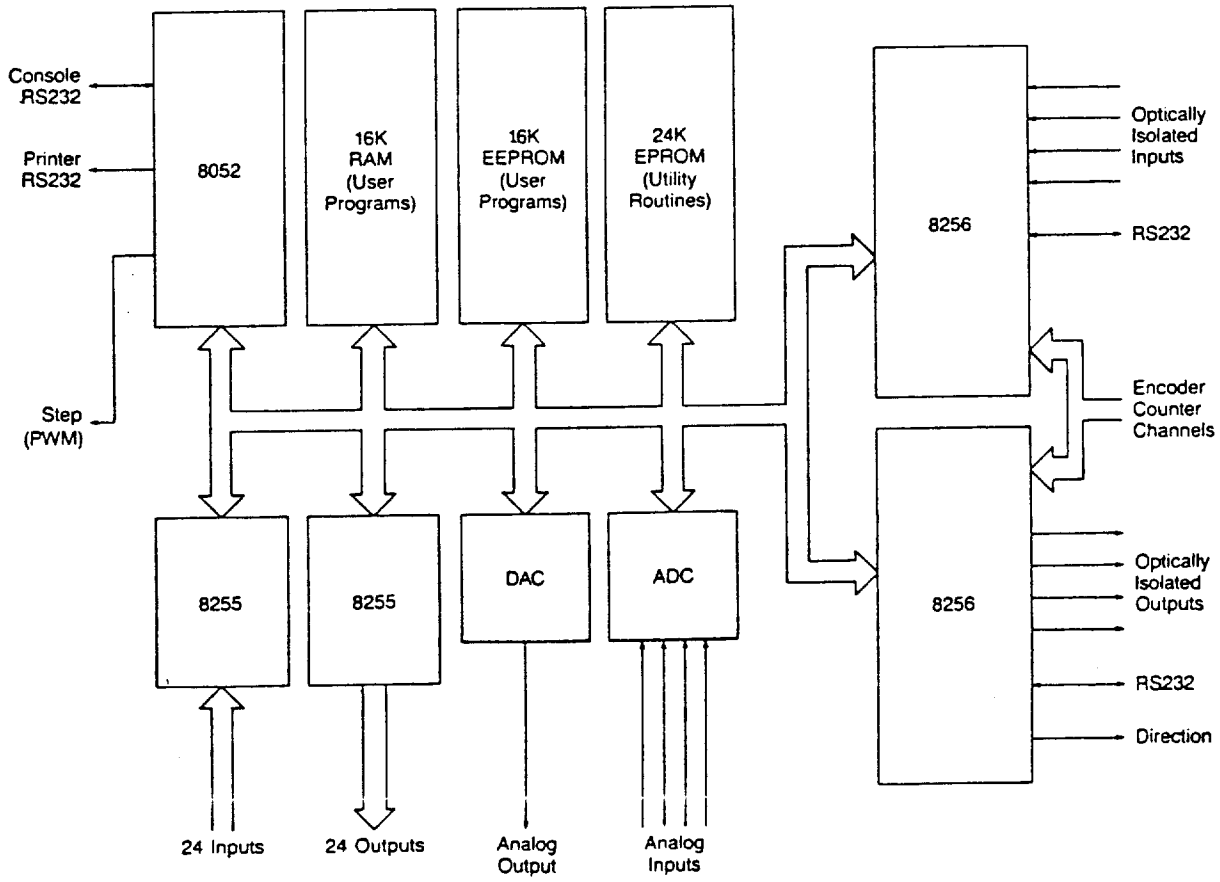
or RAM. An additional 24 kilobytes of permanent memory (EPROM) contains machine language "device drivers" for B52 peripheral devices, and some Compumotor utility programs. See Section 4.2.11 and Chapter 5 for listings and details on the functions of these utilities.

The B52 can be configured to run programs from power on without operator input. Programs are easily transmitted into or out of the unit for editing or storage.

The B52's analog inputs can be used to read temperature, pressure and other transducers with analog voltage outputs. The analog output can be used to control servo amplifiers and other voltage controlled devices. Figure 1.1 below depicts the system block diagram.

The programmable peripheral I/O devices used in the Model 52 are the 8255 and the 8256. Specifications for these devices and the 8052 microcontroller can be found in the Intel Microprocessor and Peripheral Handbook and the Intel Components Data Catalog. Specifics on the Basic programming language used by the 8052 can be found in the Intel MCS BASIC-52 USERS MANUAL. Machine language programmers will need the Intel Microcontroller Handbook.

Figure 1.1 System Block Diagram



1.4 Quick Start

It is a simple matter to get the B52 running if a suitable terminal device is on hand.

Required Equipment:

Terminal - some keyboard/display device with RS232 communications capability, configured for three wire operation (no handshaking)

115 VAC Power and cord

If 230 VAC operation is required, or other questions come up, refer to the Initialization and Installation sections below.

How to do it:

1. Connect power to the B52.
2. Connect the terminal with a standard RS232 cable to the CONSOLE connector.
3. Press the Space bar - the B52 should respond with its opening message

If no user programs have been saved in EEPROM, the resident Compumotor Directory program will run automatically. Use it to access other internal B52 test and demonstration programs. Press "Control C" to stop the program.

The B52 is then ready for programming.

The experienced operator will need the Intel BASIC-52 USERS MANUAL for syntax reference.

Section 3.1 of this manual deals with the quirks of BASIC-52, Sections 4.2 through 4.5 describe the custom instructions and programming tools provided for I/O operations.

1.5 Initialization

This section the installation procedure for the Model 52 Industrial Control Module, including options and considerations for remote terminal operation and auxiliary RS-232C ports and printer alternatives.

1.5.1 INSPECTION

Inspect the shipping carton carefully for evidence of physical abuse or damage. Report any such findings immediately to your receiving department and to the carrier. Compumotor Corporation cannot be responsible for in transit damage.

Unpack the shipping carton and inspect the B52 for any damage, cracks, broken parts, or damaged cables. Save the packing materials until functional checks have been completed.

1.5.2 POWER

The Model 52 will run on 120 or 240 VAC. The unit is factory set for 120 VAC. To convert to 240, it is necessary to remove the top cover, locate the four pin jumper connector J5 near the fuseholder, and move it to the adjoining 240 volt plug, J6 as shown on the circuit assembly drawing in Appendix E. The 120VAC .25A fuse should then be replaced with the 240VAC .125A fuse supplied.

1.5.3 CONSOLE REQUIREMENTS

Any full duplex serial device which allows the operator to enter alphanumeric commands, and displays echoed characters will serve as the console for the B52. The unit supports Baud rates up to 19200. Programmers will want to use another computer to communicate with the B52 for programming in order to take advantage of their computer's editing facilities.

When a computer is used to emulate a dumb terminal, care must be taken when using the PRINT and LIST commands. The B52 sends characters at a high rate, and is likely to overflow the computer's input buffer unless the computer uses the "XON/XOFF" protocol. LIST small portions of code, and restrict or delay PRINT operations to avoid this condition. By the same token, if a computer and communications utility software are used to transfer (download) programs to the B52, programs might be transmitted too fast for proper reception.

To avoid this problem, either the downloading software must wait for the B52 to respond with a prompt (">") after each line, or a time delay must be added between transmitted program lines. A delay of 250 to 500 milliseconds is adequate. This will give the Model 52 time to process each incoming line, and higher Baud rates can be used.

1.5.4 OPENING COMMUNCATIONS

After power has been applied, the B52 initializes its internal devices. Unless it has been programmed, to a specific Baud rate, it enters an automatic baud rate setup routine. The operator must send a Space character (press the space bar).

Once the space character is received (ASCII 32), the Model 52 measures the transmission rate and sets it's own baud rate to match that of the console device. Following this "AUTO-BAUD" setup, the B52 will run a program. If programmed to do so, it will run a stored program, otherwise it will run its internal Directory program.

> NOTE: If a space character is not the first character sent to the B52, it will set it's Baud rate to an unpredictable value. If this happens the screen of the remote console will display random characters, and it will be impossible to communicate. In this event, a reset will be necessary, either by cycling the power, or by activating the reset input.

If the B52 fails to respond at all, either the terminal (Console device) configuration is incorrect, or it is automatically running a stored program. To correct Console problems, make sure the terminal is configured for three wire DTE operation:

> The terminal output must connect to B52 *CONSOLE* connector pin 2. This output will measure -12 volts or so to Ground (pin 7). Also, any required hand-shaking protocol must be disabled (or defeated: jumper terminal pins 4 to 5 and 6 to 20).

Note that the Model 52 can be programmed to a fixed Baud rate and can automatically run a stored program after reset if desired. See Section 3.3.2: Saving Programs.

1.5.5 GETTING STARTED

Once the Model 52 has been initialized as discussed above, the operator can begin to use the BASIC interpreter right away to explore the capabilities of the computer. The Directory program provides access to the internal Test and Demonstration program, and any user programs that have been saved in memory.

The Test and Demonstration program will present a menu of options for I/O testing.

To stop any program, type "Control C". The B52 responds:

```
STOP IN LINE nnn
```

then:

```
READY
>
```

The BASIC-52 is now in **Direct** command mode. As with most BASIC interpreters, MCS BASIC 52 allows operating in either a **Direct** mode (no program line numbers), or in program **Run** mode.

Direct mode will only allow the execution of a single command line at a time. Even so, the operator can calculate equations, or control various I/O devices in this mode without doing any programming.

Example:

```
> PRINT PI*3**2*6
```

(volume of a 6 by 6 cylinder)

Other Direct mode commands include program control commands.

Type: **LIST** (and RETURN) to inspect the program

Type: **RUN** (and RETURN) to restart it.

This program and others can be stopped, and the B52 returned to direct command mode by typing "Control C". (hold down the Control key and type "C").

Once communications have been established, programming can begin for the desired application. Once an application program is entered, debugged, and saved (in "EEPROM"), the unit is ready for site installation.

1.6 Installation

Field installation of B52 units involves mechanical mounting and various connections.

1.6.1 MOUNTING

The Model 52 is designed for vertical mounting. Number 10 screws are suitable for fixing the unit to a vertical surface using the mounting ears on the rear corners. Refer to Appendix D for dimensional details.

Vertical orientation provides the optimum convection cooling of internal components.

The B52 must be mounted in an environment protected from contamination by particles, corrosive atmosphere, excessive humidity, and fluids. In this situation, the unit should be mounted in a suitable enclosure. Enclosures should be ventilated to prevent internal heat build up.

1.6.2 WIRING: POWER

The B52 must be wired for Power and signal connections. Connect standard color power wires to B52 power terminals as follows:

LINE	BLACK	(BROWN)
NEUT	WHITE	(BLUE)
EARTH	GREEN	(GREEN/YELLOW)

Suitable wire guage for Power: 18 AWG

In industrial environments where heavy power use may upset the line, it may be necessary to use a line filter to protect the B52.

1.6.3 WIRING: SIGNALS

Signal wiring includes RS-232, Parallel Input and Output, and screw terminal connections.

RS-232 connections should be made with shielded cable, the shield being connected at the other end of the cable. Cables are plugged into the appropriate connectors in the bottom of the unit, and must be screwed down to avoid intermittant connections, or cables falling out. The maximum recommended cable length is 50 ft. The connectors used include:

RS232#1	*RS232#0*
PRINTER	*CONSOLE*

Parallel connections are usually made to standard signal conditioning panels using standard flat cables obtained with the panels. These cables are not shielded so cable lengths below three feet are recommended. The connectors used are:

PARALLEL INPUT
PARALLEL OUTPUT

Refer to Control Outputs section 1.7.5 for additional details on signal conditioning connections.

Screw terminal connections (other than Power) include both optically *ISOLATED* and non-isolated terminals. Non-isolated connections should be shielded (or at least twisted pairs) to avoid electrical interference. The sheild can be connected to the *SHIELD* and *EARTH* terminals or the frame.

DO NOT CONNECT SHIELDS TO THE "*GND*" TERMINALS

Suitable wire guage for discrete wiring: 24 AWG

References:

I/O Functions:	Section 1.7
Screw Terminals:	Section 2.2
Parallel I/O:	Section 2.3
Signal Conditioning:	Section 1.7
RS-232:	Section 2.4

1.7 Control

Process control involves monitoring various process conditions, the inputs, and actuating various devices, the outputs, to keep the process under control. Like any feedback control system, the controller measures the error in various process parameters, and decides what response is called for.

The process controller must make logical decisions. In a simple temperature control situation, for example, the controller needs to shut off the heat when an over-temperature detector becomes active. The controller logic has the form:

"If Input #1 comes ON then turn OFF Output #1"

In the Model 52 BASIC computer language, one or two statements will convert any single input condition to any single output condition.

A common design for an industrial control program is to organize it in two sections, input and output. The program "scans" or "samples" the inputs, and then processes the outputs. This sequence constitutes the main body of the program, and is repeated as fast as possible. The time required to complete one cycle is the scan time or sample rate.

Some process control requirements do not lend themselves to a linear programming approach, such as serial data input or input timing. When processing reqirements cannot wait for the program to get around to them, it is advantageous to use the interrupt capability of the Model 52.

Several kinds of interrupts may be employed:

Discrete inputs
Timer timeout
Preset event counter
Incoming RS-232 characters

The programmer has the option to have his program be interrupted on any, all, or none of the above of conditions.

When interrupts are used, the portion of the program devoted to handling them, known as the Interrupt Service Routine, is separate from the body of the main program, and operates independently.

A simple control program might be organized as follows:
(Examples are provided in parentheses)

Preliminaries

1. Initialize process control variables:
   (Set outputs, preset a counter)

2. Establish any interrupt conditions:
   (Emergency stop switch, end of count sequence)

Main program

3. Scan discrete inputs, set any discrete outputs:
   (Read control switches, turn on indicators, etc)

4. Calculate any other response to discrete inputs:
   (Convert BCD switches to analog output value)

5. Read Analog inputs, calculate output response:
   (Transmit input voltage to remote display)

6. Return to step 3 and repeat.

Interrupt Service

7. Shut off all outputs, zero analog output, wait for instructions.

The following scetions describe the various control and Input/Output functions available on the Model 52.

References:

I/O Programming:	Sections 3.3, 4.2
Interrupts:	Section 4.4
Sample Program:	Section 5.1

1.7.1 TIMING

Process control frequently requires that events be timed, or separate activities be coordinated in time. The B52 has a considerable variety of ways to manage time. Elapsed time is easily managed with the 8052 BASIC real-time clock function, and multiple external events may be timed to the millisecond with the numerous Model 52 hardware counter/timers.

The encoder input and optically isolated input connections below have alternate functions which can facilitate the timing (or counting) of external events.

References:

Real-time clock:	BASIC-52 USERS MANUAL: Chapter 4.20
Counter inputs:	Section 2.2.4: Encoder inputs
Counter/timers:	Section 4.2.4: CTR Instruction

1.7.2 ENCODER FEEDBACK FUNCTIONS

One of the more specific counting function capabilities of the B52 is its ability to decode and count quadrature signals, typically from incremental encoders. This capability provides a good way to monitor the speed or position of physical objects in motion.

References:

Encoder Inputs:	Section 2.2.4
Counting quadrature:	Section 4.2.5: QUAD Instruction

1.7.3 FREQUENCY OUTPUT FUNCTIONS

Many devices used in process control are pulse or frequency controlled, ranging from audible signalling devices, to pulsed motor drive amplifiers. Two outputs are provided to facilitate low level motor control, the pulse output, and a level output for direction control.

The pulsed output frequency range is suitable for audible signals. Maximum frequency is about 23kHz. This function is handled by the 8052 processor's PWM instruction.

References:

Motor Outputs:	Section 2.2.5
Motor control:	Section 4.1.6

1.7.4 ANALOG I/O

Some industrial devices will require a continuously adjustable signal for proportional control. This signal is most often a low power control voltage or current. Either type of signal can be produced using the B52 analog output and little or no external circuitry. Higher power signals for voltage or current driven devices will require an external amplifier which itself can be controlled by the analog output. The analog output device is an "8 bit" device; the ±10 VDC output range is divided into 256 discrete output voltages.

Any industrial control operation requires monitoring various aspects of the process. In addition to the discrete (on/off) I/O above, many types of monitoring devices or transducers provide a continuously variable voltage output signal which must be measured.

The B52 has four analog inputs which allow measuring voltage from temperature and pressure transducers or other analog voltage output devices. The analog input device is also an eight bit device. Each input range is also divided into 256 discrete values.

References:

Analog connections:	Sections 2.2.6, 2.2.7
Analog Programming:	Sections 4.1.1, 4.1.2, 4.2.1

1.7.5 REMOTE SIGNAL CONDITIONING I/O

For most applications I/O is connected to the B52 through signal conditioning panels. The point of using signal conditioning equipment is to allow monitoring and control of high voltage and high power signals, AC or DC, with the low level inputs and output signals generated by the B52. This signal conditioning equipment provides optical isolation to protect the B52.

One signal conditioning panel is connected to the Model 52 for input, and another is connected for output. These panels or "module mounting racks" are available in 8, 16, and 24 channel versions.

There are two connectors for 50 conductor flat cable on the front of the Model 52 for programmable I/O. These connections are compatible with standard optically isolated signal conditioning equipment. One connector provides 24 inputs, the other provides either 24 outputs or 16 outputs and 8 additional inputs for maximum flexibility.

For example, a single 16 channel I/O rack may be set up for eight inputs and eight outputs of mixed low or high voltage AC or DC.

OPTO-22, Crydom, and Potter & Brumfield all manufacture signal-conditioning products suitable for use with the Model 52. These modules come in different voltage and current ratings. There are versions for interfacing with signals ranging from 5VDC to 280 VAC. Consult your local OPTO-22, Crydom, or Potter & Brumfield distributor for details.

The following Opto-22 module mounting racks and flat cables work with the Model 52:

a. Module mounting racks

(1) PB8 - 8 lines
(2) PB16A - 16 lines
(3) PB24 - 24 lines

b. Cables

(1) OD-2 - 2 feet
(2) OD-4 - 4 feet
(3) OD-8 - 8 feet

Where I/O requirements are minimal, the four optically isolated inputs and outputs may eliminate the need for the above signal conditioning hardware.

References:

Parallel I/O:	Sections 2.3, 3.3
Programming:	Sections 4.1.3, 4.1.4, 4.2